DOCTOR OF PHILOSOPHY

Co-Innovation in Bioplastic Packaging

An exploratory study of supplier-customer collaboration for product innovation

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Co-Innovation in Bioplastic Packaging: An exploratory study of supplier-customer collaboration for product innovation

By

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By

Liliani

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Abstract

This thesis aims to develop a conceptual understanding of the process and mechanisms of co-innovation in the context of bioplastics packaging product innovation, focusing on the business to business (B2B) supplier-customer relationship between the bioplastics packaging manufacturers and product manufacturers. Following the critical realism paradigm, this study places the inter-firm co-innovation experience within a framework grounded in the relational view theory and the absorptive capacity theory as theoretical lenses. This study adopts a multiple case study strategy to explore how co-innovation occurs in real situations, the problems arising during the bioplastic packaging implementation and essential factors within this particular context. The case selection is theory-driven, focusing on developing and packaging application processes for consumer goods, among the biopolymer producers, converters and product manufacturers in the UK and Indonesia. Data from semi-structured interviews and documentation were analysed using template analysis.

The findings of this study illustrate the co-innovation processes in two stages: development of a packaging prototype and further development for specific bioplastic packaging applications. This study presents a framework, which built upon the integrated joint activities, joint resources and relationship management as the key mechanisms. These mechanisms are driven by an intensive knowledge transfer, signifying the supplier-customer absorptive capacity in facilitating successful co-innovation, while there is limited creation of specialised assets for bioplastic packaging. In addition, this study presents possible approaches to co-innovation partners in penetrating the packaging market, working in complex development and cultivating supplier-customer interdependency. The research reveals that co-innovation improves bioplastic material, bioplastic packaging quality and the customer's manufacturing processes to work with the bioplastic packaging. More importantly, this study suggests that a successful co-innovation should be followed by creating relational benefits that contribute to the partner's sustainability agenda and commercial benefits, which would preserve partner interdependence for the long term.

The primary contribution of this thesis lies in extending the conceptual understanding of co-innovation, emphasising collaborative work and exclusivity among co-innovation partners, bringing forward the concept of relational benefits, enforcing innovation and sustainable values, which bind the partnership in the long-term. This study extends the relational view theory within an interlinked network of stakeholders and indicates a slight anomaly within a strong existing 'regime' of the plastic packaging industry. It also provides a framework that potentially brings bioplastic packaging to a broad implementation while acknowledging the challenges in developing and commercialising bioplastic packaging and penetrating a well-established packaging industry. It therefore adds a valuable reference for sustainable product development studies and managerial practices.

Keywords:

Co-innovation, bioplastics, sustainable packaging, product development, supplier-customer collaboration, relational view theory, case study.

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Publications

1. Liliani, Tjahjono, B. and Cao, D., 2020. Advancing bioplastic packaging products through co-innovation: A conceptual framework for supplier-customer collaboration. Journal of Cleaner Production, 252, p.119861.
2. Liliani and Tjahjono, B., 2020. A conceptual framework for a dyadic supplier-customer co-innovation of bioplastic packaging. *Procedia CIRP*, 90, pp.339-343.
3. Liliani, Tjahjono, B. and Cao, D., 2021. The Mechanisms of Co-innovation in the Development of Bioplastic Packaging: Evidence from Practice. *2021 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM)*, pp. 172-176.

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1. Introduction

1.1. Bioplastics packaging industry and the challenges

Plastics packaging is widely used in daily life, industries and other sectors in the economy because of its high performing features and low cost of production (Ahmed et al., 2018; Nilsen-Nygaard et al., 2021). Its application as packaging is the largest in the plastics industry (Beltran et al., 2021; Dobrucka, 2019; EMF, 2017) and the increasing global population and changed demographics leading to an increase in the world's consumption, have also caused the increased use of plastic packaging (Boesen et al., 2019). Although their use in the economy is inevitable, plastics leave solid waste material that harms biodiversity and ecosystems, and creates other serious environmental problems, which threaten sustainability in the future (EMF, 2017; Lewis et al., 2017; Soylu & Dumville, 2011). Plastics waste leakage into the environment is inevitable regardless of the effort to recycle, reduce or reuse the plastic. Recycling is no longer the only option because the recycling capacity has great difficulty in overcoming the plastic waste volume; for example, the recycling capacity in Europe only reaches 30% of the total recycling plastic waste (Dobrucka, 2019), and only 14% of plastic packaging waste is recycled globally (EMF, 2017), so the excess plastic waste remains as a solid waste pollutant in the ecosystem. The limited capacity of recycling, i.e., reduce the material or reuse plastic packaging, and waste management systems compared to the amount of plastics use in all its forms have created an urgent need for a solution to this environment leakage (EMF, 2017).

Bioplastic packaging was developed in response to this environmental issue (Chadha, 2011; de Vargas Mores et al., 2018), and increased attention towards a circular bio-economy (Beltran et al., 2021; Nilsen-Nygaard et al., 2021), and considered to be a potential alternative sustainable packaging (Beltran et al., 2021; de Vargas Mores et al., 2018; Keränen et al., 2021). Bioplastics are the plastic materials that are either bio-based or biodegradable at the end-of-life or have both properties (European Bioplastics, 2018b). Bioplastics are often claimed to have more advantages compared to conventional plastic packaging because of their biodegradable feature, i.e., the ability to break down into natural elements with the help of microorganisms or specific processes (Verghese et al., 2012), which may solve the solid plastic waste problem in the environment (Ahmed et al., 2018). In addition, bioplastics are less dependent on fossil-based resources (Beltran et al., 2021; Kishna et al., 2017) and potentially reduce the CO_2 emissions through the planting and harvesting of bioplastics raw material (de Vargas Mores et al., 2018). Bioplastics are considered to be a radical environmental innovation (Chadha, 2011) and, as their use could bring environmental, social and economic benefits (de Vargas Mores et al., 2018), they can also be considered as an innovation in sustainability (Beltran et al., 2021; Keränen et al., 2021).

Even though the bioplastics packaging industry is developing due to the increased awareness of sustainability, regulations and market demand, there are still barriers to the further development of the industry. The problems are related to the high cost of new technology, limited resources and expertise in bioplastics and sustainable technology or product development, problems with product performance and future market uncertainty. Developing bioplastic packaging involves new technology and manufacturing processes that must comply with intricate environmental requirements and requires high investment in research and development (R&D) (de Vargas Mores et al., 2018; Theinsathid et al., 2009). Therefore, most of the new entrants in the bioplastics industry are experiencing technical barriers due to little experience and capabilities in the bioplastics engineering, technology, and manufacturing processes, including knowledge of the environmental standards or regulations (Chadha, 2011; Keränen et al., 2021; Theinsathid et al., 2009). Overall, this new technology has created uncertainty in the dynamic business environment, market, and in supply and demand (Chadha, 2011; Cheung et al., 2010) and currently the global transition to bioplastics is facing a number or barriers (Beltran et al., 2021; Keränen et al., 2021).

Currently, the turnover of bioplastics is limited to only around 1% of the global plastic circulation, but demand and global production capacity is estimated to rise more than 30% in 2021 (European Bioplastics, 2018a, 2020). However, there are problems in the application of bioplastic packaging that impede its broad implementation in the industry. Bioplastics packaging for particular desired functions or performance is lacking and its quality is lower compared to the conventional fossil-based plastic (Khan et al., 2017; Nilsen-Nygaard et al., 2021; Theinsathid et al., 2009). For example, certain bioplastics packaging has a low barrier to air or water vapour (Benetto et al., 2015), so when used for food and fresh produce, the contents easily lose moisture through evaporation, becoming dry and causing a shorter product shelf life (Khan et al., 2017). Other bioplastics packaging is less heat resistant (Boesen et al., 2019; Razza et al., 2015; Sarobol et al., 2013) and therefore cannot be filled with hot liquid during production or for serving hot drinks.

A typical packaging supply chain (see Figure 1) consists of the raw material supplier, biopolymer producer, packaging manufacturer, also known as the converter, product manufacturer, logistics company and wholesalers, retailers and consumers (Verghese & Lewis, 2007). As the bioplastic is applied to the existing packaging supply chain, which has been well established for conventional plastics, problems between the supplier and customer often exist during the bioplastic packaging fabrication at the converter (Benetto et al., 2015; Sossa et al., 2015) and implementation at the product manufacturer (Boesen et al., 2019; Khan et al., 2017). For example, the packaging manufacturer processes the bioplastics raw material in several stages, such as mixing with additive, moulding and shaping into packaging, and needs many iterations to enable the biopolymer, which has different characteristics from conventional plastic, to run in the production processes and achieve the desired quality. At the product manufacturer, the bioplastic packaging is not always fit for use for the product manufacturer's product and cost more than the conventional plastic packaging (Theinsathid et al., 2009). These problems become one of the reasons behind the limited application of bioplastics packaging in wider industries (Khan et al., 2017).

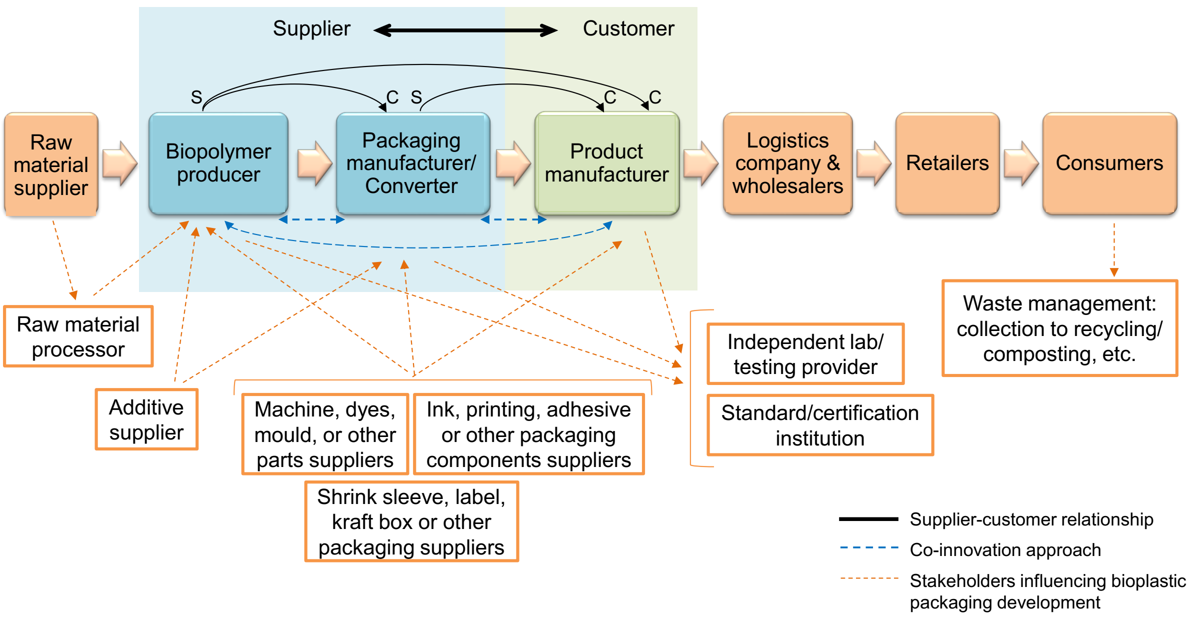


Figure 1 Bioplastic packaging supply chain and the stakeholders' interactions

1.2. Need for collaboration for bioplastics packaging innovation

Successful product development is not only about implementing new technologies, but also ensuring that it is fit for customers' needs and becomes a solution for customers' problems. Understanding users' needs and providing solutions will promote market acceptance of the new invention (Lacoste, 2016; Theinsathid et al., 2009), reduce the risk of market uncertainty and overcome technical barriers (Chadha, 2011; Melander, 2017). Collaboration also increases marketing performance (Dangelico, 2016; Farrow et al., 2000; Morgado, 2008), financial performance (Arnold, 2017; Dangelico, 2016; de Vargas Mores et al., 2018; Morgado, 2008), and environmental performance (Arnold, 2017; Dangelico, 2016; Farrow et al., 2000; Lee & Kim, 2011; Soylu & Dumville, 2011). De Propris (2002) suggests that companies achieve higher innovation performance, indicated by the creation of a new or improved product or process, if they cooperate with other companies instead of working in isolation. Supplier-customer collaboration is therefore believed to be key to this success.

The importance of supplier-customer collaboration in the packaging industry, bioplastics and sustainable product development, has been highlighted by several studies (Arnold, 2017; Chadha, 2011; Jeong & Ko, 2016; Kishna et al., 2017; Morgado, 2008; Theinsathid et al., 2009). Through a case study, Morgado (2008) and Slater (2010) show that supplier-customer collaboration in packaging product development results in the improvement of product functionality and creates innovative packaging. Accordingly, in the bioplastics sector, the supplier contributes to new technology (Chadha, 2011; Kishna et al., 2017; Lee & Kim, 2011; Melander, 2017), new material (Bos-Brouwers, 2010; Kishna et al., 2017), and also covers the lack of technology and competences (Slotegraaf, 2012) on the customer's side. On the other hand, customers share their specification needs, consumers' complaints and their expectations regarding the product, with the supplier which benefits the product concept development, user testing and implementation of the production (Lacoste, 2016; Morgado, 2008). De Vargas Mores et al. (2018) argued that collaboration along the bioplastic supply chain would mean cost reduction from supply chain integration and add value to the final product from the recognition of being eco-friendly.

Nevertheless, supplier-customer co-innovation in bioplastics packaging product development needs to be studied to address problems regarding the limited application of bioplastics packaging. Co-innovation in developing bioplastic packaging becomes more necessary as more regulations and incentives are applied to environmentally friendly products, including bioplastics packaging (Abdullah et al. 2016; EMF, 2017; Lee & Kim, 2011; Melander, 2017). In the future, more demand for bioplastics packaging is predicted (European Bioplastics, 2020) and companies can create competitive advantage by being first movers or leaders in this green technology (Kishna et al., 2017; Melander, 2017).

1.3. Co-innovation in developing bioplastic packaging

Several studies have addressed inter-firm collaboration in bioplastic packaging with its relevance to bio-economy, circular economy, and sustainability (Beltran et al., 2021; Chadha, 2011; de Vargas Mores et al., 2018; Keränen et al., 2021; Neutzling et al., 2018), or using bioplastic packaging specific for biodegradable food packaging (Beltran et al., 2021), and the fashion industry (Friedrich, 2021). These studies emphasise the importance of collaboration among actors in the supply chain (de Vargas Mores et al., 2018; Kishna et al., 2017; Neutzling et al., 2018). Previous studies on the biopolymer development through co-innovation with the upstream value chain (de Vargas Mores et al., 2018; Neutzling et al., 2018) highlighted the benefits of using bio-based plastics for enhancing business customers' sustainability and the importance of supply chain integration for sourcing the renewable material extraction until it is ready to be processed into biopolymer (de Vargas Mores et al., 2018). Moreover, based on the secondary data from the bioplastic alliances database, another study presented that collaborations enhance the market and social legitimacy and potentially progress into technology legitimacy (Kishna et al., 2017), while Neutzling et al. (2018) acknowledge the challenges in developing bioplastic material due to limited knowledge sharing with the supply chain as most of the development relies on internal R&D at the biopolymer producer. Furthermore, a number of studies have explored how far the potential of bioplastic packaging can grow in the future (Beltran et al., 2021; Keränen et al., 2021), presenting the transition of biodegradable food packaging to circular bio-economy and the challenges in diffusing bioplastic packaging to the mainstream that are related to packaging performance, cost and compatibility with the end-of-life waste stream.

After conducting the literature review, as presented in Chapter 2, the research gaps become apparent, indicating limited studies on co-innovation in developing bioplastic packaging. Moreover, there seem to be fragmented studies when viewed from the value chain, particularly on the implementation of bioplastic packaging for business customers. The previous studies have focused on developing bioplastic technology and collaboration with the upstream supply chain, and also extensively discussed the technical limitations of bioplastic packaging and challenges in diffusing to the mainstream. Other studies (de Vargas Mores et al., 2018; Keränen et al., 2021; Kishna et al., 2017; Neutzling et al., 2018) have discussed different approaches for inter-firm collaboration; however, the key mechanisms of co-innovation have not been prominent. There seems to be little empirical evidence or details available, as previous studies have not extensively captured co-innovation after the bioplastic material is ready to be manufactured into packaging and applied for various products. Therefore, supplier-customer co-innovation in developing bioplastics packaging is important to study in order to shape a robust understanding of the co-innovation process and mechanisms.

A case-based study will provide references that complement or extend the existing studies in bioplastic packaging development and help the industry players advance that development through co-innovation strategies. An in-depth understanding of co-innovation in developing bioplastic packaging involving biopolymer producers, converters and product manufacturers or brand owners would extend previous research (Kishna et al., 2017) by showing more evidence in achieving technology legitimacy from co-innovation in developing that packaging; albeit the existing research has identified challenges in diffusing bioplastic packaging to the mainstream (Beltran et al., 2021; Keränen et al., 2021; Tjahjono et al., 2021) due to lack of performance, high cost, problems at the end of life waste stream and complexity of the packaging value chain. Co-innovation experiences of the biopolymer producers, converters and product manufacturers would provide more perspectives on the extent to which co-innovation potentially advances bioplastic packaging innovation and promotes bioplastic packaging to the mainstream.

In this thesis, supplier-customer collaboration in bioplastics packaging product development refers to the concept of co-innovation, as new ideas or approaches from various internal and external sources are synergised to create new value for customers or other stakeholders (Baldwin & von Hippel, 2011). The core of co-innovation includes convergence, the collaboration on ideas, actions and resources, and co-creation of values that is difficult to imitate by the competition (Bitzer & Bijman, 2015; Lee et al., 2012). Furthermore, the 'customer' refers to the product manufacturer, such as confectionery, pharmacy, food and beverages, brand owner or other companies that use the bioplastic packaging for their product. The 'supplier' refers to the converter and biopolymer producer. The 'converter' is the one that processes the biopolymer or bioplastic material into bioplastic packaging and supplies the product manufacturer. Biopolymer producers play essential roles in developing the technology and supplying the biopolymer or bioplastic material to the converter. The scope of co-innovation in developing bioplastic packaging occurs from the development of the packaging to its implementation at the business customer. It may involve the converter working with the product manufacturer or the biopolymer producer, or all three of them working together, as seen in the co-innovation approach (blue dotted line) in Figure 1.

1.4. Research aim and objectives

The research questions (RQs) represent the areas that are most wanted to be explored. RQs can be formulated before, simultaneously or after a conceptual framework is developed and, if required, can be adjusted during the study (Miles et al., 2014). In this study, the RQ is created after research gaps were found from the systematic literature review (SLR) and the conceptual framework were synthesised based on the results of the SLR so that research has a focus, perspective, contributes to gaps that need to be investigated and does not extend without clear boundaries. The importance of determining RQs at the beginning of the research project is to provide direction on the research design (Sekaran & Bougie, 2016), such as planning the instruments for data collection, actors, events, settings, processes and analyses to be carried out (Miles et al., 2014). Research can be performed better if the conceptual framework, RQs and research design are explicitly defined (Miles et al., 2014).

An RQ must be researchable, which means it needs to be answered, i.e., it is not merely a cliché question, and it can be measured qualitatively or quantitatively (Miles et al., 2014). The results of the SLR indicate problems with bioplastics packaging applications that involve suppliers and customers. Therefore, collaboration between supplier and customer is needed in co-innovation for the development of bioplastics packaging products. To be able to implement co-innovation, we need to understand the process and mechanism, but the literature that discusses co-innovation in bioplastics packaging is very limited, and this is a research gap that needs to be followed up. Thus, the research question (RQ) in this study is:

RQ: How does co-innovation in developing bioplastics packaging work between the supplier and customer?

This study aims to inductively develop a conceptual understanding of the process and mechanisms of co-innovation in the context of bioplastics packaging product innovation, focusing on the business to business (B2B) relationship between the bioplastics packaging manufacturer as the supplier and the product manufacturer as the customer. The scope of the bioplastics packaging manufacturer covers raw material processing to producing packaging for the product manufacturer in accordance with the plastic packaging supply chain; and the product manufacturer uses the packaging until their product is ready for the next part of the supply chain (Verghese & Lewis, 2007).

To address the aim of this study, the following objectives are determined:

Objective 1: To identify the extent to which co-innovation has been studied specifically in the bioplastic packaging innovation context. *(RO1)*

Objective 2: To reconstruct the process and unveil the key mechanisms of co-innovation between supplier and customer in developing bioplastics packaging. *(RO2)*

Objective 3: To identify the relevant measures for successful bioplastics packaging product innovation to serve as an objective to achieve through the process and underlying mechanism. *(RO3)*

Objective 4: To illustrate how the key factors and the roles of supplier and customer influence a successful co-innovation in developing bioplastic packaging. *(RO4)*

Objective 5: To propose a theoretical framework portraying the underlying mechanisms of how co-innovation in developing bioplastic packaging occurs in the dyadic B2B supplier-customer relationship. *(RO5)*

1.5. Summary of findings and contributions

This thesis presents the process and mechanisms of co-innovation in the context of bioplastic packaging and specifically pinpoints detailed works among the biopolymer producer, converter and product manufacturer in developing and implementing bioplastic packaging on an industrial scale. This thesis also reveals that the co-innovation process in developing bioplastic packaging occurs in two stages. The first stage aims to develop the packaging prototype, targeting good functionality and readiness to produce on a small industrial scale. The second stage aims to develop further the bioplastic packaging for a specific application that meets the product manufacturer's requirements. This thesis further presents a detailed illustration of these processes based on actual experiences found from the multiple case studies. In addition, it presents the key mechanisms of co-innovation in developing bioplastic packaging, consisting of joint activities, joint resources and relationship management, functioning as a form of integration. Joint activities consist of knowledge transfer and iteration works, while joint resources mechanism encompasses sharing tangible assets and complementary capability. Relationship management incorporates formal mechanism from partner selections, contributions, responsibility, and sharing benefits from the co-innovation outcomes, hence functioning as a governing mechanism. The absorptive capacity appears as the substantial mechanism that facilitates knowledge transfer between the supplier and customer, i.e., accumulation of new knowledge, which is highly valuable for accommodating the customer's needs and innovation.

This thesis assembles the key mechanisms into a framework underpinned by the relational view (RV) and absorptive capacitive theory, and inductively refined. This framework reveals the underlying mechanisms of co-innovation, which show how the key mechanisms correlate in achieving bioplastic packaging innovation and relational advantages that potentially attach partners in the long term. The framework also illuminates that co-innovation potentially delivers considerably valuable incremental innovations of the bioplastic material, packaging quality and customer's manufacturing processes to be more compatible with the bioplastic's unique properties. Moreover, this thesis suggests relational benefits that contribute to the partner's sustainability agenda and that indirect financial returns should materialise subsequent to a successful co-innovation. In addition to the framework, it offers different approaches in engaging co-innovation partners to collaborate for a complex bioplastic packaging development, penetrating the market and nurturing a mutually beneficial co-innovation for the long term. Finally, as the biopolymer producer, converter and product manufacturer positions in the value chain shape their roles in co-innovation, this implies that regardless of the biopolymer producers' own the technology, the downstream value chains, such as the converter and product manufacturer, hold the key to bringing bioplastic packaging to commercialisation.

The contributions to knowledge of this thesis are first, by extending the conceptual understanding of co-innovation through adopting collaborative work, open innovation and co-creation, underpinned by the RV and absorptive capacity theory. This thesis embraces the exclusivity among co-innovation partners in preserving specific knowledge of sustainable technology, whilst previous co-innovation studies embraced interactions with stakeholders, the public or users' community to create innovation (Arnold, 2017; Baldwin & von Hippel, 2011; Lee et al., 2012). Second, from this point, this thesis illuminates the concept of relational benefits (Dyer & Singh, 1998) to bring sustainability value beyond product innovation that potentially binds the partnership in the long term. In addition, through the unique phenomena in the context of bioplastic packaging, this thesis extends the RV theory to work in the dyadic collaboration, which eventually expands into triadic embeddedness, and shows the conditional application of the theory in a well-established plastic packaging value chain. Third, reflecting on the challenges in diffusing bioplastic packaging to the mainstream, this thesis suggests that co-innovation with the downstream would facilitate commercialisation and diffusion of sustainable innovation.

Whilst acknowledging that co-innovation has yet to become the ultimate solution to address challenges in developing bioplastic packaging and diffusing this technology to the mainstream, this thesis offers several recommendations for business practices to engage in co-innovation partnerships with downstream business customers, collaborate towards an extensive and complex development project, and create relational values for business customers. Finally, this thesis has addressed the research gaps, adding a detailed co-innovation process and mechanisms in developing bioplastic packaging and providing a framework as references for business practices or further exploration in future studies.

1.6. Structure of the thesis

This thesis is organised into the following chapters, and Figure 2 illustrates the structural flow of this thesis:

Chapter 1: This chapter briefly introduces the bioplastic packaging industry and the challenges, particularly related to implementation at business customers. Next, previous studies highlighting the importance of co-innovation, including those in developing bioplastic packaging, are presented. Subsequently, the research question, aim and objectives of this study are specified, followed by a summary of the findings and contributions.

Chapter 2: In this chapter, a systematic literature review (SLR) is presented, exploring the recent development of bioplastic packaging and to what extent co-innovation has been studied in the context of bioplastic packaging product innovation. Accordingly, the SLR identifies the research gaps and proposes a theoretical framework underpinned by the RV theory and absorptive capacity theory.

Chapter 3: This chapter presents the philosophical perspectives of this thesis. Accordingly, the research approach and research design are presented to address the research question and achieve the aim and objectives of this study. A multiple case study is employed as the research strategy, and this chapter provides further details on the data collection, case analysis, validity and reliability.

Chapter 4: This chapter presents the findings of this thesis, which covers the within-case analysis of 15 cases used in this study. The analysis is presented in descriptive form, demonstrating detailed illustrations of the process and mechanisms of co-innovation in developing bioplastic packaging.

Chapter 5: In this chapter, the cross-case analysis is elucidated. The analysis embraces the thematic analysis to reveal patterns and uniqueness across cases, then presented in narrative complemented by tables and illustrative figures. This chapter addresses the research objectives and reveals the refined framework.

Chapter 6: This chapter presents the discussions, elaborating the findings in relation to the theoretical framework. Following the discussions, the contributions to knowledge and implications for practice are presented.

Chapter 7: In this chapter, the thesis is concluded in broad perspectives, which integrate the answer to the research question and key takeaways from this study, including its limitations, and suggests avenues for future research.

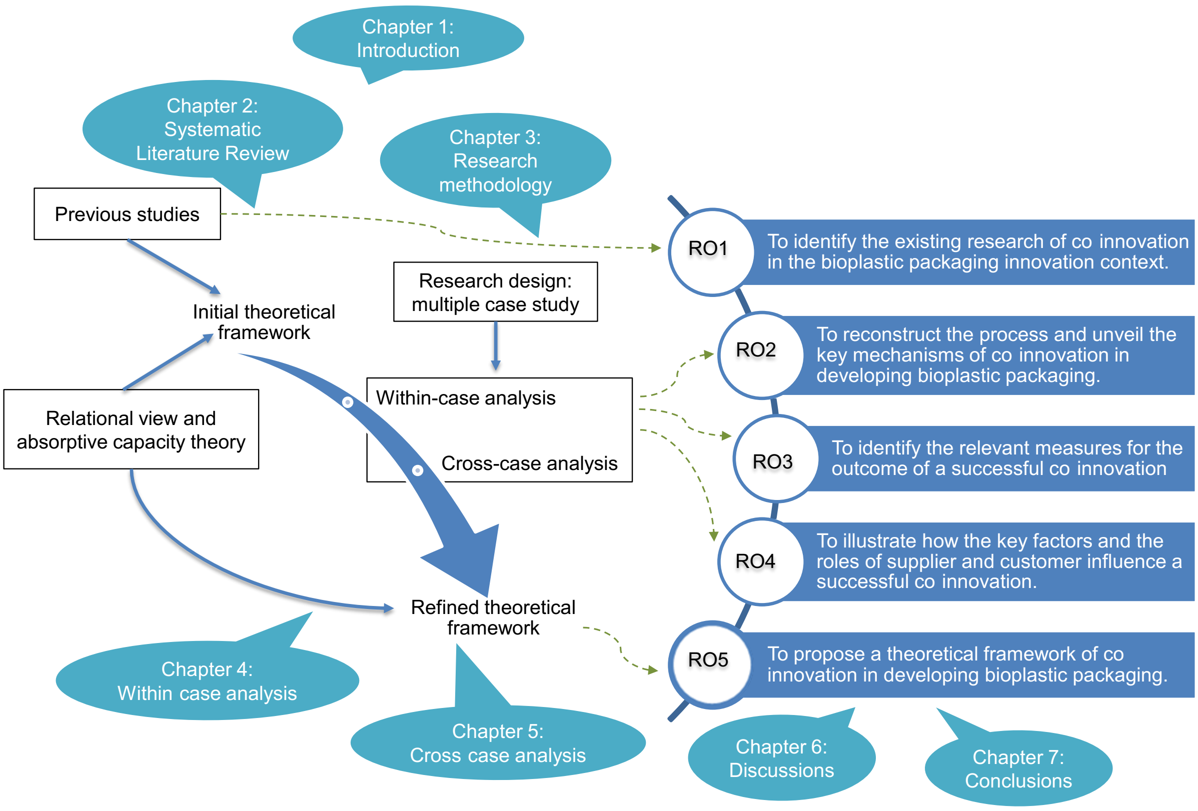


Figure 2 Structural flow of the thesis

2. Systematic Literature Review

Supplier-customer co-innovation in bioplastic packaging product development is essential and needs to be studied to address problems regarding the limited application of bioplastic packaging due to product fit for use issues. A literature review is employed to find the extent to which co-innovation is implemented in the context of bioplastic packaging, addressing the first research objective (RO1). Therefore, a systematic literature review is aimed to answer the following questions:

LRQ1: What is the recent development of bioplastic packaging, including product attributes and performance, and development methods?

LRQ2: To what extent has co-innovation been studied in the context of bioplastic packaging product innovation?

LRQ3: How is bioplastic packaging co-innovation conducted between organisations?

LRQ4: What indicates the outcomes of bioplastic packaging co-innovation?

The sections of this SLR are structured as follows. Section 2.1 presents the methodology chosen to conduct the literature review, comprising the mechanism of data collection from publication databases, the filtering process and data analysis. Section 2.2 presents the descriptive and thematic analyses, respectively, leading to the interpretation of findings that aim to answer the LRQs and identify the research gaps. Next, the discussion in Section 2.3 further elaborates the findings and explains the theoretical lenses underpinning the synthesis of a conceptual framework and the research propositions. Finally, the conclusions present the contributions to knowledge, implications for managerial practices, limitations, and opportunities for future research.

2.1. Methodology

This thesis employs an SLR as it provides a clear mechanism and a stringent review protocol performed to minimise researchers' bias and maintain the independence of the research process, yet allows exploration and discovery that contributes to developing an understanding (Tranfield et al., 2003) about the process of co-innovation in the bioplastic packaging context. The SLR method in this study is adapted from Tranfield et al. (2003), consisting of data collection, data analysis and synthesis phases.

2.1.1. Data collection

Data collection was carried out following the protocol, in the form of a step guide, to maintain the focus of the research on problems that need to be answered while maintaining the objectivity of the SLR (Tranfield et al., 2003). The protocol used in this SLR included a search strategy and criteria for inclusion directed to answering the literature review questions.

The search strategy included the identification of and decision for using the relevant keywords and search terms (see Table 1), database selection, followed by the trial and modification of keywords and search terms, and implementation of the search strategy. This SLR used five databases considering the context in the areas of business management, strategy and sustainability, and the availability of full-text peer-reviewed scientific literature: Business Source Complete (EBSCO), ABI/INFORM (ProQuest), Scopus, Science Direct, and Emerald. The search used Boolean operators such as AND, OR, and NOT to narrow or expand the search using combinations of keywords (Galvan & Galvan, 2017). Additional criteria were applied to limit the results to peer-reviewed academic journal articles written in English, within a 20-year period, i.e., from 2000 to 2019. This was mainly due to the need to cover a wide range of publication periods so as to ensure further exploration of bioplastic packaging studies, ideas and the concept of co-innovation. The search from the five databases retrieved 1440 articles. Figure 3 shows the search strings and filtering criteria used in the EBSCO database.

TI (("Collaborative innovation" OR "Co-innovation" OR "Co-creation" OR ((collaboration OR cooperation OR alliance OR joint OR partnership) AND innovation) AND (dyadic OR bilateral OR B2B OR "business to business" OR (buyer AND supplier OR seller) OR inter-firm)) OR AB (("Collaborative innovation" OR "Co-innovation" OR "Co-creation" OR ((collaboration OR cooperation OR alliance OR joint OR partnership) AND innovation) AND (dyadic OR bilateral OR B2B OR "business to business" OR (buyer AND supplier OR seller) OR inter-firm)) NOT (consumer OR B2C OR "business to consumer" OR individual OR personal)
Limiters - Full Text; Scholarly (Peer Reviewed) Journals; Publication Type: Academic Journal; Document Type: Article; Language: English; PDF Full Text
Expanders - Apply related words
Search modes - Find all my search terms

Figure 3 An illustration of the search strings in EBSCO

Table 1 The keywords used in the SLR.

Keywords	Synonyms and combinations
Collaborative innovation	Co-innovation, Co-creation, Co-development, (Collaboration/cooperation/alliance/joint/partnership) + (innovation/new product development/product innovation/ product improvement.
Dyadic	Bilateral, supplier-customer, buyer-supplier
Sustainability	Sustainable, natural, green, environment, renewable, reuse, recycle, eco/bio, biodegradable, compostable, bio-based, bio-benign, edible, water soluble, green product innovation, green product development, sustainable product innovation, sustainable product development.
Plastics/ packaging	Packaging, polymer, fast moving consumer goods, food n5 packaging, sustainable packaging, bag/wrap/box/ container/bottle/sachets/lids/caps/cups/cutlery/sachet/ pouch/carrier/straw/converters, primary/secondary/ tertiary package
Bioplastics	Bioplastic, biopolymer, bio based plastic/polymer, biodegradable plastic/polymer, compostable plastic/polymer

The selection of articles in this SLR followed a systematic protocol that included determining the selection criteria and documentation, filtering article duplication among the databases, and selection based on the title, abstract and full-text (Tranfield et al., 2003). The criteria for inclusion of the articles were predetermined to ensure the selection process was consistent for all articles, and minimised human error and bias (Tranfield et al., 2003) by using an assessment checklist that prioritised the purpose, findings and implications related to the LRQs or topic of the research, and also the relevant context of the study (Lusiantoro et al., 2018). These criteria enabled an extensive exploration of existing and emerging ideas, and concepts relevant to co-innovation in bioplastic packaging.

The title selection was made by including only peer-reviewed articles from an academic journal. Next, the article was evaluated by considering first, the title that contains any of the words: innovation/collaborative/co-creation/dyadic, and secondly, the relevance of the title to the context of co-innovation, co-creation, co-development or co-production in B2B supplier-customer relationships, packaging/sustainable innovation. The articles selected for the next stage are those with the relevant context or contain relevant words, and the context is moderately relevant. The title selection was recorded in the spreadsheet and exemplified in Table 2.

Table 2 An example of the title selection spreadsheet.

Reference	Title	Source	Assessment			
			Peer rev	Title contains specific words	Relevance	Decision
			(1)	(2)	(3)	(4)
de Vargas Mores et al., 2018	Sustainability and innovation in the Brazilian supply chain of green plastic	Journal of Cleaner Production	Y	Innovation	Y	Include
Lacoste, 2016	Sustainable value co-creation in business networks	Industrial Marketing Management	Y	Co-creation	M	Include
Chadha, 2011	Overcoming competence lock-in for the development of radical Eco-innovations: The case of biopolymer technology	Industry and Innovation	Y	Co-innovation	Y	Include
Chen et al., 2013	A sustainable collaborative research dialogue between practitioners and academics	Management Decision	Y	Collaborative	N	Exclude
Holmes & Smart, 2000	Exploring open innovation practice in firm-nonprofit engagements: a corporate social responsibility perspective	R&D Management	Y	Innovation	N	Exclude

Assessment criteria:

1. Consider the articles from peer-reviewed journal. Put a note: Yes/No.
2. Consider the title that contains any of the word: innovation/collaborative/co-creation/dyadic. Put a note.
3. Consider the relevance of the title to the context: co-innovation, co-creation, co-development or co-production in B2B supplier-customer relationships, packaging/sustainable innovation. Choose the following code:
   - Y : Yes, the context is highly relevant
   - M : Maybe, the context might be relevant
   - N : No, the context is not relevant
4. Decision for inclusion:
   - Include : The context is relevant (point 2 is Y) or the title contains relevant words (point 1 has a value) and the context is moderately relevant (point 2 is M).
   - Exclude : The article does not meet the inclusion criteria.

Next, the selection of articles based on the abstracts followed the assessment criteria, which considered the relevance of the abstract to B2B co-innovation, product development, conventional plastic and bioplastic packaging as well as sustainability. Each abstract was carefully assessed and scored 3 to 0 to reflect its potential contribution to addressing the LRQs. An article was included based on being relevant to the context and where the contributions to at least one of the LRQs were significant. See the example in Table 3.

In the full-text selection, all articles were carefully read; each was then evaluated based on three categories: contribution, theory and methodology, then given a score from 0 (absence), 1 (low), 2 (medium) to 3 (high) following predetermined assessment criteria, as seen in Table 4. Each article was reviewed to ensure the theory and references used in the article provide sufficient foundation for the analysis. Moreover, the research methodology was reviewed, such as whether the research strategy, design, and data collection were clearly explained or how the analysis was relevant to answering the LRQs. Articles were selected if they scored at least 2 (medium) for the overall importance of addressing the LRQs.

The researcher assessed the articles by following predetermined criteria, and the assessment was recorded in the spreadsheet. In this process, the researcher kept regular updates with two supervisors of the study regarding the assessment criteria and processes to ensure that the articles were given scores consistently and to finalise the assessment. The researcher also discussed the inclusion of an article with all supervisors of the study when different views between the researcher and one of the supervisors occurred. Lastly, three articles were added manually to include the most recent studies, which were relevant and appropriate to enrich the understanding of co-innovation, misalignment in packaging design and knowledge sharing in developing a product using new technology. The implementation of the data collection protocol, selection procedures, and the search results are summarised in Figure 4.

Table 3 An example of the abstract selection spreadsheet.

Reference	Abstract	Assessment			
		Relevance	Potential contribution		Decision
			Score	Note	
		(1)	(2)		(3)
de Vargas Mores et al., 2018	Climate change has intensified the demand for better social and environmental conservation efforts, motivating organisations to become more engaged in the development of sustainable technologies. This study analyses the innovation process…	Y	3	Mechanisms, factors	Include
Lacoste, 2016	Even though the Service Dominant Logic (SDL) paradigm has contributed to the conceptualization of "value co-creation", no academic study has further investigated the role played by sustainability in business-to-business (BtoB) value co-creation…	Y	3	Framework, mechanisms	Include
Chadha, 2011	The plastics industry is trying to avoid the price spiral of fossil fuels by utilizing renewable resources and simultaneously aims to contribute to the fight against climate change. Hence, this industry is in the midst of a hybridization process…	Y	3	Factors	Include
Preikschas et al., 2017	Abstract: This paper aims to explore how value co-creation processes can influence the generation of dynamic capabilities and the retention of industrial customers. The authors explore this influence with the support of social exchange theory and resource-based view…	Y	1	Benefits	Exclude
Su et al., 2015	Abstract: This paper explores the role, patterns, and characteristics of technological knowledge co-creation in a cross-organizational setting and examines the relationship between ownership structure and the value of co-created technological knowledge…	N	0	-	Exclude

Assessment criteria:

1. Consider the relevance of the abstract to the context: co-innovation, co-creation, co-development or co-production in B2B supplier-customer relationships, packaging/sustainable innovation. Put a note: Y/N
   Y : The context is highly relevant
   N : The context is not relevant
2. Assess the potential contribution to address the LRQs. Give score of 0 to 3 and put a note of the relevance to LRQs.
   3 : The abstract indicates significant contribution to at least one of the LRQs
   2 : The abstract indicates moderate contribution to at least one of the LRQs
   1 : The abstract indicates limited/little contribution to at least one of the LRQs
3. Decision for inclusion:
   Include : abstract is relevant to the context (point 1 is Y) and indicates at least moderate contribution (point 2 is at least 2).
   Exclude : The article does not meet the inclusion criteria.

Table 4 An example of the full-text selection spreadsheet.

Author(s)	Title	Source	Assessment				
			Contribution	Theory	Method	Score	Decision
			(1)	(2)	(3)	(4)	(5)
de Vargas Mores et al., 2018	Sustainability and innovation in the Brazilian supply chain of green plastic	Journal of Cleaner Production	Y	Y	Y	3	Include
Lacoste, 2016	Sustainable value co-creation in business networks	Industrial Marketing Management	Y	Y	Y	3	Include
Chadha, 2011	Overcoming competence lock-in for the development of radical Eco-innovations: The case of biopolymer technology	Industry and Innovation	Y	Y	Y	3	Include
Park & Lee, 2018	Early stage value co-creation network-business relationships connecting high-tech B2B actors and resources: Taiwan semiconductor business network case	Journal of Business and Industrial Marketing	N	Y	Y	1	Exclude
Townsend et al., 2017	Characteristics of project-based alliances: Evidence from the automotive industry	International Journal of Automotive Technology and Management	N	Y	Y	1	Exclude

Assessment criteria:

1. Consider the relevance of the abstract to the context: co-innovation, co-creation, co-development or co-production in B2B supplier-customer relationships, packaging/sustainable innovation. Put a note: Y/N
   - Y : The context is highly relevant
   - N : The context is not relevant
2. Assess the potential contribution to address the LRQs. Give score of 0 to 3 and put a note of the relevance to LRQs.
   - 3 : The abstract indicates significant contribution to at least one of the LRQs
   - 2 : The abstract indicates moderate contribution to at least one of the LRQs
   - 1 : The abstract indicates limited/little contribution to at least one of the LRQs
3. Decision for inclusion:
   - Include : abstract is relevant to the context (point 1 is Y) and indicates at least moderate contribution (point 2 is at least 2).
   - Exclude : The article does not meet the inclusion criteria.

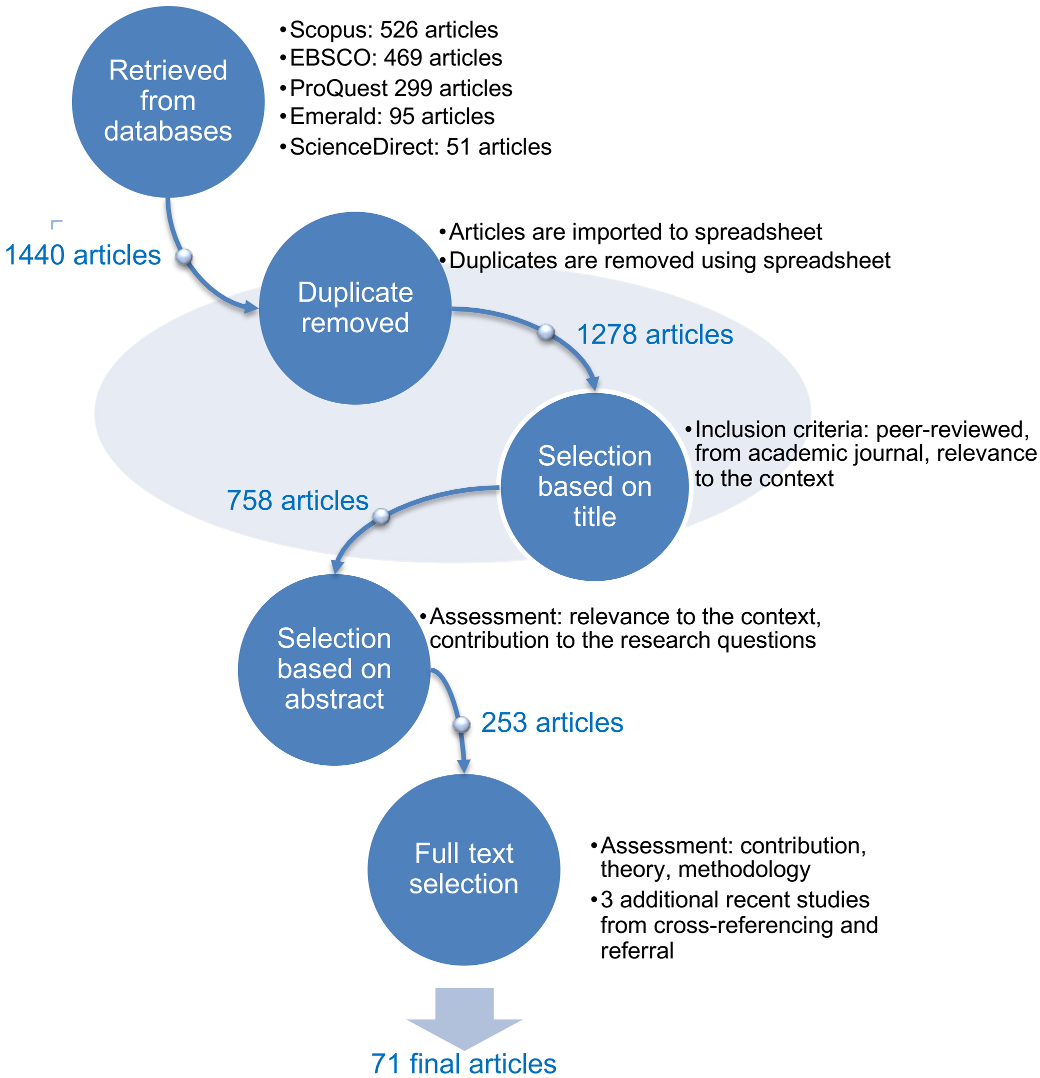


Figure 4 The implementation of the data collection protocol

2.1.2. Data analysis

After retrieving the final set of articles from the multiple appraisal processes, the next process was to analyse the data using both descriptive and thematic analyses. Descriptive analysis was used to depict the profile of the articles using simple categories (Tranfield et al., 2003) to facilitate the recognition of patterns and trends among categories in order to support the interpretation and understanding of a phenomenon. Thematic analysis was adopted to identify, analyse and report patterns (themes) within the data as well as organise and describe data sets in rich detail (Braun & Clarke, 2006). In the thematic analysis, the interpretative approach was used to extract data from the collection and identify consensus or emerging themes (Tranfield et al., 2003).

Template analysis was adopted as the data extraction technique due to its advantages in accommodating a balance between structure and flexibility by using a coding template to correspond to the researcher's need during the analysis with less time-consuming and complicated procedures (King, 2012). Therefore, the template analysis can manage large data more efficiently, as with the number of articles to be analysed in this SLR. *A priori* codes were developed based on the LRQs, which included 'bioplastics materials for packaging', 'bioplastic packaging product characteristics', 'challenges in the bioplastic packaging industry', 'co-innovation in bioplastic packaging', 'mechanism of co-innovation', 'the existing framework of co-innovation', and 'the outcomes and impacts of co-innovation'. The *a priori* codes also included 'research design', 'unit of analysis' and 'definitions' of important terms related to co-innovation.

The researcher carried out the coding process by extracting relevant data addressing the LRQs. In this process, the researcher kept close updates with the supervisors of the study regarding the details of the codes being made, the coding process, and how codes were iteratively modified and improved to ensure coding was carried out appropriately. In this process, the articles were carefully read, then relevant text, significant information and recurring topics were each given a code using a word or short phrase representing the essence (Braun & Clarke, 2006; Saldana., 2013; Tranfield et al., 2003). The coding process was managed using NVivo, a qualitative data analysis software tool. The following are some examples of codes emerging from the coding process, which are related to the implementation of supplier-customer co-innovation: *co-location to customer's plant, environmental knowledge, joint investment, allocation of idiosyncratic investment, joint team, work as a team with client's staff, specialised production units* and *technology integration*. All of these codes were grouped under the 'mechanism of co-innovation' code.

Having examined the entire articles, the next process was to collate the themes that emerged from the coding process. This was done by the two researchers who had coded the data, and an additional researcher who provided a neutral perspective, especially if there was a difference in opinion in assessing the relevant patterns to become themes. During the review process, codes were updated, added, combined or deleted if necessary. For example, the ‘allocating idiosyncratic investment’ code was merged with the ‘joint investment’ code, which represents the tangible or intangible investments dedicated by both supplier and customer involved in the collaboration. Subsequently, the emerging patterns were discussed and themes were created, given names based on the essence of a particular pattern, then the relevant codes were re-arranged under a specific theme.

For example, the theme of ‘joint resources’ was created to represent the resources allocated by customers in joint product development; this theme comprised the codes of ‘co-location to buyer’s plant’, ‘environmental knowledge’, ‘joint investment’, ‘joint team’, ‘specialised production units’ and ‘technology integration’.

2.1.3. Synthesis

Data synthesis presents the known and unknown facts, the extent of which consensus exists across themes based on the descriptive and thematic analysis that contributes to answering the literature review questions (Tranfield et al., 2003). The interpretation and arguments are more than just showing the meaning of the data; they also reveal the assumptions, implications, conditions, and reasons to present robust logical analysis (Braun & Clarke, 2006). In addition, template analysis accommodates discussion of the differences and consistencies between case studies to present the participants’ perspectives (King, 2012). This is adopted in the synthesis by presenting consistencies and specificity based on industry sectors, general packaging and sustainable product. Furthermore, the synthesis in this study presents the phenomena of the application of bioplastic packaging that reinforce the need for co-innovation, comprehensive indicators for bioplastic packaging product innovation and a conceptual framework for the mechanisms of supplier-customer co-innovation.

2.2. Data analysis

Descriptive analysis has provided a profile of the papers based on the journal, year of publication, industry and keywords. This simple grouping facilitates discovery of the emergence of trends, specific themes or differences between groups. The following section presents the descriptive analysis of the final 71 articles covering various disciplines, such as strategic management, operations management and supply chain management. Table 5 presents the number of articles based on the source, out of these 71 articles, 10 were retrieved from the Journal of Cleaner Production and five from the Business Strategy and the Environment journal, all of which were closely pertinent to bioplastics, packaging and sustainable products; they were also relevant to the scope of the journals in interdisciplinary research contributing to the understanding of business views and strategies regarding environmental management practice and regulation. Three articles were retrieved from Management Decision journal, which covers studies in operations management, problem-solving and strategy, all of which were in-depth studies in co-innovation. Other articles from various journals, such as Sustainability, Technovation, Innovation: organization & management and Journal of Product Innovation Management, were also captured using the data collection protocol, supporting the contributions to the research aim and objectives.

Table 5 Number of articles based on the source.

Journal	Number of articles
Journal of Cleaner Production	10
Business Strategy and the Environment	5
Management Decision	3
International Journal of Production Economics	2
Industrial Marketing Management	2
Sustainability	2
British Food Journal	1
Business Strategy & the Environment (John Wiley & Sons, Inc)	1
Creativity and Innovation Management	1
Ekonomicznego We Wrocławiu	1
Environmental Science and Pollution Research	1
Espacios	1
EuroMed Journal of Business	1
European Business Review	1
European Journal of Innovation Management	1
European Journal of Marketing	1
European Journal of Purchasing and Supply Management	1
European Journal of Training and Development	1

European Research Studies	1
Global Business & Organizational Excellence	1
Independent Journal of Management & Production	1
Industry and Innovation	1
Innovation: organization & management	1
Interfaces	1
International Journal of Automotive Technology and Management	1
International Journal of Human Resource Management	1
International Journal of Market Research	1
International Journal of Operations & Production Management	1
International Journal of Physical Distribution & Logistics Management	1
International Journal of Production Research	1
International Journal of Quality Innovation	1
International Journal of Recent Technology and Engineering	1
Journal of Business & Industrial Marketing	1
Journal of Business Ethics	1
Journal of Food Process Engineering	1
Journal of Information Technology Case and Application Research	1
Journal of Knowledge Management	1
Journal of Manufacturing Technology Management	1
Journal of Marketing	1
Journal of Open Innovation: Technology	1
Journal of Operations Management	1
Journal of Product Innovation Management	1
Journal of Strategic Marketing	1
Journal of Technology Management and Innovation	1
Journal on Chain and Network Science	1
LogForum	1
Maritime Economics & Logistics	1
Metals	1
Processes	1
R&D Management	1
Review of Managerial Science	1
Sustainable Production and Consumption	1
Technovation	1
Grand Total	**71**

The articles are also reviewed based on their geographical setting, see Figure 5. Seven papers were conducted in the global setting, exploring co-innovation in a diverse area and its conceptualisation and three of them were specific to bioplastics, such as its implementation in the automotive industry (Jeong & Ko, 2016), the outlook of biodegradable packaging (Sossa et al., 2015) and using this technology to establish firm's legitimacy in sustainability (Kishna et al., 2017). Five articles are taking specific settings in Brazil, explicitly discussing sustainable innovation and bioplastic packaging made of PLA. Brazil initiated a bioplastic project, and these studies provide an overview of the sustainability impact, product development, working with the supply chain (de Vargas Mores et al., 2018), key capabilities (Júnior et al., 2019), and success factors (Bossle et al., 2016; de Medeiros & Duarte Ribeiro, 2013; de Medeiros et al., 2018). Besides Brazil, specific references in bioplastics are also found taking specific regional contexts in Thailand, and these studies revealed the environmental assessment (Leejarkpai et al.,2016; Sarobol et al., 2013) and innovation in the start-up phase (Theinsathid et al., 2019). Moreover, previous studies in developing bioplastic packaging are also found in other specific geographical contexts, such as in the EU, which disclosed stakeholders' collaboration in a consortium and problems related to packaging design (Dobrucka, 2019; Granato et al., 2022); while research in the UK discussed the implementation of bioplastic packaging in the consumer goods and circular economy (Gong et al., 2019).

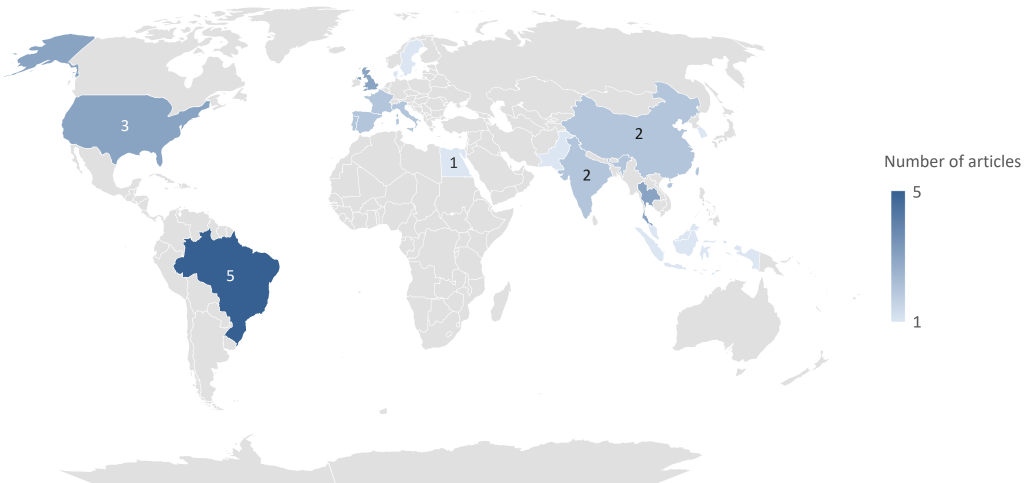


Figure 5 Number of articles based on geographical distribution

The articles included in the analysis are mostly specific to the manufacturing industry (61%) comprising diverse sectors, such as bioplastics or plastics in primary form, packaging, electronic components, automotive, machinery and equipment, chemicals, food and beverages; information and communication industry (4%); followed by construction; mining and quarrying industry. Furthermore, 23% of the articles focus not only on one industry but incorporate multiple industries; these include professional, scientific and technical activities; wholesale and retail trade; and also the manufacturing, information and communication industries. Figure 6 shows the percentages of articles based on each industry, which refer to the International Standard Industrial Classification (ISIC). This distribution indicates the prevalence of inter-firm co-innovation for product development in the manufacturing industry. Additionally, concepts and best practices from other industries, which were relevant to the purpose of this study, were included in order to build a comprehensive understanding of the concept of co-innovation and its implementation.

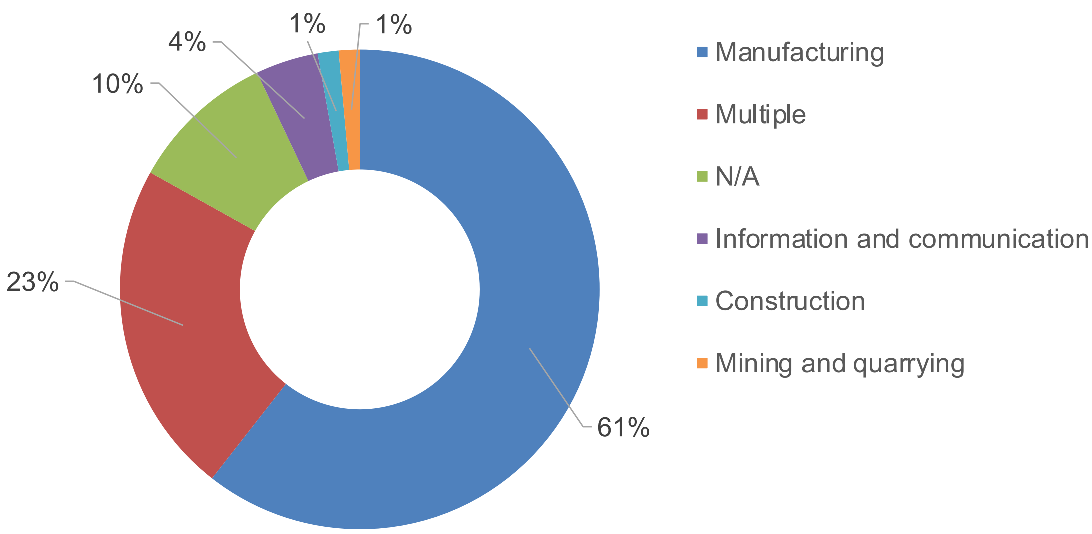


Figure 6 Distribution of articles based on the industry

In addition, the existing studies are primarily explorative in nature and case study research design is mainly used, i.e., in around 32% of the articles. Next, 24% of the articles use the survey method, 13% use a literature review, followed by experimental research, mixed methods and other qualitative approaches that include observation, Delphi method, event study, a document study, and others, see Figure 7. In addition, studies specifically in bioplastics mostly adopted qualitative approaches, such as case studies, experimental research, and other qualitative reviews, indicating an extensive exploration needed in bioplastics studies.

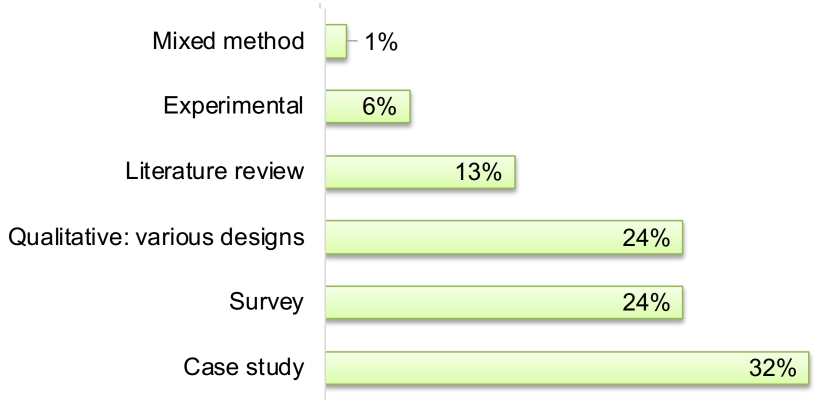


Figure 7 Percentage of articles based on the research design/approach

Keywords indicate important terms that describe a particular study. Figure 8 presents several keywords that appeared frequently in the literature and shows the general view of the research topics in the selected literature.

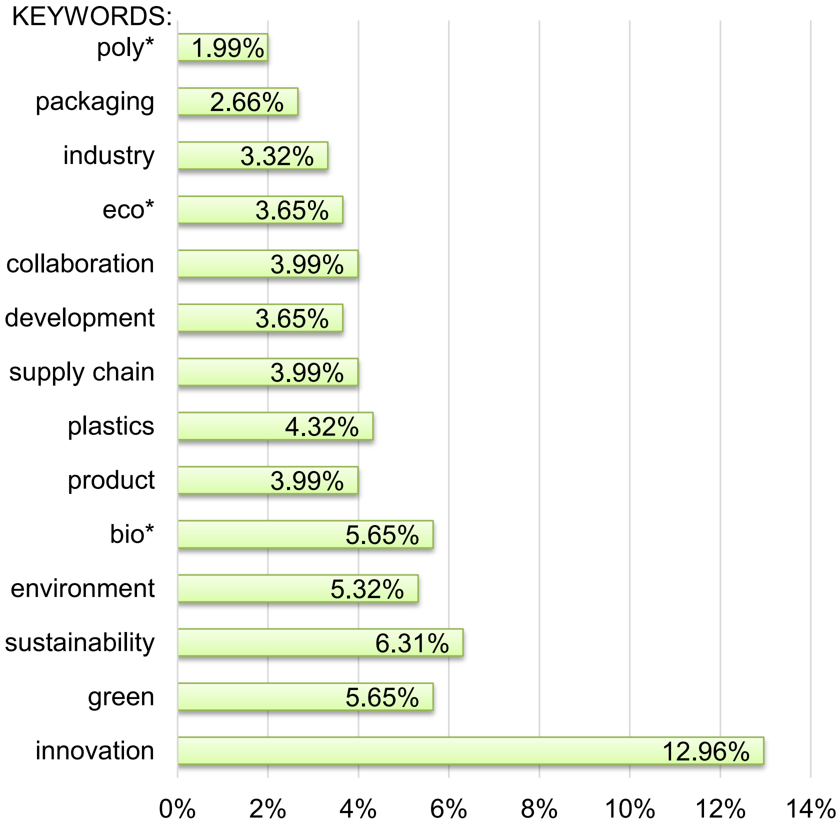


Figure 8 Distribution of articles based on the keyword frequency

The most widely used keyword was “innovation”, which was used in over 12% of all keywords, and found in various combinations such as “green/environmental/sustainable innovation”, “collaborative innovation”, “open innovation” and “co-innovation”. Besides, the keywords “green”, “sustainable” and “environment” are each used at around 6%, where examples of usage are “green products”, “sustainable development”, and “environmental collaboration”. In addition, the keywords “bioplastics” and “biopolymers” are used in a number of combinations, such as “bio-based plastic”, “biopolymer technology”, the frequency being less than 3%. Furthermore, equivalent terms for “bioplastic” were found, such as “green plastic”, “biodegradable packaging”, “bio-based packaging”, “sustainable packaging”, “green polyethylene”, “polylactic acid (PLA)", “biodegradable packaging”, all of which comprise 4% of all keywords. Overall, the keyword frequency described a large part of the selected literature that studied innovation, and some keywords were specific to co-innovation; thus are in accordance with the objective of this study. However, specific co-innovation studies on bioplastic packaging were still limited.

Moreover, there were some references, which were widely cited and can be said to be important as references for other studies, including this study; for example, the work of Lee et al. (2012), which described the evolution from closed innovation to open innovation and co-innovation, and developed the concepts and scope of co-innovation that integrates ideas from internal and external organisations to produce shared values through a platform. Lee et al. (2012) introduced the principles of co-innovation as aiming at the convergence of expertise and ideas, collaboration and value co-creation. Another important work was a case study about the adoption of sustainability and innovation practice by SMEs in the rubber and plastic manufacturing industry (Bos-Brouwers, 2010), which pointed out that sustainable innovation is not easily attainable in SMEs, and the practice of incremental innovation is more apparent than radical innovation. These studies suggested more research on the mechanisms of sustainable innovation due to the infancy of studies in this field (Bos-Brouwers, 2010; Lee et al., 2012).

2.2.1. Thematic analysis

This section corresponds to the first LRQ, and elucidates the recent development of bioplastic packaging, by focusing on the product characteristics that have been developed and their implications for the adoption of bioplastic packaging. First, the evolution of bioplastic packaging is briefly illustrated, followed by the analysis of the bioplastic packaging product characteristics based on the themes that were found during the data extraction process.

Over the last 10 years, bioplastic packaging has evolved and gained more significance. However, before 2010, the bioplastic industry was a long way behind commercialisation (Theinsathid et al., 2009). Although bioplastic packaging offered advantages to the environment, and its demand was increasing, the mechanical properties of the bioplastics made from starch-based, polylactic-acid (PLA) and Polyhydroxyalkanoate (PHA), had not well developed, and the cost of production was less feasible for commercial application (Theinsathid et al., 2009). Then, from 2010 to 2015, there seem to have been significant efforts from the plastic industry to expand into bioplastics (Chadha, 2011). In line with that, more studies focusing on the product development were found, which was mostly evaluated on the environmental aspects using Life-Cycle Assessment (LCA) and on the performance aspect using comparisons with conventional plastics (Benetto et al., 2015; Kuzincow & Ganczewski, 2015; Razza et al., 2015; Sarobol et al., 2013; Sossa et al., 2015). Since 2016, there have been more adoptions of bioplastic packaging in the industry (Boesen et al., 2019; Khan et al., 2017; Salwa et al., 2019) thanks to its relevance to the closed-loop principle of the circular economy (Dobrucka, 2019; Gong et al., 2019).

The development of bioplastics is apparent, as research evolves to create characteristics desired for packaging (Dobrucka, 2019; Khan et al., 2017; Sossa et al., 2015). The bioplastic packaging characteristics found in the literature are *grouped based on the material, manufacturing process, product performance, end-of-life and LCA*. The bioplastic materials are derived from either fossil-based materials or renewable resources, and the recent development shows the increasing use of the latter (Boesen et al., 2019; Dobrucka, 2019; Khan et al., 2017; Theinsathid et al., 2009), such as the starch-based PLA, which is currently used more for commercial than other bioplastic materials (Chadha, 2011; Dobrucka, 2019; Salwa et al., 2019). Alternative bioplastic materials are developing, such as cellulose-based, chitin-based, PHA, polyhydroxybutyrate (PHB), and Poly or 3-hydroxybutyrate-co-3-hydroxyvalerate (PHBV) (Dobrucka, 2019; Salwa et al., 2019). The production process is similar to that of conventional plastics (de Vargas Mores et al., 2018) but needs further development towards a more feasible cost (Theinsathid et al., 2009). Bioplastic packaging product performance includes similar features to conventional plastics (Khan et al., 2017), such as barrier properties, rigidity and hardness, rheological properties, strength, elongation, antistatic properties, printability, mechanical properties, heat resistance (Chadha, 2011; Dobrucka, 2019; Khan et al., 2017; Theinsathid et al., 2009). The end-of-life of bioplastic packaging includes being recyclable and compostable, and emphasises biodegradability (Ahmed et al., 2018; Boesen et al., 2019; Sarobol et al., 2013; Sossa et al., 2015; Theinsathid et al., 2009). Finally, bioplastic packaging is designed to have a better LCA, compared to conventional plastic (Leejarkpai et al., 2016; Sarobol et al., 2013; Theinsathid et al., 2009), but it raises concern over competing land use in food production along with health and safety considerations (Kuzincow & Ganczewski, 2015).

The literature, however, pinpointed that not all of the characteristics of bioplastics have been fully understood and there are differing (and somewhat contradictory) findings regarding a particular characteristic. For example, PLA has good rigidity, as well as water vapour and gas barriers (Ahmed et al., 2018; Leejarkpai et al., 2016) while starch-based bioplastics are lacking in these qualities (Khan et al., 2017). Not only many different sources of material lead to different characteristics, but the same sources of material may also indicate different specific characteristics, for example PLA. Some studies showed that PLA is known for its good mechanical properties (Ahmed et al., 2018; Khan et al., 2017; Leejarkpai et al., 2016) while other studies claimed that PLA has low mechanical properties (e.g., Theinsathid et al., 2009). These limitations impact on bioplastics application in the packaging industry.

The problems in application are related to the use of renewable material and its processing, product performance, biodegradability and the side effects of implementing sustainable management to achieve better LCA. First, changing the source of material from fossil-based to renewable impacts significantly on the overall manufacturing and supply chain. Bioplastic packaging is made from bio-polymers processed using injection moulding, thermo-processes to obtain the desired shape, thickness, colour or other specification for packaging (Khan et al., 2017; Sossa et al., 2015). Subsequently, the packaging will be processed along with the main products, given an additional labelling, then processed with secondary and tertiary packaging, until it reaches the end users. The process in the supply chain currently follows the same process, using the same equipment as the conventional plastic packaging (de Vargas Mores et al., 2018; Sarobol et al., 2013). However, bioplastics require additional materials and techniques such as the application of plasticisers (Benetto et al., 2015; Khan et al., 2017; Sossa et al., 2015), so not all conventional plastic packaging production processes can be used for bioplastics.

Second, the bioplastic packaging product performance and quality often fall below those of conventional fossil-based plastics (Khan et al., 2017; Theinsathid et al., 2009). This means bioplastic packaging often does not meet the desired function, and therefore cannot be used for certain products (Chadha, 2011; Khan et al., 2017; Salwa et al., 2019), or needs adjustment for existing products (Theinsathid et al., 2009). As exemplified by the application of food packaging, bioplastic packaging must be able to protect and maintain the physical properties of the food, including ensuring hygiene and safety (Salwa et al., 2019). The same characteristics of conventional plastic should exist in bioplastic packaging, such as barrier properties, meaning the bioplastics should be able to provide barriers to air, water or any other external environment. However, when using a starch-based packaging for fresh produce or bakery items, the lower water barrier causes water to permeate easily and fresh produce becomes dehydrated or dry, causing a shorter product shelf life (Khan et al., 2017). Similarly, the application of PLA as packaging is often compared to the polyethylene terephthalate (PET) used for water or cold drink bottles (Boesen et al., 2019; Razza et al., 2015; Sarobol et al., 2013), but PLA has limitations in its heat resistance and mechanical properties compared to conventional plastics (Theinsathid et al., 2009). Hence, the recent solutions to improve these issues by adding a reinforcing agent or even utilising nanotechnology, are being intensively studied (Salwa et al., 2019).

Third, biodegradability is one of the features that make bioplastics a promising substitute for conventional plastics (Ahmed et al., 2018; Khan et al., 2017; Sarobol et al., 2013). To achieve a maximum biodegradable advantage, the biodegradable plastic packaging needs further processing at the biodegradable facility and cannot be mixed with the recycling process. There are still problems at the after use stage; for example, due to the fact that PLA packaging is physically similar to conventional plastics, i.e., PET, and bioplastics are likely to cause confusion during the recycling facility, thus risking the loss of biodegradable benefits and adding contamination to the recycling process (Benetto et al., 2015).

Last, bioplastic packaging is expected to have a better LCA than conventional plastics and as an environmentally friendly product, it should therefore be processed following the environmental regulations, considering health and safety to humans and the environment (Khan et al., 2017; Kuzincow & Ganczewski, 2015). These complicated requirements affect all the supply chain, leading to a higher cost of production (Benetto et al., 2015). Furthermore, agricultural or farming processes, harvesting the raw material, and complexity of the manufacturing may further exacerbate the LCA and the environmental impacts (Razza et al., 2015).

In answering LRQ1, we found that not all characteristics of bioplastic packaging have been well understood by the customers. This circumstance, at present, limits its application in the packaging industry, thus corroborates the need for further research on how the bioplastic packaging manufacturers and the users (i.e., product manufacturers), and should co-innovate in producing better, fit-for-purpose products so as to increase the uptake of bioplastic packaging. Bioplastic product development is ongoing and directed to improve the properties of bioplastics and improve product performance for a variety of applications in industry – mostly the packaging industry. Intensive R&D is undertaken to develop alternative materials or improve the properties of existing bioplastic materials in the market, such as starch-based and PLA, through modification of materials by utilising reinforcement agents and nano-technology, meanwhile still working to achieve a more feasible cost of production.

2.2.2. Existing studies on co-innovation in bioplastic packaging

This section illustrates the findings regarding the studies of co-innovation in bioplastic packaging, which also address the second LRQ. The following analysis consists of trends around specific co-innovation in bioplastic packaging and expansion into fields of study relevant to that context, such as packaging, green product development and best practices of co-innovation in other industries that can enrich the synthesis of this research.

Before 2010, studies related to bioplastics and co-innovation were limited due to the indication that the bioplastic industry was far behind commercialisation (Theinsathid et al., 2009). One of the strategies suggested to drive innovation in this industry was that of devoting attention to the technology push and demand pull, and integrating economic feasibility through open innovation practices among supply chain members (Theinsathid et al., 2009). Next, signifying the expansion of the plastic industry into bioplastics, Chadha (2011) urged the need for supplier-customer collaboration in order to learn about the technical area, overcome competence lock-in and achieve radical eco-innovation. Furthermore, dyadic or network co-innovation at the pre-competitive stage was seen as likely to be successful (Kishna et al., 2017). A study illustrating an example of successful co-innovation in developing breakthrough bioplastic was identified, showing the involvement of the green plastic supply chain and sustainability-oriented strategy as a critical foundation for the operation (de Vargas Mores et al., 2018).

Most studies of co-innovation in bioplastics packaging found from the SLR, either directly or indirectly, emphasise inter-firm collaboration as a strategy for advancing product development, innovation and tackling the challenges in the application of bioplastic (de Vargas Mores et al., 2018; Dobrucka, 2019; Khan et al., 2017; Kishna et al., 2017). Since 2019, more attention has been given to co-innovation in bioplastic but the direction for future studies has yet to become prominent. Boesen et al. (2019) briefly mentioned that collaboration with the supplier helps in both improving the environmental aspects of bioplastic packaging and addressing the market pressure. A case study highly relevant to the aim of this study was found, illustrating a successful green plastic development in Brazil, in which an intensive co-innovation in R&D is seen as the key to its success (de Vargas Mores et al., 2018). However, the existing co-innovation studies that are specific to bioplastics are case studies, but the contexts of all of them all highly specific to the green plastic project in Brazil (de Vargas Mores et al., 2018) and provide limited details on how co-innovation addresses the development of bioplastic properties or achieves product fit for use in the packaging industry.

Interestingly, in association with the circular economy, the UK Fast Moving Consumer Goods companies are moving more towards optimising the recycling system, and showing less support for bioplastic packaging due to cost, insufficient disposal infrastructure and disruption to existing recycling systems (Gong et al., 2019). Moreover, a recent study by Granato et al. (2022) learned from a European packaging consortium and discovered misalignments between user and designer in developing bioplastic packaging, which eventually limits its adoption by the consumers and market success. Value gaps exist regarding the ideal sustainable packaging, of which the packaging designers emphasised technical, rational parameters and had not fully grasped more consumer's emotional value into their design (Granato et a., 2022). Further misalignments occur in the bioplastic packaging value chain (Gong et al, 2019), inhibiting its adoption by business customers and transition to the mainstream (Beltran et al, 2021). Different suggestions for future studies were found, such as collaboration with suppliers (Boesen et al., 2019), understanding initiatives and actions towards the circular economy (Gong et al., 2019) and using a more progressive consumer-oriented approach in packaging design to address misalignment with the users (Granato et al., 2022). These facts indicate the research gap that need addressing in future studies.

Due to the above limitations, the analysis of this study was extended to explore the process and mechanisms of co-innovation in different industries, by focusing on case studies that describe best practices in detail. Table 6 summarises the implementation of co-innovation in several industry sectors that need to be considered.

Table 6 Summary of co-innovation best practice from other industry sectors.

Industry sector	**Co-innovation**		**References**
	Area of implementation	**Process and mechanism**	
Manufacturing-aeronautics	Highly intensive R&D investment to develop products that meet the industry requirements, such as system complexity, high reliability demand, multi-domain characteristics, extremely long life cycles, valuable products.	Involving large network collaboration, consisting of government, universities, and suppliers.	Pinilla et al. (2019)
Manufacturing-automotive	Supplier involvement in R&D collaboration for a range of vehicle systems, such as body assembly, steering, braking systems,	Mostly supplier-customer collaboration, focuses on R&D collaboration at an early stage. Engagement starts from the partner selection process; the	Croom (2001); González-Ciordia et al. (2019); Huber et al. (2011);

	etc.; often focused on the technical issues related to design; the development of specific alloys, machine equipment and production processes to meet the customer's requirements.	existence of a suppliers' pyramid. Transfer of product-related knowledge, detailed investigation of failures as the basis of new design improvement, access to real production setting, support customer's technology legitimacy.	Jeong and Ko (2016);
Manufacturing-packaging	Packaging development based on solution to customer's needs/problems, additional support services.	Supplier-customer collaboration from conception to commercialisation; the supplier commits to continuous supply, takes on role of business consultant; co-locates to customer's site; promotes customer's innovation; shares sensitive/confidential information.	Baraldi et al. (2014); Morgado (2008); Slater (2010)

A study in the aeronautical manufacturing industry illustrated that network collaboration strategies successfully facilitate the maximum utilisation of resources, have extensive access to data and operation, and extend the capacity of research to achieve technological excellence (Pinilla et al., 2019). The aeronautics field relied on intensive R&D, and involved high complexity in the supply chain, manufacturing and technology (Pinilla et al., 2019), which has a quite strong relevance for co-innovation in bioplastics. Furthermore, González-Ciordia et al. (2019) illustrated the process of forensic metallurgical failure analysis that led towards improving newly designed equipment in automotive manufacturing. Working with this mechanism, the customer should give access to perform such a detailed investigation in a real production setting, be open to sharing information about their needs and expectations, and possibly make adjustments on the customer's side (González-Ciordia et al., 2019); their study is relevant when co-innovation in bioplastic packaging has to address the root cause of a lack of product performance. Finally, co-innovation studies in the packaging industry show how suppliers successfully create innovative packaging that is not only fit for purpose but also becomes the solution to the customer's problem (Baraldi et al., 2014; Morgado, 2008; Slater, 2010). Albeit the current studies are limited, those studies are within the same industry sector, hence are highly relevant in addressing the current problems of bioplastics packaging.

Furthermore, themes emerged through a careful data extraction of the existing studies. The literature in the bioplastics, green plastic product category explains that collaboration exists mostly between customer and supplier (Baraldi et al., 2014; Chadha, 2011; Farrow et al., 2000; Morgado, 2008), especially in R&D (Ahmed et al., 2018; Jeong & Ko, 2016) and co-development of a new product (Theinsathid et al., 2009). The literature in the bioplastics context argues that collaboration in the early stage of product development will increase the chance of successful product development (Theinsathid et al., 2009). In bioplastics co-innovation, learning, exchanging knowledge and absorbing partners' capability all occur when suppliers learn to understand the customers' needs and customers learn about the bioplastics technology (Jeong and Ko, 2016; Kishna et al., 2017; Theinsathid et al., 2009). In the case when customers are the final product industry leader, alliance strategies are involved which aim for maximum future competitive advantage, such as building their own bioplastics production (Jeong and Ko, 2016), establishing a standard of bioplastic packaging use for the industry and achieving technology legitimacy (Kishna et al., 2017). However, detailed discussions on the process of co-innovation in product development, and in particular bioplastic packaging, are limited since the data are collected from secondary sources (Jeong and Ko, 2016; Kishna et al., 2017). *These findings answer LRQ2 and subsequently pinpoint the research gaps* that need addressing.

2.2.2.1. Co-innovation between organisations: from the development towards the final product

The co-innovation process describes a series of steps carried out in a specific order to achieve results, which in the context of the literature review is bioplastic packaging product innovation. Due to the limitation of any specific references to bioplastic packaging, the analysis of the co-innovation process refers to co-innovation in the general packaging and sustainable product industry. The literature in the general packaging context is considered due to the similarity of product functionality, value chain, production and supply chain (Ahmed et al., 2018; de Vargas Mores et al., 2018; Khan et al., 2017; Sarobol et al., 2013), while the literature in the sustainable or product innovation context is highly relevant to the environmental aspects, new technology involved and emerging new markets (Chadha, 2011; Dobrucka, 2019; Melander, 2017).

The literature, especially on sustainable product innovation, reveals the stages of collaboration and product development, which are important to allow exploration of the systematic process, and the importance of each stage to achieve bioplastic packaging product performance and sustainability performance. Based on the references, the stages of collaboration refer to the general collaboration for the product development process. In particular, sustainable product innovation involves positive sustainable or environmental impact at every stage (Lacoste, 2016; Soylu & Dumville, 2011), or at least one stage (Lee & Kim, 2011). The initial stage is the partnership development stage that exists before the product conception starts. In this stage, partners align their shared vision, values and objectives on sustainability, set goals and strategies, and establish commitment and contracts (Bossink, 2002; Oinonen & Jalkala, 2015; Perez et al., 2013). Partner selection considers the partner's sustainable portfolio, technology and knowledge in sustainable areas (Melander, 2018), reviewing the partner's management policy on sustainability (Morgado, 2008) and their environmental audit (de Vargas Mores et al., 2018).

After establishing a partnership, the partners enter the concept development stage. In this stage, customer and supplier engage in interactive ideation (Oinonen & Jalkala, 2015) to formulate novel product concepts (Rai et al., 2010), share knowledge and learn in a reciprocal way (Perez et al., 2013). During product conception, a joint project or specialised department is necessary (Bossink, 2002) involving skilled human resources in the area of sustainability (Abdullah et al., 2016), who will necessarily work in a high confidentiality environment (Morgado, 2008). At the concept development stage, product design should include sustainable features, functionality and material (Lacoste, 2016). Next, the product development stage consists of constructing the product, raw material selection, developing a prototype, user testing and validation, and customers putting more resources into investment (Lacoste, 2016; Perez et al., 2013; Rai et al., 2010). The following stage is the implementation of the real production process (Bossink, 2002; Lacoste, 2016; Rai et al., 2010), which is followed by commercialisation (Oinonen & Jalkala, 2015).

Furthermore, the concept development stage is defined as the early product development stage, while the prototype development and product validation is the later stage (Melander, 2018). Supplier-customer collaboration timing varies from concept to prototyping stage (Lee & Kim, 2011), but the references emphasise the importance of early stage collaboration allowing the supplier to incorporate the customer's needs, improve the use of sustainable material, develop better offerings and increase the customer's contribution to the knowledge of product functionality, end-of-life (Lacoste, 2016), health and safety (Arnold, 2017), and clarify the need for particular sustainable product features, ideas for product concept and market information (Melander, 2018). Meanwhile, customer involvement at the later stage is also critical in product testing and validation (Melander, 2018) to increase product acceptance during commercialisation.

Similarly, the literature on general packaging reveals that the supplier-customer co-innovation process starts with the conceptual phase (Slater, 2010), in which the supplier involves the customer in designing and engineering the product (Morgado, 2008), and continues with product development or the prototyping phase and trials (Morgado, 2008; Slater, 2010) to commercialisation (Slater, 2010). A number of authors also disclosed a prominent factor facilitating success in the collaboration process, i.e., when the supplier prioritises the customer's needs then provides solutions through innovation and integrated services (Baraldi et al., 2014; Morgado, 2008; Slater, 2010). Consequently, collaboration promotes the customer's innovation (Morgado, 2008), increases the customer's strategic competitiveness and, in the end, leads to close engagement and a long-term relationship (Slater, 2010).

Morgado (2008) explains co-innovation and co-creation in the case of a leading plastic packaging company in Portugal, which includes product innovation with a significant improvement in the product function, both technical and usage. In this collaboration, the supplier co-located to the customer's plant, and insisted on the sharing of confidential information and taking on the role of business consultant. The supplier is highly competent and a leader in the packaging industry that is able to fulfil the client's need for innovative product with lower cost (Morgado, 2008). Likewise, Slater (2010) revealed that the packaging supplier committed to a continuous supply by sharing confidential demand information, then implemented a computerised integrated inventory program for the customer that include training during its implementation. In both studies, the suppliers immersed their activities complementarily to the customer's value chain (Baraldi et al., 2014; Morgado, 2008; Slater, 2010). As a result, the collaboration contributed to the customer's improved manufacturing, just in time delivery (Morgado, 2008) and even won a product innovation award (Slater, 2010).

2.2.2.2. The mechanisms of co-innovation

Due to the limitations, with specific reference to bioplastic packaging, the analysis of the co-innovation mechanisms in this section has been inferred from co-innovation in the general packaging and sustainable product. The term 'mechanism' is referred to as a way of doing co-innovation that is influenced by factors such as drivers and success factors in a system, and the articles being reviewed pointed out three prominent themes: *joint activities* and *joint resources*, supported by strong *relationship management* both at the strategic and operation levels. Joint activities refer to interactive, reciprocal, pro-active activities with business partners to achieve the objectives of the collaboration. Joint resources include tangible and intangible resources committed to and invested in by all partners involved in the collaboration. Relationship management with business partners aims to build a productive relationship through activities, behaviours, knowledge and skills.

Sustainability oriented relationship management

Relationship management is important in sustainable product innovation; it also shares factors similar to collaboration in general, such as trust, open communication, constructive coordination (Huber et al., 2011; Revilla & Knoppen, 2015; Yang et al., 2015), engagement (Croom, 2001; Tomlinson & Fai, 2013), conflict management, clear expectation (Lager & Frishammar, 2010; Tsou et al., 2015), contract agreement (Bossink, 2002; Greer & Lei, 2012), and power balance (Bossink, 2002; Huber et al., 2011). In a recent study, relationship with co-innovation partners depend on the contribution of the co-innovation initiator. Inter-dependence will be enhanced when the co-innovation initiator strongly contributes to the co-innovation project and maximise flow of knowledge among partners (Lingens & Huber, 2021).

The specific features in the sustainable product innovation context include, first, the selection of a partner who possesses an innovative capability (Farrow et al., 2000) and complementary know-how in the environmental sustainability areas (Baraldi et al., 2014; Chadha, 2011), possibly confirmed through an environmental certification

(Cheung et al., 2010; Melander, 2017). Second, the customers and suppliers are often problem solver types who are concerned with sustainability or environmental issues (Hofmann et al., 2012). However, the motivation towards sustainability may become a challenge in this instance when there is doubt as to whether the customer or supplier is genuinely concerned with sustainability-related problems or they are merely compelled by regulations (Arnold, 2017).

Several factors are considered critical in developing a collaboration: a strong binding is related to joint investment in distinct activities or other resources (Cheung et al., 2010); and flexibility, tolerance and agreement to common standards instead of complicated detailed standards to resolve technological or other uncertainties (de Medeiros & Duarte Ribeiro, 2013; Fadhilah & Andriyansah, 2017; Melander, 2017). The collaboration should be built within a strategically close relationship (Lee & Kim, 2011) towards a synergy to improve value creation, address problems in bioplastics (Chadha, 2011), and thus lead to sustainable production and consumption.

Joint activities through knowledge transfer and co-creation

Collaboration between customers and suppliers involves activities that are carried out jointly and reciprocally, by integrating sustainability principles (Chen et al., 2017), and the interactions are emphasised as supporting customer innovation (Farrow et al., 2000). The literature shows the activities jointly performed by customers and suppliers are mostly related to knowledge transfer and co-creation.

Knowledge transfer is achieved through continuous learning, knowledge sharing and exploration of new knowledge. Continuous learning includes acquisition, assimilation of diverse knowledge to innovate and the development of novel technology (Chadha, 2011) in KSR (Hofmann et al., 2012; Huber et al., 2011). The customer and supplier share information and knowledge in order to explore new technologies, cutting edge manufacturing and product technologies (Dangelico, 2016). They are also involved in R&D activities and learn specific technical needs and requirements (Chadha, 2011). Both customer and supplier monitor emerging technology and regulation in bioplastics, which may change the business environment and affect their investment and operation (Chadha, 2011).

Co-creation activities commonly found in different contexts of collaboration (Lee et al., 2012; Rai et al., 2010) including packaging (Morgado, 2008) and sustainable product innovation (Arnold, 2017; Lacoste, 2016). Co-creation is a process of creating tangible or intangible values, such as experiences, products, services, processes, etc., through the cooperation of stakeholders (Bharti et al., 2015; Ehlen et al., 2017; Rai et al., 2010). Supplier-customer co-creation activities create desirable outcomes in sustainable or green product innovation (Fadhilah & Andriyansah, 2017) by emphasising the understanding of customers' behaviour, which means matching their needs, and receiving feedback from customers (Oinonen & Jalkala, 2015; Granato et al., 2022), receiving market information (Fang et al., 2015), increasing the awareness and acceptance of sustainable product (Arnold, 2017), influencing customers' behaviour and adaptation towards the sustainable offering (Lacoste, 2016; Granato et al., 2022), and also involving the customers in the product development process (Fang et al., 2015).

Joint resources in product development

Collaboration in sustainable product innovation is beyond the transactional buyer-seller relationships. In contributing to a fruitful and lasting relationship, all members of the collaboration share tangible and intangible resources. The essential resources shared in the sustainability context are environmental knowledge and technology (Dangelico, 2016; Yin et al., 2019; Melander, 2018) which are jointly shared between firms, or flow from the external to the internal partner. In addition, collaboration may require joint investments (Baraldi et al., 2014) focusing on the product development project, such as infrastructure (Chen et al., 2017; Cheung et al., 2010), a dedicated production unit (Morgado, 2008), and research facilities and equipment, and human resource training & development related to environmental management and knowledge (de Medeiros & Duarte Ribeiro, 2013). Sharing resources facilitates a stronger relationship, learning, competence lock-in and minimises negative behaviour (Cheung et al., 2010). An example from a case study of supplier-customer collaboration in plastic packaging product development revealed that the supplier dedicated a production facility, a co-location that created interdependencies with the customer (Baraldi et al., 2014; Morgado, 2008).

In answering LRQ3, it was found that the process and mechanisms of co-innovation are often viewed from the general packaging and sustainable product innovation contexts, revealing the stages of new product development and the mechanism, comprising *relationship management*, *joint activities* and *joint resources*. The literature in the general packaging context emphasises high responsiveness to customers' specifications and integrated services for customers; while the sustainable product innovation context includes environmental and technological know-how, and sustainable processes throughout the value chain for better LCA. Co-innovation in bioplastic packaging requires a comprehensive process and mechanisms that encompass both product improvement and sustainability practices; however, the existing studies provide limited detail about these.

2.2.2.3. Towards an advanced bioplastic packaging as the outcome of co-innovation

The importance of co-innovation for developing bioplastics and sustainable products has been highlighted in previous research and the following section explains the benefits and positive outcomes derived. The literature described how co-innovation is adding value to the final product by being recognised as an eco-friendly product and reducing cost as a result of integrating the supply chain (de Vargas Mores et al., 2018; Farrow et al., 2000). Co-innovation has been proven to enhance overall corporate performance (Baraldi et al., 2014; Dangelico, 2016; Farrow et al., 2000; Morgado, 2008), especially financial performance (Arnold, 2017; Dangelico, 2016; de Vargas Mores et al., 2018; Morgado, 2008), product performance (Fadhilah & Andriyansah, 2017; Farrow et al., 2000; Lacoste, 2016), environmental performance (Arnold, 2017; Dangelico, 2016; Farrow et al., 2000; Soylu & Dumville, 2011) and innovation performance (Chadha, 2011; Slater, 2010). As a result of engaging in co-innovation with the customer, the supplier can increase its know-how in product development and may create a stronger interdependence with the customer (Baraldi et al., 2014).

From the literature on green product innovation, several contributions are relevant to the bioplastic packaging characteristics, such as using fewer resources, having lower impacts on and risks to the environment, preventing waste generation at the conception stage, leading to a long-term higher quality of life, and improving environmental responsibility (Abdullah et al., 2016; Dangelico, 2016; Fadhilah &

Andriyansah, 2017); while from the literature in conventional packaging context, emphasis is on product performance, innovation and organisational performance, and less on environmental performance (Baraldi et al., 2014; Morgado, 2008; Slater, 2010).

Finally, the literature shows that the outcomes of co-innovation, which answer LRQ4, are related to improving product quality and performance, reducing production costs, developing the organisation's capability and performance, decreasing the negative impact on the environment, promoting environmental responsibility and quality of life. The literature in the conventional plastic packaging co-innovation and sustainable product innovation shows varying outcomes from co-innovation, thus are insufficient to measure the outcomes of co-innovation in bioplastic packaging, which should incorporate both product functionality and environmental performance.

2.3. Discussion and synthesis

The first LRQ in this SLR seeks to understand the current state concerning the application of bioplastic packaging and the findings show inconsistencies between studies regarding characteristics, positive and negative aspects of the manufacturing processes, and use as packaging. Different characteristics are found across the material and within different applications of the same material, indicating the complexity of bioplastics technology (Benetto et al., 2015; Chadha, 2011; Khan et al., 2017; Razza et al., 2015). Having reviewed the current state of bioplastic packaging, it was apparent that there are issues in the application of the product from the bioplastic packaging manufacturer which mostly affect the product manufacturer as the direct user. The literature suggests that manufacturing expertise in bioplastics packaging technology is currently lacking to ensure the full-scale production of bioplastic packaging, nor is it ready to establish bioplastics as a replacement for conventional plastic packaging. Therefore, involving product manufacturers in the bioplastic product development through co-innovation is considered a promising strategy to enhance that development towards a better fit for users' needs. This is supported by the literature, in the packaging industry and sustainable product innovation context, which explicitly and implicitly specifies that co-innovation contributes, or is directly related, to product innovation (Dangelico, 2016; de Medeiros and Duarte Ribeiro, 2013; de Medeiros et al., 2018; de Vargas Mores et al., 2018; Fadhilah & Andriyansah, 2017; Morgado, 2008; Slater, 2010), thus supporting the need for co-innovation in bioplastic packaging product development.

2.3.1. Indicators for co-innovation performance in bioplastic packaging

A significant effort and resources dedicated to the co-innovation process should be directed towards a measurable targeted output or performance. Indicators based on the unique characteristics of bioplastics product are important to measure the intended performance of its development; however, the existing literature has not addressed this. Therefore, this thesis addresses this gap by initiating the development of comprehensive indicators for bioplastic packaging product innovation, as seen in Table 7, that include product quality, sustainability, cost and innovation performance.

First in the table are the product quality indicators, initially developed based on Garvin's (1984) study comprising performance, feature, reliability, conformance, durability, aesthetic and perceived quality. In order to define the specific characteristics of bioplastics and sustainable products, the proposed indicators for bioplastic packaging include eco-friendly final product image (de Vargas Mores et al., 2018), appearance of natural-featured products (Fadhilah & Andriyansah, 2017), high performance, great looks (Farrow et al., 2000), improved use and functionality (Lacoste, 2016).

Table 7 Proposed indicators of bioplastic packaging product innovation.

Indicators	Sub-indicators	References
Product quality	Meets customer specification, comparable to fossil-based plastic or improved use, functionality, performance, aesthetic, eco-friendly image.	de Vargas Mores et al. (2018); Fadhilah & Andriyansah (2017); Farrow et al. (2000); Lacoste (2016)
Sustainability	Cyclic: using renewable resources and biodegradable, efficient use of renewable resources, less material footprint, environmentally friendly design product development and production process, minimum polluted residue after biodegradable process, alternative waste reduction process, recycling, reuse, etc.	Abdullah et al. (2016); Farrow et al. (2000); Lee & Kim (2011)

Cost	Efficient cost of production.	de Vargas Mores et al. (2018); Farrow et al. (2000)
Innovation	Incremental or radical innovation.	Dangelico (2016); de Propris (2002); Farrow et al. (2000)

Second, the sustainability indicators in this study adopt the cyclic principle in the sustainable packaging principles developed by Verghese et al. (2012), which considers the use of renewable materials and recoverability at end-of-life. The proposed cyclic indicator refers to the biodegradability and use of renewable resources to address the importance of biodegradability in bioplastics as a solution to the solid waste problems. It also promotes changes to renewable material to reduce the dependence upon fossil-based material in conventional plastic packaging, thus, corroborates the closed-loop principle in the circular economy.

The next two indicators are related to cost and innovation, which are developed based on the recurring patterns from the literature. The cost indicators are used to present the efficiency and cost of production (de Vargas Mores et al., 2018; Farrow et al., 2000), which can become an important target of co-innovation due both to customer and end user sensitivity to price. Lastly, the innovation indicators adopt the incremental or radical innovation indicated by the creation of a new or improved product or process (de Propris, 2002) or recipient of official recognitions in the field of environment or sustainability (Dangelico, 2016).

2.3.2. The process of co-innovation

The findings of the literature review reveal that the co-innovation process occurs throughout all stages of product development, from the concept development and product development through to packaging production, and readiness for implementation in mass production. The timing to start the collaboration may vary from case to case. The literature revealed that there are clear benefits from starting the collaboration at different stages of product development, with regard to the different dynamics of the joint resources, joint activities and relationship management.

The dynamics of supplier-customer in co-innovation embrace active interactions through which customer and supplier’s roles contribute to the process. In the concept development stage, the supplier, as the knowledgeable partner in bioplastic packaging technology, communicates their ideas about sustainability at the early, conceptual stage, and builds an understanding with the customer about the feature of the new product (Melander, 2018; Morgado, 2008). On the other hand, the customer gives information on and understanding about the product features and specifications needed (Melander, 2018). This is supported in the RV theory, that partners provide sources of ideas for innovation and absorptive capacity increases the exploitation of knowledge (Dyer & Singh, 1998) into enriching the product concept, design and the concept development stage performance.

At the next stage, the product development phase includes product construction, raw material selection, prototype development, product testing and validation activities (Lacoste, 2016; Perez et al., 2013; Rai et al., 2010). Each customer or supplier will decide to add more investment to the activities or resources considering the extent to which the co-innovation would further support each partner's interest. In the product development, detailed work, technology and knowledge are more intensively dedicated to creating a product prototype. The supplier provides the new materials, design and technology used in the prototype, by considering the environmental management (Melander, 2018; Morgado, 2008). In the product development stage, more R&D expertise, skills and facilities are needed, and a greater contribution from each partner is likely to overcome any problems during prototype building. In the user testing stage, the customer plays an important role in small scope trials or larger pilot projects in order to check and validate if the product is fit for implementation on a mass production scale (Melander, 2018). In this stage, both partners learn from errors and contribute to the improvements.

2.3.3. Co-innovation mechanisms in developing bioplastic packaging

Having identified the indicators of successful co-innovation, a systematic mechanism of collaboration between customer and supplier should be devised in order to achieve successful co-innovation. However, limited studies reveal how to work on the product development mechanism through co-innovation, as most of the literature on bioplastics, including in the packaging industry, is focused on bioplastics engineering, technology, supply chain and in a general context (Benetto et al., 2015; Chadha, 2011; Dobrucka, 2019; Jeong & Ko, 2016; Kishna et al., 2017; Morgado, 2008; Theinsathid et al., 2009). For example, one study in bioplastics co-innovation is a case study in the car manufacturing industry (Jeong & Ko, 2016) showing the importance of an alliance portfolio for promoting product innovation; however, this study does not discuss how the mechanism of collaboration is able to improve biodegradability and increase the use of renewable resources, nor other characteristics of bioplastics product. Therefore, this corroborates the need for further study to fill the gap in order to contribute to understanding how co-innovation should be implemented to address problems related to its application as packaging and to create greater organisation capabilities.

2.3.3.1. Theoretical perspective underpinning the synthesis

This SLR unveils that the mechanisms of co-innovation lie in the joint activities, joint resources and relationship management between supplier and customer. This is in accordance with the concept of co-innovation related to synergising various internal and external ideas, actions and resources to create new value that is difficult to be imitated by competitors (Baldwin & von Hippel, 2011; Bitzer & Bijman, 2015; Lee et al., 2012). Furthermore, an initial framework is synthesised from this SLR underpinned by the RV theory (Dyer & Singh, 1998) and the absorptive capacity theory (Zahra & George, 2002) as the theoretical lenses to understand how co-innovation works and thus synthesise an initial framework. The following sections present the definition of co-innovation, the RV theory and absorptive capacity theory that guides the identification of possible mechanisms, principles and causal relationships in the supplier-customer co-innovation.

A. Definition of co-innovation

The supplier-customer collaboration in bioplastic packaging product development refers to the concept of *co-innovation* – firm activities that involve the collaboration of business partners in a process and the mechanism to create value (Bitzer & Bijman, 2015; Tsou et al., 2015). Maniak & Midler (2008) used the automotive manufacturing new product development context to define co-innovation as cooperation with the supplier with the aim of developing innovative features. Similarly, inter-firm cooperation over innovation is termed joint innovation, and mostly occurs between buyer and supplier; it involves joint activities and joint commitment on resources such as R&D, technology development, new products and processes development, training, financing and marketing (de Propris, 2002).

Essentially, co-innovation is considered as a way to synergise efforts and investments from internal and external contributors to create valuable new products, processes or services (Baldwin & von Hippel, 2011). Tsou et al. (2015) consider co-innovation to be a mechanism for producing or improving products or services for the customer; and from the service delivery perspective, value for the customers can be created through the integration of products with service. Furthermore, co-innovation is also seen as a three-dimensional process: the collaboration of actors; complementary integration of technology, organisations and institutions; and coordination among levels in the value chain (Bitzer & Bijman, 2015). Similarly, Yeniyurt et al. (2014) used co-innovation terminology to address the longitudinal process of collaboration involving suppliers for new product development; and demonstrated that co-innovation positively influences performance, measured by new product launches and sales.

Co-innovation can be viewed as a platform that brings together internal and external contributors in an open project, where all information flowing into and output from collaborations are shared openly for use by anyone (Baldwin & von Hippel, 2011). In addition, Lee et al. (2012) view co-innovation as a paradigm centred on the convergence of expertise and ideas, inter-organisational collaboration and value creation for users or other stakeholders. However, this study views co-innovation as an exclusive inter-firm collaboration, where information involving new valuable technology flows exclusively for partners, hence this study adopts the underlying principle of co-innovation from previous studies. This thesis also views co-innovation as a mechanism (Baldwin & von Hippel, 2011; Maniak & Midler, 2008; Tsou et al., 2015) and process (Bitzer & Bijman, 2015; Yeniyurt et al., 2014), involving inter-organisational collaboration, complementary convergence or integration of multidimensional resources (Bitzer & Bijman, 2015; Lee et al., 2012), joint activities (de Propris, 2002), knowledge absorption (Maniak & Midler, 2008) and value creation for customers that is difficult to imitate by competitors (Lee et al., 2012).

B. Relational view

The relational view (RV) theory suggests that resources should be combined with those of the external organisation to achieve a competitive advantage (Dyer & Singh, 1998). This theory defines sources and mechanisms that should be developed with the external entities to achieve relational rent (Dyer & Singh 1998, p. 662), i.e., "*a supernormal profit jointly generated in an exchange relationship that cannot be generated by either firm in isolation and can only be created through the joint idiosyncratic contributions of the specific alliance partners*". Relational theory is developed from resource-based theory, using the concept of Valuable, Rare, Inimitable and Non-substitutable (VRIN) resources and capability of the firm (Barney, 1991). According to Dyer & Singh (1998), the resource-based view (RBV) (Barney, 1991) recommends that distinctive resources and capabilities be protected from outside parties, especially competitors. While the RBV emphasises the creation of powerful VRIN resources to achieve competitive advantages on a firm level, RBV theory has not clearly directed the mechanisms to achieve VRIN and has overlooked the influence of firm collaboration in building VRIN resources (Miles, 2012). Therefore, Dyer & Singh (1998) suggest that resources and capabilities be shared as a form of exchange of partners, based on a systematic strategy and effective governance, and the unit analysis expanded from the individual firm, as in the RBV, into a dyadic relationship, which also posits a fundamental difference in its concepts from RBV.

Dyer & Singh (1998) argue that the source of relational rent is not from individual firms but from collaboration with external entities, and that collaborating partners would also share the rent. Moreover, Dyer & Singh (1998) argue that four sources: relation-specific assets (RSA), knowledge-sharing routines (KSR), complementary resources/capabilities, and effective governance, should be developed with the supplier, customer or other external entities to achieve relational rent. First, RSA are unique assets that include location, physical assets, or human resources built in conjunction with assets owned by collaborative partners. Second, KSR are regular interactions deliberately created between partners to generate exchanges, combinations, and specialised knowledge. Third, complementary resource endowments (CRE) combine distinctive resources from each partner to significantly increase those obtained from individual endowments. CRE emphasises complementary resources to lead to synergy. Last, effective governance stands for a structured mechanism that minimises transactional costs and maximises value for collaborating partners.

In line with other theories such as transaction cost economics and organisational design theory, the RV implies that successful supplier-customer collaboration requires a mechanism (Petersen et al., 2005). Two mechanisms for achieving competitive advantages in relational theory are adopted from the RBV (Barney, 1991), then applied at dyadic levels; first, the causal ambiguity that makes the competitor unclear about the source of rents and second, time compression diseconomies that make the source of rents difficult to imitate by the competitors (Dyer & Singh, 1998). Furthermore, Dyer & Singh (1998) added the following inter-organisational mechanisms to preserve rents: asset interconnectedness, partner scarcity, resource indivisibility, and institutional environment. Asset interconnectedness creates joint assets that are difficult to separate from the accumulation of a bundle of relation-specific investments during collaboration. Partner selection is crucial, and partners must complement the lack of strategic resources and have the relational capability to collaborate. Finding a compatible partner is rare; hence, being the first mover that develops capability through an alliance with the right partner would significantly contribute to competitive advantage (Dyer & Singh, 1998). In the collaboration, the resources comprising assets and capabilities transform and co-evolve into greater and indivisible forms, which are difficult to imitate by competitors or each partner alone; collaboration would benefit from the institutionalised environment mechanisms that foster cooperative behaviour formalised by culture and regulation (Dyer & Singh, 1998).

RV theory has been updated to address specific topics, such as the firm's relational capabilities (Kale et al., 2002), distribution of relational rent (Dyer et al., 2008; Lavie, 2006) and the alliance dynamic over time (Dyer et al., 2018). Kale et al. (2002) emphasised the importance of specialised organisational units to maintain relationships with partners and stakeholders and become the knowledge management point that captures partners' know-how and disseminates accumulated knowledge to increase alliance performance. Lavie (2006) developed an inter-firm alliance framework that included the interaction of shared and non-shared resources among partners influencing the value creation, which eventually leading to a disproportionate distribution of relational rent between partners. Each partner's absorptive capacity, resources uniqueness among partners, opportunistic behaviour and alliance governance are likely to lead to a partner gaining more than the others (Lavie, 2006). Later, Dyer et al. (2008) defined the distribution of relational rent into common and private benefits and proposed that the factors of contributing more critical resources and having a higher absorptive capacity with synergistic resources would lead to higher distributions. Finally, Dyer et al. (2018) acknowledged the limitation of the static model in the original theory (Dyer & Singh, 1998), and revisited that theory by adding a dynamic perspective to address its limitations and explain inconsistencies in co-specialised assets, and the informal governance found in several studies. In a dynamic business environment, diminishing value of relational rent is inevitable, hence further understanding on how the source of relational rent evolves over time and would preserve the alliance would be a valuable addition to the theory.

By drawing upon the concept of the RV, several studies supported the importance of learning from collaborating partners for successful value creation. In particular, learning and exchanging product-related knowledge should be a routine in every stage of product development (Huber et al., 2011). Perez et al. (2013) explored the strategic alliance between start-up companies that master technology and their customers who are industry leaders, and demonstrated that a learning mechanism evolves from exchanging existing knowledge, to the accumulation of new knowledge, to intensive joint development for product innovation, stressing the role of absorptive capacity. Their study argues that the higher the company's ability to interact and learn about its customers, the higher the likelihood that the company invests resources for its customers, and so is successful in developing breakthrough products (Perez et al., 2013).

C. Absorptive capacity theory

In order to gain more understanding of the inter-organisational learning mechanism, such as learning in technical areas (Chadha, 2011), and sharing information for developing sustainable products (Lacoste, 2016), the absorptive capacity theory (Zahra & George, 2002) is used to complement the understanding of KSR (Dyer & Singh, 1998).

Absorptive capacity theory seeks the extent to which an organisation can recognise external new knowledge, and acquire and implement it to achieve innovation (Cohen & Levinthal, 1990). The mechanism to exploit external knowledge depends on four capabilities: acquisition, assimilation, transformation and exploitation (Zahra & George, 2002), and is also determined by demand-pull and science-push to achieve innovation (Murovec & Prodan, 2009). To further investigate the role of absorptive capacity, Aboelmaged & Hashem (2019) used the green, small and medium-sized enterprises (SMEs) context and revealed the absorptive capacity to be a strong predictor of green innovation adoption. However, Tavani et al. (2014) showed that a certain level of absorptive capacity is required in order to achieve successful co-innovation.

2.3.3.2. Mapping the themes of the co-innovation mechanisms to the theory

Underpinned by the RV theory (Dyer & Singh, 1998) and the absorptive capacity theory (Zahra & George, 2002), co-innovation between customer and supplier is enabled by the integration of complementary resources and knowledge to create greater benefits that cannot be achieved individually. Reflecting on these theories, if a bioplastic packaging manufacturer can improve the resources and capabilities to overcome the problems in the application that many of its competitors cannot, then a competitive advantage can be achieved. Without co-innovation in the bioplastic packaging product development, the packaging manufacturer, while having valuable expertise in bioplastics yet lacking a fundamental understanding of its application to the product, may not in the end be able to market the packaging. On the other hand, product manufacturers will find it less feasible to build a bioplastic packaging production unit due to lacking capabilities in this field (Yin et al., 2019). In this study, co-innovation is intended to generate bioplastic product innovation, measured by indicators comprising product quality, sustainability, cost and innovation. This is aligned with the previous studies (Cheung et al., 2010; Murovec & Prodan, 2009; Tavani et al., 2014) that indicate the role of absorptive capacity and collaborative innovation in supporting product innovation capability and new product innovation.

Furthermore, the themes regarding the possible mechanisms to achieve the bioplastic packaging product innovation are mapped by using concepts from the RV theory (Dyer

& Singh, 1998) and absorptive capacity theory (Zahra & George, 2002). These themes are mapped according to the sources of relational rent and mechanisms to preserve profits in the RV (Dyer & Singh, 1998) and dimensions of the absorptive capacity theory (ACap) (Zahra & George, 2002). Figure 9 shows the 'joint activities', 'joint resources' and 'relationship management' themes and sub-themes mapped into categories according to the concepts of both theories.

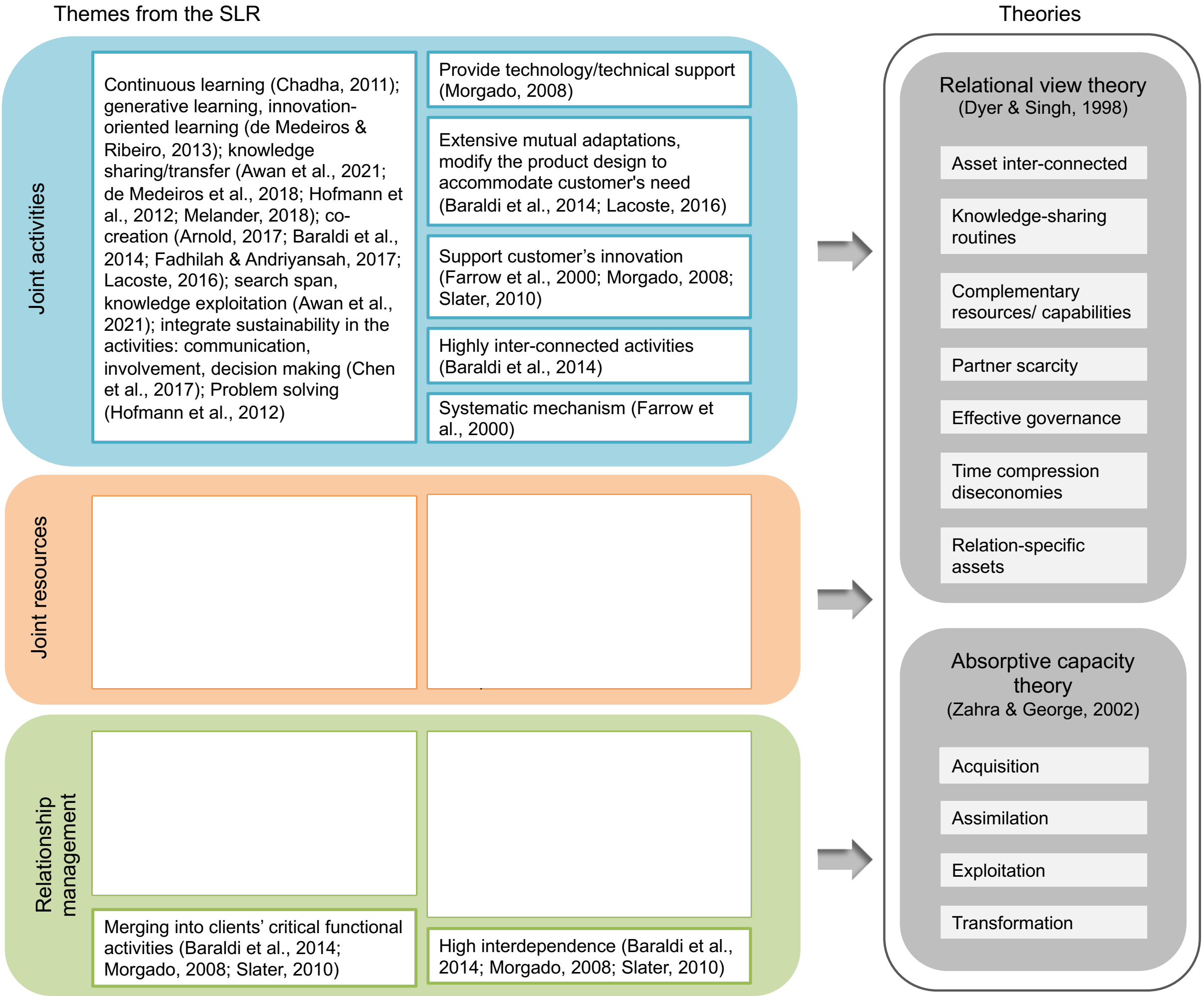


Figure 9 Mapping themes and sub-themes into the theory

2.3.3.3. The initial framework of co-innovation

A. Joint activities, joint resources, relationship management for bioplastic packaging product development

Customer and supplier are involved in reciprocal activities to develop new product in the collaboration. The RV explains the source of relational rent from the interaction of partners to enhance the transfer of knowledge or the creation of specialised knowledge, as the KSR (Dyer & Singh, 1998). The "Joint Activities" theme in the findings highlights the reciprocal interactions of customer and supplier in continuous innovation-oriented learning (Chadha, 2011; de Medeiros & Duarte Ribeiro, 2013); gathering and processing complementary information from each partner, such as the new bioplastics technology and manufacturing, industry and regulation, the application of packaging in the product, expected function from each type of packaging, all create a new combined knowledge that will contribute to product development success. Learning should be incorporated into a routine in the knowledge-sharing activities (Awan et al., 2021; de Medeiros et al., 2018; Hofmann et al., 2012; Melander, 2018) to increase the creation of valuable information and know-how that will also increase the product innovation capability. Besides learning, communication, involvement, decision making (Chen et al., 2017) and problem solving (Hofmann et al., 2012) should be integrated in sustainability practice to contribute to the sustainability performance in the bioplastic packaging product indicators. The association of joint activities and performance is represented by the following proposition:

Proposition 1

In the bioplastic packaging co-innovation context, higher supplier-customer joint activities will increase the success of bioplastic packaging product innovation.

The customer and supplier contribute both tangible and intangible resources and capabilities to the collaboration, in which the RV is defined as the RSA (Dyer & Singh, 1998). Resources needed in co-innovation are, for instance, location, cost, cross-functional team, production unit (Baraldi et al., 2014; Morgado, 2008), special product development project (Chen et al., 2017), R&D investment, provision of HR training in environmental management (Shete et al, 2020) and other infrastructures (Chen et al., 2017). By sharing resources, the customer can use the supplier's resources and capabilities related to bioplastics or the sustainability field, such as environmental knowledge, technology (Awan et al., 2021; Yin et al., 2019; Melander, 2018), and the supplier can use the customer's location, or production facilities (Morgado, 2008). The complementary resources and capabilities when combined will become a source of greater outcome (Dyer & Singh, 1998), such as increased productivity of individual resources, knowledge transfer, reduced cost, and subsequently increase the success of product development. This is postulated by the following proposition:

Proposition 2

In the bioplastic packaging co-innovation context, *higher supplier-customer joint resources will increase the success of bioplastic packaging product innovation*.

Maintaining and developing a fruitful collaboration requires a relationship management that includes partner selection, goal alignment and dialogue (Arnold, 2017). Partner selection, with important suppliers (Chadha, 2011) or key customers (Slater, 2010), is also important in relationship management (Melander, 2018), emphasising the complementary innovation capabilities (Farrow et al., 2000), environmental skills and expertise (Baraldi et al., 2014; Chadha, 2011) confirmed through environment audit or certification (Cheung et al., 2010; Melander, 2017). A compatible partner with complementary capability will contribute to the heterogeneity of resources that benefit the quality of input in the product development and learning. Communication (Chen et al., 2017; Dangelico, 2016, Yin et al., 2019), coordination, balancing work and position (Lee & Kim, 2012), lessening the organisation boundaries (Baraldi et al., 2014) and building a close relationship (Lee & Kim, 2012) will promote effective and productive activities, reconciliation and problem solving (Lacoste, 2016; Melander, 2018), therefore are likely to achieve bioplastic packaging product innovation success.

Proposition 3

In the bioplastic packaging co-innovation context, *higher supplier-customer relationship management will increase the success of bioplastic packaging product innovation*.

The importance of relationship management in co-innovation not only influences the product output, but also the input dedicated to the collaboration (Melander, 2018), referred to as joint activities and joint resources in this study. Selecting the right partner allows good communication and coordination that will grow the involvement beyond only sharing knowledge and learning, for example, joint problem solving. Through close coordination in day-to-day activities, and solving problems in the process, both consumer and supplier build a stronger relationship, trust and initiatives for problem solving that lead to an increase in resources dedicated to the success of the collaboration.

Proposition 4

In the bioplastic packaging co-innovation context, *the higher the relationship management*, *the higher the joint activities dedicated to co-innovation*.

Proposition 5

In the bioplastic packaging co-innovation context, *the higher the relationship management*, *the higher the joint resources dedicated to co-innovation*.

B. Strong interdependence between supplier and customer

The RV theory explains how the benefits from collaboration can be earned from creating causal ambiguity and time compression diseconomies (Dyer & Singh, 1998) such as trust, close relationship, dependency and specific capacity. Activities dedicated to the collaboration, such as solving a customer's problem, providing training for the customer's employees, moving to the customer's location, and providing technical support, sharing market information, sales and end user's complaints with the supplier; blurring organisation boundaries in communication and coordination, will all lead to a strong relationship and high interdependence (Baraldi et al., 2014; Morgado, 2008; Slater, 2010). Assets dedicated to the collaboration, such as sharing facilities, infrastructure, dedicated team and other resources, will accumulate and create interconnected assets (Baraldi et al., 2014; Dyer & Singh, 1998), specialised in bioplastic packaging production, or possibly expand for greater use in the future.

Proposition 6

In the bioplastic packaging co-innovation context, *the higher the joint activities*, *the higher the supplier-customer interdependence*, *and therefore the bioplastic packaging product innovation*.

Proposition 7

In the bioplastic packaging co-innovation context, *the higher the joint resources*, *the higher the supplier-customer interdependence*, *and therefore the bioplastic packaging product innovation*.

C. Promoting the customer's innovation motive underlying the co-innovation

The SLR finds that some cases emphasise that joint activities aim to promote the customer's innovation (Farrow et al., 2000; Morgado, 2008; Slater, 2010), and technology legitimacy (Jeong & Ko, 2016). Accordingly, the supplier invests in resources for their customers to increase the supplier's success in developing breakthrough products (Perez et al., 2013). The supplier dedicates their expertise to solve the customer's problem, provide training for the customer's employees, move to the customer's location, and provide technical support, special teams and infrastructure. Lingens & Huber (2021) found that the contribution of the co-innovation initiator determines alignment with the co-innovation partner and interdependencies. Specifically, the complementary partners will be interested in having more influence in the collaboration and learning more from the other partners (Lingens & Huber, 2021). Correspondingly, the more a customer feels the supplier makes a real contribution to innovation in the customer's company will lead to reciprocal action. The customer will likely contribute more to the collaboration, be willing to share more information, including confidential matters, and contribute to a team, facility, infrastructure, and other resources. These activities will accumulate and increase KSR, inter-firm learning, and form strong mutual dependence relationships and interconnected assets (Baraldi et al., 2014; Dyer & Singh, 1998; Lingens & Huber, 2021). The following proposition adds that the motive to promote customer's innovation underlying the collaboration will contribute to the resource RSA represented in the joint resources and KSR represented in the joint activities.

Proposition 8

In the bioplastic packaging co-innovation context, *the higher the perceived contribution of the supplier to the customer's innovation*, *the more the customer responds more actively to the ongoing co-innovation*, *the higher the supplier-customer interdependence and*, *therefore*, *the bioplastic packaging product innovation*.

D. The role of absorptive capacity in the mechanism

In the joint activities, customer and supplier reciprocal activities involve an intensive transfer of knowledge or the creation of specialised knowledge (Dyer & Singh, 1998). In these activities, customer and supplier's absorptive capacity allows the acquisition of new valuable knowledge, to assimilate, transform and exploit (Zahra & George, 2002) from the collaborating partner (Dyer & Singh, 1998) to achieve bioplastic packaging product innovation. In the bioplastic packaging co-innovation, customer and supplier acknowledge and acquire valuable information from each other (Dyer &

Singh, 1998; Zahra & George, 2002) about the new bioplastics technology industry, environmental regulation, details of packaging applications for the product, and the function of packaging for different products. Activities in the knowledge sharing should consider certain search spans that are relevant for exploitation (Dangelico, 2016, Awan et al., 2021) to contribute to the innovation indicators in the product.

Following that, the KSR (Awan et al., 2021; de Medeiros et al., 2018; Hofmann et al., 2012; Melander, 2018; Hoosbeek & de Vries, 2021) embedded in the joint activities will facilitate the assimilation of new knowledge, which is then transformed into a new or more advanced knowledge that promotes customer and supplier actions, solutions, decisions, and adaptation applied to the product being developed (Hoosbeek & de Vries, 2021). In a co-innovation project, absorptive capacity at the organisational and inter-firm levels grows from absorptive capacity at the individual level (Hoosbeek & de Vries, 2021). Specifically, Hoosbeek & de Vries (2021) highlighted teaming mechanisms such as collaboration, dialogue, reflections, and experimentation to boost acquisition, assimilation, and transformation. Adaptation can either be shown at the supplier side, such as learning about the customer's needs (Baraldi et al., 2014; Cheung et al., 2010) then accommodating these needs into the product design; or at the customer side, for instance, by adapting the requested product specification to correspond to the supplier's offering (Lacoste, 2016). This process is likely to enrich the design, speed up the development process and minimise correction at the user testing stage, thus contributing to a more effective product development process (Hoosbeek & de Vries, 2021). Therefore, the previous studies claimed that the absorptive capacity will act as a strong predictor of green innovation adoption (Aboelmaged & Hashem, 2019), and co-innovation towards performance, but only in the existence of absorptive capacity (Tavani et al., 2014).

Proposition 9

In the bioplastic packaging co-innovation context, the absorptive capacity mediates the relationship between co-innovation and bioplastic packaging product innovation.

The absorptive capacity increases after partners in the collaboration interact in communication, coordination, a strong engagement, trust, and openness that allows an understanding of each partner's expertise and then uses the specific expertise to solve problems or make significant improvements (Dyer & Singh, 1998). As in the relationship management theme, a compatible partner (Chadha, 2011; Cheung et al., 2010; Melander, 2017; Slater, 2010), communication (Chen et al., 2017; Awan et al., 2021), coordination, and balancing work and position (Lee & Kim, 2012), lessen the organisation's boundaries (Baraldi et al., 2014) and build close relationships (Lee & Kim, 2012) that will increase the absorption capacity.

Proposition 10

In the bioplastic packaging co-innovation context, the stronger the relationship management, the higher the absorptive capacity and therefore bioplastic packaging product innovation.

The proposed mechanisms of the supplier-customer co-innovation in developing innovative bioplastics product is presented in Figure 10. Additionally, the propositions in the initial framework are summarised in Table 8.

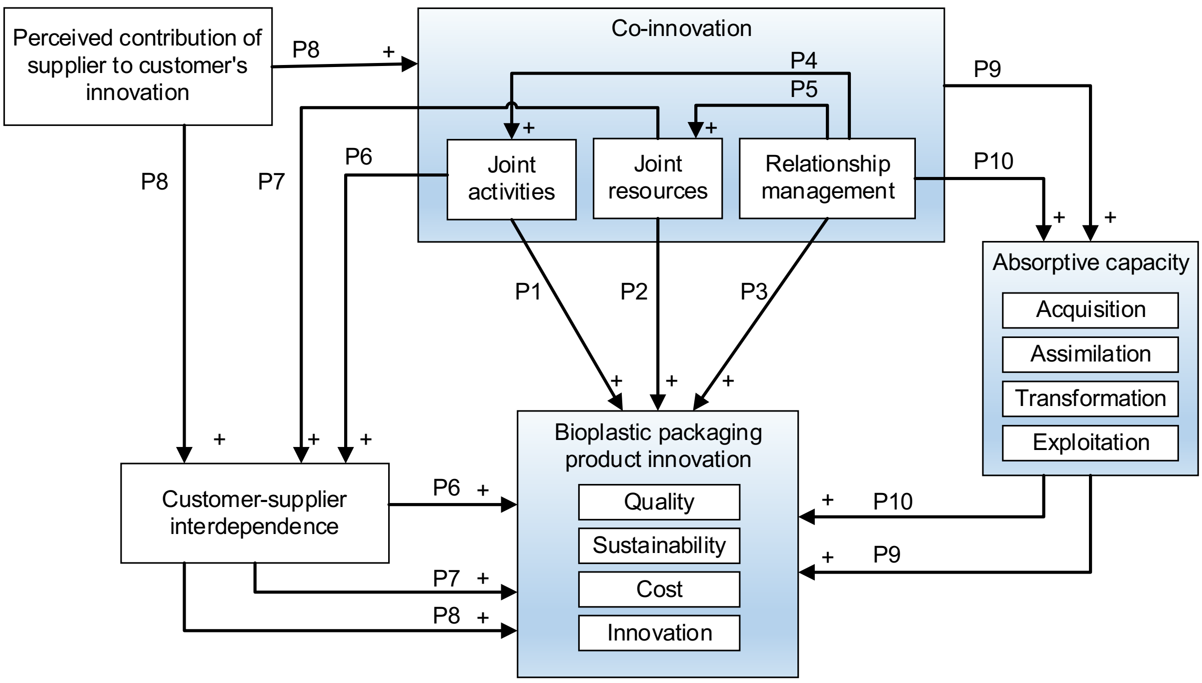


Figure 10 The conceptual framework of the co-innovation mechanisms

Table 8 List of the initial propositions

Propositions	
P1	In the bioplastic packaging co-innovation context, higher supplier-customer joint activities will increase the success of bioplastic packaging product innovation.
P2	In the bioplastic packaging co-innovation context, higher supplier-customer joint resources will increase the success of bioplastic packaging product innovation.
P3	In the bioplastic packaging co-innovation context, higher supplier-customer relationship management will increase the success of bioplastic packaging product innovation.
P4	In the bioplastic packaging co-innovation context, the higher the relationship management, the higher the joint activities dedicated to co-innovation.
P5	In the bioplastic packaging co-innovation context, the higher the relationship management, the higher the joint resources dedicated to co-innovation.
P6	In the bioplastic packaging co-innovation context, the higher the joint activities, the higher the supplier-customer interdependence, and therefore the bioplastic packaging product innovation.
P7	In the bioplastic packaging co-innovation context, the higher the joint resources, the higher the supplier-customer interdependence, and therefore the bioplastic packaging product innovation.
P8	In the bioplastic packaging co-innovation context, the higher the perceived contribution of the supplier to the customer's innovation, the more the customer responds more actively to the ongoing co-innovation, the higher the supplier-customer interdependence and, therefore, the bioplastic packaging product innovation.
P9	In the bioplastic packaging co-innovation context, the absorptive capacity mediates the relationship between co-innovation and bioplastic packaging product innovation.
P10	In the bioplastic packaging co-innovation context, the stronger the relationship management, the higher the absorptive capacity and therefore bioplastic packaging product innovation.

2.4. Summary of the SLR (fulfilling RO1)

This research provides further understanding about the extent to which co-innovation is relevant to be applied in bioplastic packaging product innovation. Addressing the objectives of this study, four conclusions have been reached:

- The current situation regarding bioplastic packaging indicates that there are problems where original equipment manufacturers (OEMs) cannot immediately use packaging products produced by the manufacturers.
- Literature examining the work on co-innovation in the context of bioplastic packaging applications and product development is remarkably lacking.
- Thematic analysis demonstrates the co-innovation process and mechanisms through joint resources, joint activities and relationship management.
- The SLR reveals the positive outcomes of co-innovation in the form of product innovation, increased company innovative capabilities and corporate performance.

This SLR provides a valuable contribution by showing the research gaps for further investigation of co-innovation in bioplastic packaging due to the limited literature on this subject, including how to solve the problems in bioplastic packaging application between the bioplastic packaging and product manufacturers. This SLR also extends the concept of co-innovation through joint activities and commitment to resources for innovation, and innovation performance (de Propris, 2002) by adding clear mechanism of joint activities and joint resources. The previous studies on the mechanism of co-innovation between buyer and supplier that successfully improved product performance and innovation (Baraldi et al., 2014; Morgado, 2008; Slater, 2010) have also been expanded in the proposed framework, by adding sustainable management practices and performances, as indicated by the literature on sustainable product development (Awan et al., 2021; Dangelico, 2016; Lee & Kim, 2011; Melander, 2017; Yin et al., 2019). The proposed framework, therefore, incorporates the outcomes of co-innovation indicated by both product and sustainable performances, which also promote the benefits of bioplastic packaging.

The framework also encompasses the mechanisms of co-innovation between the customers and suppliers of bioplastic packaging, denoted by the RV theory (Dyer & Singh, 1998) and absorptive capacity theory (Zahra & George, 2002), and subsequently extends several studies adopting both theories. Specifically, this thesis extends the work of Baraldi et al. (2014), which adopted the RV to see the supplier's perspective on outsourcing and proposed that value should be co-created with the customer via high mutual dependence. Co-innovation extends the scope of outsourcing into a more intensive supplier-customer collaboration and, through the proposed framework, a supplier-customer mutual dependence construct is developed by showing the joint activities and joint resources as the antecedents. A previous study by Cheung et al. (2010) indicated that the learning engaged in the buyer-supplier dyad is positively related to value creation and provides the indicators of relationship learning and value. These indicators are also adopted in the proposed framework to increase the robustness of the co-innovation construct development and could be refined based on the bioplastic packaging context in a future study.

Another significant finding of this SLR is the relevance of the suppliers' contribution to assist customers to innovate. This finding reflects those of Perez et al. (2013) who argue that the higher the company's ability to interact and learn about its customers, the higher the likelihood that the company will invest resources for its customers so as to increase success in developing breakthrough products. The initial framework applies the *perceived supplier's contribution to customer's innovation* construct that reflects the partnership development point or early conceptual stage, in which the supplier indicates an investment plan or positive efforts to accommodate customer needs. This concept provides a valuable insight into whether the motive to promote customer's innovation will contribute to the resource RSA (Dyer & Singh, 1998).

The proposed framework and indicators have important implications for promoting further collaboration in bioplastic packaging, and helping practitioners find new ways of developing breakthrough in bioplastics research and sustainable products through supplier-customer co-innovation. The expertise in bioplastics engineering involves a complex combination of skills and knowledge in bioplastics technology, engineering, and environmental management (Bossle et al., 2016) and, thus, is a valuable organisation capability. Through co-innovation, this capability can be enhanced through learning about the customer's needs, improvement in the operations, stronger relationship with the customers and creating innovative product, thus creating a specialised expertise (Baraldi et al., 2014), overcoming environmental problems (Hofmann et al., 2012), and obtaining new knowledge (Melander, 2018). From the managerial perspective, these resources would greatly contribute to the organisation's competitive advantages.

3. Research Methodology

3.1. Research philosophy

The research paradigm provides a general idea of a matter considered substantial, legitimate and acknowledged by sound logic (Patton, 2014). This study embraces the critical realist paradigm, which endorses the presence of underlying causal structures and mechanisms (Easton, 2010). Critical realism is considered a radical way to reclaim reality by reconnecting ethical deliberation and real causal processes, synthesising positivism and post-positivism (Patomäki & Wight, 2000). Ontology concerns "What is the nature of social reality?" (Blaikie, 2007, p. 13). The assumption of a critical realist paradigm lies in the realism or positivism ontology (Patomäki & Wight, 2000), which views that reality can be understood directly through the process of perception and sensation. Critical realism ontological assumption is based on transcendental realism, which believes that a real-world is out there and exist independently beyond our knowledge (Easton, 2010). Critical realism assumes that reality not only consists of events, experiences, impressions and discourse, as in positivism but also consists of structures and powers that the observer may not see in its external existence (Patomäki & Wight, 2000). Put another way, critical realism assumes the existence of mechanisms in which entities or objects have certain ways of performing, with particular influences and susceptibilities (Easton, 2010).

Bhaskar (1978) implied that the ontology of critical realism adheres to the stratified ontology that comprises three domains of reality, empirical, actual, and real. These domains show actual events or experiences, whether observed or not, activated by the causal mechanism that produces the event (Blaikie, 2007). The empirical domain is perceived or experienced through human senses and perceptions (O'Mahoney & Vincent, 2014). In comparison, the actual domain is a deeper level of events that occur but might not be experienced or observable due to conditions that limit an actor to be in or understand the particular event (O'Mahoney & Vincent, 2014; Patomäki & Wight, 2000). Last, the real domain is the underlying causal mechanisms and structures that generate the actual and empirical worlds (O'Mahoney & Vincent, 2014). The real domain is more abstract yet able to provide a complete causal explanation that produces the pattern of events or outcomes in such a complex reality where the actual cause of an event is no longer observable (Easton, 2010; O'Mahoney & Vincent, 2014).

Moreover, epistemology is one way in philosophy to reach an understanding of the truth of knowledge, in which all efforts are made to achieve one goal, namely disclosure of the truth. As a theory of knowledge, epistemology answers the question "How can social reality be known?" (Blaikie, 2007). Critical realism is committed to epistemological relativism, in which all beliefs are potentially fallible because they are socially produced, and epistemological judgemental rationalism, that states having justifiable grounds for preferring one theory over another is possible (Easton, 2010; Patomäki and Wight, 2000). These epistemologies have opposing views with positivism, which limits the understanding based on empirical evidence. Positivism views that there is an independent reality; it claims that knowledge is a derivative of the objective reality out there, based on logical deduction from theory, operationally measurable and could be empirically verified (Patton, 2014). However, critical realism tries to understand the complexity and open nature of the social world in a multi-paradigm principle, hence embracing a dynamic synthesis that is constantly reformulated (Patomäki & Wight, 2000). Critical realism also adopts neo-realism epistemology that suggests the regularity is to be used as the initial point, followed by an investigation of the structure and mechanism that creates such configuration (Blaikie, 2007).

Critical realism reflects the language and procedures routinely adopted and the causal explanations, and is suitable to justify an in-depth study such as the case study, which aims to understand why objects exist as they are (Easton, 2010). Critical realism also provides the ontological and epistemological foundation and methodological guidelines for theory generation case studies. In line with the critical realism paradigm, the analysis in this study exceeds interpretations of the participants' opinions regarding their social interactions during co-innovation. It tries to address the process and mechanisms, i.e., ways, manners or how co-innovation in developing bioplastics packaging would cause actions (Patomäki & Wight, 2000), creating an innovative, advanced bioplastic packaging. The level of analysis is processed bottom-up from the social worlds to the upper layers to accommodate the nature of social research that is hermeneutically saturated.

Furthermore, interpretations of people in their social worlds reflect the empirical domain and need to be understood first to gain insights into the phenomena and facts about where these people exist (Easton, 2010; Patomäki & Wight, 2000). Hence, the data are collected from people experiencing co-innovation in developing bioplastic packaging. Before data collection, the researcher could use theory and previous research to produce the most robust description within the context, existing knowledge and time, to limit the exploration (Blaikie, 2007). Under critical realism, a theoretical framework is beneficial to provide a causal explanation of three layers that influence each other causally (Patomäki & Wight, 2000). This research uses RV theory and absorptive capacity theory as theoretical lenses to assist the researcher in acknowledging and defining possible principal mechanisms in a natural situation. From this point, the analysis is structured to reveal the relationship between factors and the actual mechanisms.

3.2. Research design

Research design shows the logical plan undertaken to answer the RQs and fulfil the study's objectives (Sekaran & Bougie, 2016; Yin, 2015). It explains the research strategy, unit analysis, time horizon, data collection and data analysis design to promote the accuracy and robustness of the study (Sekaran & Bougie, 2016). The research strategies that constitute the logic or enquiry are determined in order to address the RQs and meet the research objectives (Blaikie, 2007; Sekaran & Bougie, 2016).

This study adopts the inductive approach, which guides the ways of knowledge generation based on linear logic from singular statements to general or universal statements (Blaikie, 2007). The inductive approach views the empirical data and facts from observation as true, then analyses and theoretically justifies these facts to draw general conclusions, which are not a universal truth; hence there is a possibility of unique or specific conditions occurring beyond the observed phenomena (Blaikie, 2007). The exploratory nature of the inductive inquiry is relevant to providing an in-depth understanding of social behaviour, perspectives of people and real conditions within a context (Yin, 2015). The inductive approach allows the exploration of variables, i.e., concepts within a small sample of participants that cannot be explained using statistical procedures nor used for testing a theory; therefore, this approach is considered relevant to shape understanding and conceptualisation of the phenomenon.

In this study, the exploration starts with specific points of an event (Blaikie, 2007) within co-innovation in developing bioplastic packaging. Afterwards, generalisation of patterns of association and measured characteristics of the social phenomenon are based on theoretical concepts or researcher-defined concepts to preserve the focus and clarity (Blaikie, 2007; Miles et al., 2014). An SLR is conducted in advance to provide background knowledge from theory and previous research in order to answer the RQ (Blaikie, 2007). In this study, an initial theoretical framework is developed from the SLR, explaining joint activities, joint resources and relationship management to represent the co-innovation mechanism, including their presumed relationship to absorptive capacities, supplier-customer interdependence, the perceived contribution of suppliers and bioplastic packaging product innovation. Moreover, this study inductively explores this area through a multiple case study guided by an initial framework (Baines et al., 2009; Blaikie, 2007), which provides the best description of co-innovation as a social phenomenon, including an array of its possible characteristics useful to collect the relevant data. Next, cases are gathered and selected to provide information that depicts the mechanism in real situations.

This study generates statements describing the observations of cases in which facts are accumulated and valued with the same importance, and analysed without using hypotheses (Blaikie, 2007). By understanding the perspective of the important actors in the co-innovation, representing customer and supplier side, and the circumstances of the collaboration in the bioplastics packaging product innovation, the driving factors and successes that influence the co-innovation process can be identified. The inductive approach enables descriptions of the characteristics and patterns of the social reality under study, starting from collecting characteristic and pattern data, generating descriptions and relating them to RQs (Blaikie, 2007). In this study, the characteristics and patterns of the co-innovation activities between supplier and consumer were explored, focusing on the processes of product development from starting to finalising the product for real production at the customer's site. Significant activities, moments, and conditions that influence the process and output of the collaboration were given codes corresponding to the mechanism, drivers and success factors of co-innovation. Descriptions of the bioplastic packaging, advantages and disadvantages of the products as the outcome of the co-innovation or were intended for future improvement or considered as the ideal product, were gathered from the informants to indicate the advanced bioplastic product.

The empirical evidence from the appropriate cases is accumulated to shape an in-depth understanding of how co-innovation in the context occurs, followed by a conceptualisation of the underlying mechanism (Meredith, 1993) in a refined framework. Through this approach, the elements of co-innovation between supplier and customer would be described accurately based on the consistency of patterns among cases. Relationships between these elements are inferred to provide a powerful explanation of how the phenomenon occurs (Meredith, 1993) in a refined framework. Nonetheless, the conclusion is drawn as a generalisation and subjected to further testing (Blaikie, 2007).

This research uses multiple case studies to obtain a clear picture of a problem or perspective from multiple organisations engaged in a specific real-life activity and situation (Sekaran & Bougie, 2016; Yin, 2018). Multiple cases provide more robust analysis by studying the important facts and patterns within a case, then comparing cases that lead to stronger conclusions (Yin, 2018). In this thesis, cases from a supplier-customer co-innovation contribute to the understanding of the processes and mechanisms of co-innovation, problems arising during the collaboration, product application problems and essential facts in a particular context of the collaboration; then they are compared across cases within several organisations to extend the understanding from more perspectives, highlighting similarities and different problems occurring from various specific contexts across cases. In this study, a descriptive case study is used to present how the supplier-customer co-innovation process is implemented in the context of bioplastics packaging product development, thus will enhance the analysis of findings and increase the robustness of the answers to the RQ.

3.3. Multiple case study

Multiple cases open the opportunity to understand in depth the process and its outcome, and test hypotheses or the initial framework (Miles et al., 2014). Therefore, multiple cases are used in this study because the RQ emphasises the co-innovation process and the outcome is the bioplastic packaging product innovation. Moreover, a multiple case study provides an in-depth understanding of the initial framework and allows refinement built upon the empirical pieces of evidence. Multiple case study is adopted to enable the investigation of multiple cases individually and in depth, then it compares patterns found across cases, in order to draw conclusions. Compared to the single case analysis, the multiple case approach facilitates a significantly more robust analysis (Chen et al., 2018; Eisenhardt, 1989). In the multiple case studies, carefully selected cases will support a stronger conclusion. In addition, when contradictory findings occur across cases, further investigation and review may need to be undertaken and may lead to the discovery of unexpected results (Yin, 2018). The availability of the resources and time to obtain a deep understanding from all cases, across cases and derive substantial findings, should be carefully considered before deciding to choose between multiple or single case study approaches.

The multiple case study research process in this study is depicted in Figure 11, following Yin (2018) and Eisenhardt (1989). The process consists of four steps: design, data collection, case analysis and shaping conclusions.

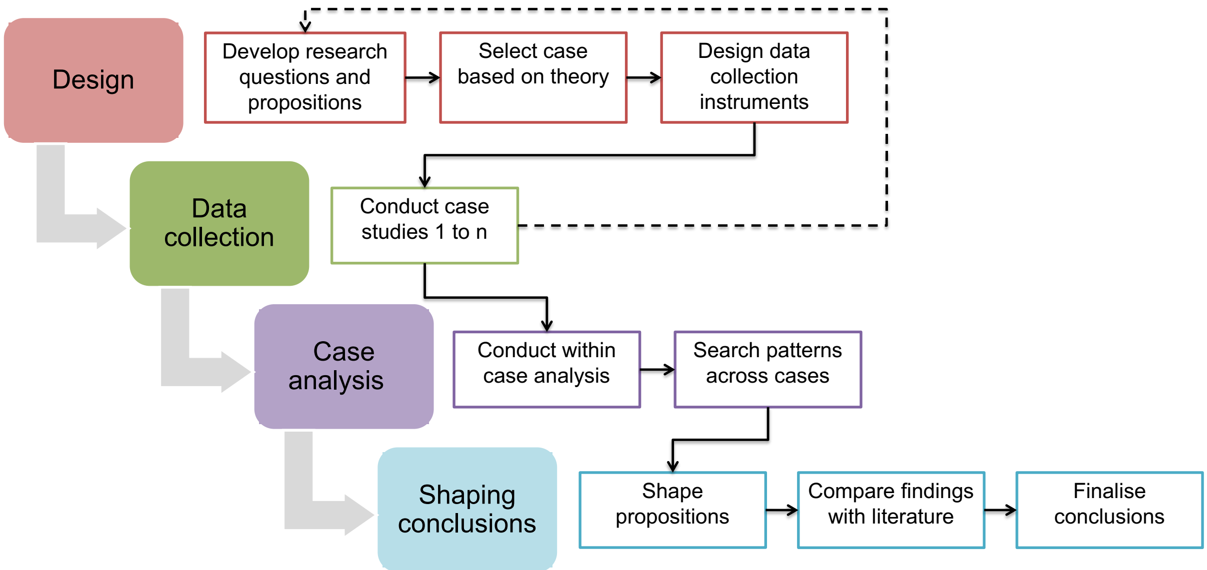


Figure 11 Research process used in this study (Adapted from Eisenhardt (1989) and Yin (2018))

3.3.1. Design

3.3.1.1. Research questions and propositions

The RQ used in this study are developed based on the results of the SLR. RQ provides direction to the case selection, data collection and analysis to address the research approach and strategy (Eisenhardt, 1989). Next, the conceptual framework and propositions are developed to lead the attention towards specific topics for examination. The conceptual framework in this study is derived from the SLR and developed using the RV (Dyer & Singh, 1998) and absorptive capacity (Zahra & George, 2002), as the theoretical lenses. Having a conceptual framework before conducting the case study provides the perspective to focus the investigation towards the RQ. The conceptual framework used for this study refers to the initial framework developed from the SLR (Figure 10).

3.3.1.2. Case selection

Case selection is theory-driven, paying attention to the elements of theory that need to be investigated so that generalisability in multiple case studies can be obtained based on their compatibility with the underlying theory and not based on the similarity of more cases (Miles et al., 2014). The case selection used theoretical consideration and the relevancy to the context of bioplastics packaging supplier-customer co-innovation. The selection of cases in this study used purposive sampling by selecting cases that represented the context to be studied, and due to the limited geographical access and timing of the cases studied, the selection also used convenience sampling (Miles et al., 2014). Case selection needs to pay attention to the activities, processes and actors involved to support within-case analysis (Miles et al., 2014). Thus, this study employs the selection of cases that can show the occurrence of co-innovation activities, co-innovation processes and mechanisms that have been or are occurring between customers and suppliers.

The following are the case selection criteria:

a. ***Object of study***: the customer and supplier organisations are chosen based on their existing co-innovation experience. The suppliers are biopolymer producers and bioplastics packaging manufacturers that process bioplastics from raw material and convert it into packaging to be used in the customer manufacturing process. The customers are product manufacturers who use the packaging in the production of product delivered to distributors/retailers/end-users. Both past experience and ongoing co-innovation in developing bioplastics packaging is considered. Experience is important to reveal the process and mechanism, and the extent of the progress and outcome of the co-innovation. For the ongoing co-innovation, the case is included if co-innovation has reached a minimum 50% of the concept development stage to ensure there is sufficient information to contribute to the RQ.

b. ***Industry***: considering the large application of packaging for consumer goods, the case study will focus on the application of bioplastics packaging in the convenience goods industry. This also considers the need to obtain an in-depth understanding of the complexity of the product development due to the complexity of the application of the packaging in the manufacturing process, health and safety of the end user consuming the product wrapped in the packaging, and that more functionality of the packaging should be met. This complexity will provide more information, patterns, and specific conditions on the dynamics, interactions, problems, solutions and learning that allow robustness in examining propositions, theory and in answering the RQ. Other sectors within the consumer goods industry will be considered as needed to complement the cases from the convenience goods sectors.

c. ***Location***: Awareness of the importance of sustainability varies in different countries. Co-innovation is also influenced by factors such as concerns to solve environmental problems, expertise in bioplastics technology, development of the bioplastics industry and government regulation. Investigation into two opposite conditions will reveal patterns and differences caused by unique situations. Similarity or patterns found in the different conditions have a strong relevance regarding co-innovation, while differences due to a unique condition context will add a more detailed understanding of the co-innovations. Therefore, this research has chosen cases from the UK and Indonesia. The former represents a developed country with higher awareness on sustainability issues, more regulation to support sustainable industry, including bioplastics, and more advanced development of bioplastics product and its application. The latter represents a country with the contrasting conditions related to sustainability; however, the bioplastics industry is developing in Indonesia, hence has become interesting to compare.

The list of companies that meet these criteria was obtained through information in the form of a list of members, reports or new press, which is available on the websites of non-governmental organisations (NGOs) related to bioplastics and packaging associations, WRAP, BBIA, BPF and the Ellen MacArthur Foundation. A search was also carried out through Google by searching for the keyword "bioplastics company UK" and the search results found links to online magazines that specifically address bioplastics, such as bioplasticsnews.com, bioplasticsmagazine.com, european-bioplastics.org and packagingnews.co.uk, and other bioplastics companies in the UK. In addition, alternative companies were also obtained from the list of participants in the packaging exhibition, "Packaging Innovations 2020", one of the largest packaging exhibition in the UK. The search was also carried out through peers' recommendations and using the snowball approach, in which the interview participants were asked for referrals of colleagues or companies that potentially met the case selection criteria.

The company name found from the search was investigated for relevance by checking the company profile, product range, annual reports and press releases available on the company website. News on the Internet and social media about companies' products and company innovation activities related to bioplastic packaging were also used as a reference. Furthermore, companies that met the selection criteria were cross-checked at companieshouse.gov.uk and ahu.go.id to ensure the existence and status of the company, and obtain more detail on the nature of business based on standard industrial classification (SIC), location and people in charge. From this process a list of companies that meet the case selection requirements was compiled, then the companies were grouped according to their position as a packaging or product manufacturer. People related to bioplastic packaging product development, such as the innovation, technical, product development director or manager, the CEO and chairman of the companies, were contacted via e-mail, telephone and LinkedIn social media, asking them to participate in this research.

In the case study, a minimum number of cases is not limited; using more cases provides stronger analysis and conclusions (Yin, 2018); however, too many cases have an adverse impact on the quality of the analysis making it less profound (Miles et al., 2014). Furthermore, the number suggested for cross-case analysis is four to ten cases to begin building theory and conduct an analytical generalisation (Eisenhardt, 1989, Miles et al., 2014). This study uses seven cases of the suppliers and eight of the customers to enable a thorough and robust analysis on the processes and the results in each case; this therefore helped in the detection of literal and theoretical replication (Yin, 2018). Instead of applying sampling logic, by finding samples of companies that reflect the population and testing the prevalence of the phenomena using statistical analysis (Yin, 2019), this case study uses the replication logic. A limited number of cases was selected; each case was then examined regarding how co-innovation was carried out, the impact on bioplastic packaging advancement and any specific conditions affecting these. This process demonstrated to what extent the propositions explained by individual case and replication occurred across cases (Yin, 2018).

3.3.1.3. Design data collection instrument

This study uses semi-structured interviews and documentation review as the methods of data collection. Interviews are a question and answer process with or without using written guidelines, conducted by interviewers with respondents (interviewees) face-to-face and have the intent to fulfil research objectives (Creswell, 2014; Yin, 2018). Semi-structured interviews aim to explore issues more openly, where the researcher questions the opinions and ideas of the parties invited to interview (but there are controls) and uses guidelines as a benchmark for interview flow (Creswell, 2014). The guidelines are developed to maintain the focus of the interview on addressing the RQ and ROs. The interview guidelines consist of questions and sub-questions that refer to the propositions, underlying theory and themes in the co-innovation. Selection of the participants for the interviews used purposive sampling, by considering their role, understanding and involvement in the co-innovation, to contribute to answering the ROs. The participants include top management, project leaders, managers specifically in R&D, production and marketing from both the customer and supplier sides.

Preparation of the interview protocol is carried out through the following stages: create a list of questions and instructions, peer review and improvement, pilot study and improvement, then finalising the protocol in an effective format making it easier for the interviewer to apply in the actual interview. See Figure 12 and the following explanation of each of these stages.

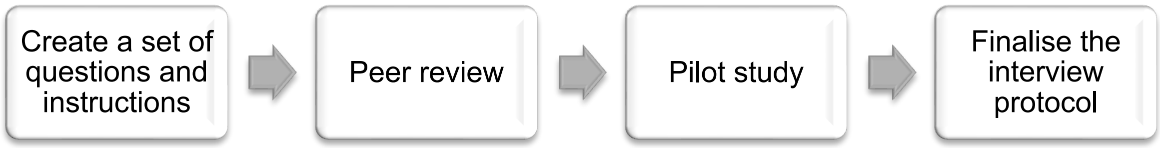


Figure 12 Process of creating the interview protocol

In making a list of questions and implementing instructions, it is important to note that good interviews consist of concise, easy to understand questions and do not cause different perceptions for interviewers and participants. These questions also open up opportunities, or encourage participants to explain in detail based on their experience, to enable the discovery of new things or unique phenomena. But most importantly, these questions are relevant to answering RQ and ROs, as well as addressing the proposed framework. The lead researcher developed the list of questions by creating open questions, which are then mapped based on their relevance to the research objectives and themes that need to be explored. After that, questions are evaluated, questions that are less relevant, mean the same as the previous questions are deleted, wordy questions are summarised, and other questions are adjusted as needed. After all the questions are ready, an interview guide is prepared that contains a sequence of implementation and technical explanation, such as a greeting, giving a brief introduction about the purpose and interview process to the respondent, asking for consent and signing of the necessary paperwork, and the estimated total duration of the interview. Finally, questions and instructions for implementation are documented as draft interview protocols.

The next step is to review the draft interview protocol through peer review. Two postgraduate researchers, and two other academics, who were experienced in research and conducting interviews, were involved in the peer review to help with improving the interview protocol. Each reviewer was asked to read it, then evaluate, first, that the implementation is in good order, and clear and easy to implement; second, the sentences should be concise, easy to understand and not cause a biased perception. Finally, the reviewers submitted their opinion and suggestions for improvement to the lead researcher, who considered them for improving the interview protocol. Figure 13 gives an example of the interview questions and the improvement after peer review, which include an introduction given to encourage the informants to share their experiences and then relate them to the co-innovation process.

Besides giving suggestions regarding the questions, the reviewers also suggested maintaining the interview time for about 60 minutes, so that participants did not become tired or feel bored because the interview was taking too long. With this input, the interview time initially set for around 75 minutes was then adjusted to 60 minutes by modifying several parts. For example, before the peer review, the question that aims to explore the dynamics of the supplier-customer role was originally given a duration of 15 minutes. After the peer review, the question was shortened to 10 minutes (see Figure 14).

How do you develop Bioplastic packaging product with your supplier/customer?

- How is the process
- How is the mechanism
- What are your roles in the collaboration
- What are your supplier/customer roles in the collaboration

So, let's talk based on your experience…
How do you work with your supplier/customer in developing Bioplastic packaging? What are the stages/steps from the beginning of the collaboration to the last stage? How does each process work?
Please explain/describe the activities in developing bioplastic packaging

- Performed collectively/jointly together with your supplier/customer
- Performed individually, either by you or your supplier/customer
- Please explain/describe the resources put into the collaboration:
- collectively/jointly/shared between you and your supplier/customer
- individually, either by you or your supplier/customer
- How does this work? How have the investment and costs been arranged? Are there any other arrangements?

Figure 13 Example of the revised interview guide (partial) after the peer review

- What are the dynamic, daily ups and downs when working with your supplier/customer? How do you manage that?
- Please tell me about your relationship with your supplier/customer, specifically in developing successful bioplastic packaging or overcoming its challenges
- How does this relationship work? How do you manage this relationship?
- Which aspects are significant to deliver the successful bioplastic product development and overcome its challenges? Why?
    - To what extent do these influence your involvement/contribution further in this bioplastic packaging development?
- What are the significant contributions from your supplier/customer, specifically in developing successful bioplastic packaging or overcoming its challenges?
    - Why they are important?
    - To what extent do these influence your involvement/contribution further in this bioplastic packaging development?

↓

- What is the role of you and your supplier/customer in the co-innovation? How are these roles implemented/performed?
- What are the dynamics, daily ups and downs when working with your supplier/customer? Why do you think that happened? How do you manage that?
- What do you think about your relationship with your supplier/customer? Why do you think so? How does this relationship work?

Figure 14 Example of the shortened interview questions after the peer review

Based on the results of the peer review, questions and technical implementation of the interview guide were arranged into an interview guide that uses a concise format, which is easy to follow during implementation. The interview guide was tested in a pilot study whose implementation can be seen in more detail in Section 3.3.2.3. Based on the pilot study, improvement of the interview guide comprised an additional question about the uniqueness of co-innovation in bioplastic packaging compared to other industries; revised the interview questions to be more concise; rearranged the sequence of the questions to be more systematic; and changed the layout to one page for ease of use during interviews. In the pilot study, the duration of the interview was finished in less than one hour, the technical guidelines and paperwork were also applied and there was no need for further adjustment. Thus, the interview guide provided in Appendix B was ready to be used for the actual interviews.

Furthermore, a case study is suggested to triangulate multiple sources of evidence to enhance the construct validity and reliability by minimising researcher bias in interpreting the participants' verbal information (Creswell & Poth, 2018; Yin, 2018). This study incorporates a documentation review to complement data collected from the semi-structured interviews. Documentation provides historical and contextual information that helps the researcher reflect and gain insights on a topic, hence facilitating discussion in approaching specific topics or sensitive issues (Creswell & Poth, 2018). Documentations were taken from the online public domain, mainly from the company websites, bioplastic or packaging news, magazines, newsletters, case studies and reports from reputable associations or endorsed by reputable companies or institutions, and other publications from associations. These documentations can be reviewed frequently and contain specific event details to corroborate and augment evidence from the semi-structured interviews (Yin, 2018). Public web-based documentations were considered to be more accessible, reduced travel and direct contact, and were overall more efficient in cost and time (Creswell & Poth, 2018), particularly during restrictions in 2020, due to COVID-19.

Secondary data collected from the company websites consisted of the company profile, product range, sustainability agenda, and press releases on bioplastic packaging development or launch. This information was essential to corroborate the details of the bioplastic packaging material, features, or technical specifications that the company produced or used in their products. In addition, the company websites typically dedicated a section to their sustainability programme, which gave an overview of the sustainability development prioritised by a company and the relevance of bioplastic packaging to contribute to this agenda. Furthermore, press releases and news on bioplastic packaging development projects in the past or ongoing served as helpful considerations for the case selection and preliminary inferences (Creswell & Poth, 2018; Yin, 2018) on the co-innovation that sharpened the discussion and increased the efficiency of the interview. Before an interview, the researcher could reflect on a topic based on the documentation review and make an appropriate approach to probe the bioplastic packaging co-innovation project, which sometimes contains confidential information. Nevertheless, information from various documentations also complements the participant's information, corroborates claims, and sheds light on a theme (Creswell & Poth, 2018) that helps in generating the coding template and further analysis.

3.3.2. Data Collection

3.3.2.1. Ethical consideration

Ethics approval needs to be obtained before the research as a form of respect for and protection of participants and researchers (Newson & Lipworth, 2015) and to ensure that the research conducted follows good ethical conduct. In addition, ethics approval can be used by researchers to build trust with informants because of the data collection procedures, the confidentiality regarding identity, delivery of sensitive information and the use of data for dissemination of research results considered to have good ethical conduct (Creswell, 2013). Ethical considerations and risk assessment in this study include the initial design phase, data collection, analysis and dissemination of study results.

When designing semi-structured interview questions, protocols and documentation review guide, ethical considerations include the possibility of involving personal or sensitive data, such as opinions from the participants, company data, procedures and events (Yin, 2018). The scope of information extracted through interviews and web-based public documentations presents a low risk to the reputation of the company being studied or the participants because of the focus of data collection, following the research objective, hence does not involve probing confidential, sensitive data, crime or traumatic experiences, and the company's internal or external conflict. In line with these ethical and risk considerations, participants were asked to sign a consent form that contains the approval of data collection, voluntary participation and withdrawal procedure, confidentially and use of the information, as well as an audio recording.

In addition, this study has a low risk of physical harm to the researcher and participants. Interviews were carried out professionally at a time and place that has an adequate atmosphere and security, such as meeting rooms, public places or online, as agreed by both interviewer and the participant. This research has minimal risk to psychological or emotional distress to participants and the researcher because the information about the co-innovation mechanisms has been delivered verbally, neutrally and objectively, and does not involve any personal trauma or crime. The interviews were conducted with managers/staff/representatives of the company and did not involve children or other vulnerable people.

This study has passed the ethics review from Coventry University and has acquired the ethics approval certificate, in page i. The certificate was shown to the participants as proof that the interview protocol has complied with the ethical aspects. If necessary, it could be used as a publication requirement in scientific journals to minimise the risk of ethical violation claims on the published research.

3.3.2.2. Interview

The interview process was outlined in three stages: preparation before the interview, the interview itself and post-interview.

Preparation included contacting the participant and scheduling an interview. The participant candidates were contacted by email or social media, i.e., LinkedIn, in which they were given an introduction to the study then asked to participate in the interview. After the candidates had agreed to participate, the interviews were scheduled via face-to-face, online or telephone. Next, the participants were given further explanations about the points to be discussed and the remaining interview protocol, such as ethics and audio recording, and were asked to sign a consent form.

The interviews were conducted according to the appointment made with the participant. Interviews lasted around 60 minutes, except the FilmpackCo case, and were conducted in English or Bahasa Indonesia, according to the mother tongue of the participants. The interviews were documented using audio recording and manual field notes, which provided highlighted points and served as back-up data. The interviewer led the interviews by following the interview guide, which contained an introduction and a list of steps derived from the interview protocol, see Appendix B. The interview started with the interviewer giving a friendly introduction that included a brief review of the interview objective, its protocol, confidentiality, and a quick reminder about the audio recording and consent form. Then the interviewer asked the questions following the guide and asked a few more questions as necessary to probe for further details. At the end of the interview, the interviewer informed the participants about using additional information from the company’s website and other online documentation, which were publicly available, then thanked the participant.

After the interview, the audio recording was kept safe in Coventry University’s cloud storage, then transcribed manually or using transcription software, Otter.ai. Subsequently, the transcripts were reviewed, transcription errors were corrected, noises, pauses and expressions, such as mumbles words, sighs or non-essential voice expressions were not included in the transcript as the priority was to capture the context of the information. In addition, the interviews in Bahasa Indonesia were manually transcribed and relevant quotes to be presented in the case analysis were translated into English.

3.3.2.3. Pilot study

This thesis uses pilot studies to help review the research design, data collection protocols, including refining the interview questions (Yin, 2018). The pilot study is regarded as beneficial to determine the feasibility of the research design and address methodological issues early on, then make any necessary improvement (Kim, 2011).

The pilot studies used in this research included an interview with a professional working in bioplastic product development and a case from a packaging manufacturer. The professional was selected from Coventry University staff or PhD students whose work was in the bioplastic product development for 3D printing. This pilot study primarily aimed to review the interview protocol and refine the interview questions, which were then applied to the second pilot study. The latter aimed to review the feasibility of the case study design and any further methodological issues (Kim, 2011). A packaging manufacturer was selected from the list of companies to be contacted for the case study. Several companies were contacted by email, and the company that gave the fastest response was chosen for the pilot case. The participant selection in this pilot study considered time-efficiency and convenience without compromising the relevance of the participant's knowledge to the objectives of this research.

The pilot study was carried out following the data collection protocol. When the participant stated his/her willingness to contribute, then the interview schedule was agreed and further information about the purpose and process of the interview, consent form and other supporting documents were emailed to the participant. Interviews were conducted through face-to-face meetings and documented in a QuickTime player audio recorder and mobile phone voice recorder; a field note was also made as a back-up.

A reflection and evaluation of the whole process for improvement were made after the interview. A reflexive journal was used to help minimise researcher bias arising from pre-owned knowledge and personal views regarding the topic (Kim, 2011), and record personal thoughts regarding the interaction and building connections with the participant, by listening and probing for more detailed information. Lesson learned from the pilot study should be explicitly reported even if only in the form of memos (Yin, 2018). The following are several highlights from the pilot study for improvement in the next data collection process:

a. At the beginning of the interview, it was necessary to probe more about experiences, participant roles in bioplastics product development and the position of the company. Simple gestures such as a smile or nods helped the participant feel confident about his or her experience and engage more in the discussion.
b. Listening skills were crucial, and there were several challenges to listening, such as while listening, taking notes which could focus on the keywords and drawing a mind-mapping diagram as necessary. Secondly, good listening skills help in connecting information from the informant into a good flow of discussion, hence also improve the interaction and engagement with the informant.
c. Using full sentences for the interview questions were not quite efficient as the interviewer overly focused on reading the questions as they were and missed the essence of the question. Therefore the interview guide was subsequently improved by showing the main questions and the essential themes within each question.

Using the packaging manufacturer as a case study is relevant to address the aim of the interview. Therefore the data will be used in the case analysis; the company is given code FilmpackCo, and the informant is given code Techdir-SC-001, see Within-case analysis in Section 4. The selection of a professional who works in bioplastic product development for 3D printing helped to improve the interview guide. Although the participant was very knowledgeable in bioplastic product development and shared key points on the co-innovation process, the interview could not maximise the detail on the bioplastic packaging and the packaging industry. Therefore this interview has not been included in the data analysis. Clearly, the next interviews must carefully consider the relevance of the professional to the scope of the current study.

3.3.3. Case analysis

Data analysis consisted of within-case and across-case analysis. The unit of analysis is determined based on the RQ (Sekaran & Bougie, 2016); it can be in the form of individuals, organisations, roles, events, relationships and processes that represents a phenomenon that occurs in a specific social and physical setting context (Miles et al., 2014). This research uses dyads as the unit of analysis to support the interest of this study in describing the interaction and relationship between firms (Dyer & Singh, 1998), i.e., bioplastics packaging manufacturer and product manufacturer, during the co-innovation. The following sections explain the process of the analysis.

3.3.3.1. Within-case study analysis

The data analysis within the case study follows qualitative data analysis from Miles & Huberman (1994) in the following steps:

a. Data reduction, which is recording, summarising the main points, focusing on important things, and choosing patterns and themes. Researchers in this stage will simplify the data obtained and group the data, providing identity so that the data have a certain meaning when analysed.
b. Presentation of data in the form of a brief description, table and chart. The researcher will process all the data in a descriptive form needed to make them easier to interpret and from which to draw conclusions.
c. Drawing conclusions and verifying data. The researchers will draw conclusions about co-innovation to answer the research questions.

The data reduction process was carried out in several stages; first, the interview transcript was reviewed, and the relevant quotes were entered into a spreadsheet, MS Excel (Appendix D). If necessary, the transcript was printed, then relevant quotes were highlighted manually with a colour marker and given an annotation. A good starting process is important to build the direction of analysis and can be done by identifying data that addresses the RQ and ROs (Yin, 2018).

For that, a template was used to map the relevant information from the transcript into the interview questions, research objectives and themes from the initial framework. Template analysis was used for data extraction from each case. Before starting the data extraction, interview transcripts were reviewed to minimise errors in the transcript process. This review process also helps in becoming familiar with the data (King, 2012). The next step is to develop the initial template by creating a placeholder code to organise the themes (King, 2012). ROs were used as placeholders so that data collected and exploratory phenomena remained directed and relevant to address the ROs. Before coding began, the initial template was determined using *a priori* themes taken from key perspectives in the initial framework: joint activities, joint resources, relationship management, and absorptive capacity. This approach followed the middle-ground approach that is in the middle between the top down and bottom up styles of analysis (King, 2012). Initial template development was iterative throughout the data extraction (King, 2012).

For this study, the initial template was first updated based on the preliminary coding of the pilot case, FilmpackCo and the result is the addition of codes that are clustered under the *a priori* theme hierarchy. The updated initial template was also used for data extraction of BarrierCo and BiopackCo. Although the template can be modified continuously if new data are found, the template still needs to be finalised so that research can be continued to the next stage. The template was updated and finalised based on the third case coding, BiopackCo. Moreover, the interview transcript were uploaded to NVivo software to be given codes using short phrases interpreted from the quotes. The codes were then put into the relevant templates in accordance with the ROs of this study (see Appendix C). The implementation of this process in the findings is exemplified in the case of BiopackCo.

Data are presented in the Within-case analysis, see Section 4, using narrative descriptions supported by workflow diagrams and tables. Narrative description provides a robust explanation not limited to code frequencies and similarity of themes, but also answer the 'how' and 'why' questions (Yin 2018), and therefore it is relevant to address the RQ and ROs of this study. The narrative description was useful to explain in detail the conditions that occur based on the experience and knowledge of each participant; it also helps the analyst to become familiar with the case and pattern (Eisenhardt, 1989). In addition, a narrative description was able to capture underlying circumstances and reasons from the participants' point of view (Yin, 2018) hence facilitated a more in-depth understanding of the underlying mechanisms of co-innovation. Furthermore, workflow diagrams were used to help in understanding the narratives by displaying visual illustrations (Miles & Huberman, 1994) of the process, the steps in chronological order and the mechanisms of co-innovation. Moreover, tables were used to summarise and describe the key points found in each case that are relevant to the ROs and themes in the initial framework. Tables are also useful for explaining themes and sub-themes in different arrays that help in reviewing any emerging patterns from each case, such as the pattern of a particular process and outcome, (Yin, 2018).

3.3.3.2. Cross-case analysis

After the within-case analysis, cross-case analysis was conducted by making comparisons between cases to sharpen the analysis so as to improve the quality of the conclusions (Eisenhardt, 1989; Yin, 2018). Comparison across cases helps justify propositions, and minimises false conclusions, due to informant-processing biases (Eisenhardt, 1989), subjective impressions from the information or avoiding disconfirming fact against the propositions. Therefore, the data must be viewed using a number of divergent techniques (Eisenhardt, 1989; Miles & Huberman, 1994).

The search tactic used in this cross-case analysis is to compare a pair of cases within the same group of supplier or customer (Eisenhardt, 1989). The highlighted facts from individual cases were compared based on themes and circumstance to find any similarities, patterns and significant differences across cases. Because the comparisons were limited to a pair of cases, subtle patterns could be more clearly detected (Eisenhardt, 1989). Next, comparisons were made between the supplier and customer group to strengthen the understanding of prominent similarity in a broader scope or a uniqueness that has a great impact on each case. The comparison was recorded in tables and matrices to help in reflecting different themes or sub-themes in the analysis and by using a sequential order (Miles & Huberman, 1994) to illustrate the process of co-innovation. The cross-case report should indicate the extent of the replication logic (Yin, 2018), and the examination should present the process and results, factors and impact regarding the co-innovation and its underlying conditions, reasons or backgrounds. Thus, the analysis in this study showed not only literal but also theoretical replication (Yin, 2018).

3.3.4. Shaping the conclusion

Shaping the conclusions was conducted by replicating the findings from the cross-case analysis to confirm, add to and sharpen the theory. Steps taken for shaping conclusions include shaping propositions, comparing findings and finalising conclusions. These steps were done to achieve internal validity, generalisation and theoretical level conclusions (Eisenhardt, 1989).

Based on within-case and cross-case analysis, the initial frameworks were reviewed and refined to address the ROs. The next step was to compare the results with the literature to capture consistency and contradiction, both within the literature and between the literature and findings. The accuracy of the conclusions from the case study can be improved if there is a convergence of the results from the comparison of several different sources (Eisenhardt, 1989; Yin, 2018). Comparisons between the findings and literature are carried out to increase the internal validity; then conclusions are finalised (Eisenhardt, 1989).

3.4. Validity and reliability

Quality criteria are implemented to ensure the validity and reliability of data. The internal validity or trustworthiness of the findings or credibility of data in this study were obtained through pattern matching and explanation building (Yin, 2018). In addition, case analyses were presented in context-rich descriptions, well linked to the themes in the initial framework (Miles et al., 2014; Yin, 2018). This study compared patterns through cross-case analysis to explain how and why the co-innovation mechanisms generate outcomes (Eisenhardt, 1989; Yin, 2018). From across the case, the pattern and facts identified will be compared to the theory and literature to ensure consistency and relevant interpretation. The explanations were iteratively associated with the initial framework and propositions to refine the theoretical framework (Yin, 2018).

Furthermore, construct validity was obtained by, first, defining the constructs from the previous literature and refining the definitions based on the evidence (Eisenhardt, 1989; Yin, 2018). Second, construct validity was enhanced by maintaining a chain of evidence and undertaking source triangulation through semi-structured interviews and documentation reviews (Yin, 2018). The ROs and initial theoretical framework were carefully linked to the interview questions in this study. After the interview, the transcripts were mapped back to the initial framework and ROs using a spreadsheet, then given codes and managed using NVivo, which aids data tracing.

The external validity or transferability in a qualitative study does not mean generalising the findings, as in a quantitative study, but building analytical generalisations to other situations (Yin, 2018). Prior to the analysis, the external validity was enhanced from the case selection phase by adopting theoretical sampling, employing criteria that fill the essential element of the theoretical framework (Eisenhardt, 1989), thus facilitating the analysis. In the context of this study, specific details of situation and facts must be recorded and explained in the analysis. In this way, other researchers will consider these aspects in a similar setting and this will help the reader to understand and make generalisations in a similar context. Moreover, the cross-case analysis was employed, facilitating discussions that were closely associated with the theoretical framework and existing co-innovation studies (Eisenhardt, 1989).

Reliability represents the dependability of the qualitative research from which the next researcher will draw consistent conclusions when conducting the same study; the fact is that subsequent researchers conducting the same study would come to the similar conclusions (Yin, 2018). Reliability in this study is managed by following the case study protocol and showing traces of field activity (Eisenhardt, 1989; Yin, 2018), such as interview records, transcripts, coding methods and other documentation of the research.

4. Within-case analysis

This section explains each case used in this study. The case description briefly describes the profile of each case to give an overview of the general condition of the company. The next section describes each case in detail which consists of: first, a general description of the company explaining in more detail the company's operational activities, supply chain and the company's future potential; second, the output of the company's bioplastic packaging products explains the detailed product features and the advantages and direction of further product development. The following sections describe the critical resources of the company, which directly relate to bioplastic packaging product development as well as other resources that are important for the business. Finally, the challenges for product development are described, consisting of the most critical obstacles, problems to be solved or any conditions that inhibit product development.

The unit of analysis in this study is the relationship between supplier and customer. Informants with relevant knowledge or experience were interviewed to describe the co-innovation mechanism. Figure 15 shows the case positions in the co-innovation between supplier and customer. There are 15 case study companies comprising seven supplier and eight customer cases, all of which were not necessarily part of the same value chain. In other words, the supplier case does not necessarily work on the same co-innovation project with the customer case. And through semi-structured interviews, information regarding the approach throughout the co-innovation project and how supplier-customer relationship works were obtained. For example, the converter cases reveal how they work with their supplier, i.e. the biopolymer producer and with the customer i.e. the product manufacturer. Similarly, the product manufacturer and the biopolymer producer cases reveal how they work together as well as collaborate with the converter. With this information, dyadic supplier-customer relationships can be described and used for the analysis.

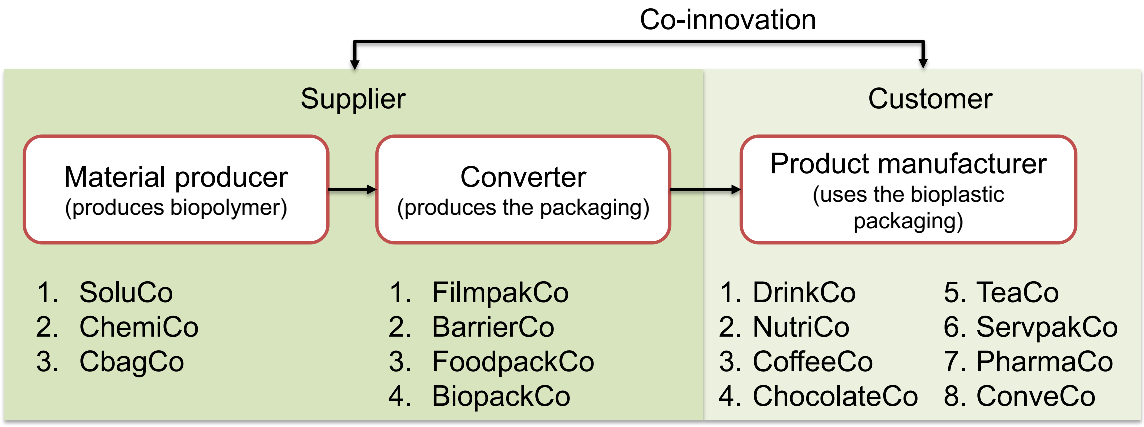


Figure 15 The case position in the supplier-customer co-innovation

The supplier cases show co-innovation at the company in developing bioplastic packaging starting from raw material to packaging that is ready for use by customers. This illustrates the supplier's point of view when interacting with customers starting from approaching, managing project development and taking advantage of the output produced together. The supplier is a raw material producer, a company that develops biopolymer derived from plant-based or other renewable material for further processing into packaging. The packaging made of this material is biodegradable and/or recyclable at its end-of-life. The converter is a packaging manufacturer that processes various raw materials, such as biopolymer, conventional polymer, paper, aluminium, or others, into various packaging using single materials, multi-layered or a combination of several materials. Some examples of packaging produced by converters and discussed in this case study include flexible films, food trays, containers, wraps, bottles, cups, bags, and many others.

The customer cases show co-innovation from the point of view of product manufacturers who produce various kinds of consumer goods, pharmaceutical products, or products for other industries and use bioplastic packaging for their products. In manufacturing their products, some customers use the facilities they own, and others collaborate with manufacturing partners. The customer case highlights the customer approach to the supplier when looking for sustainable packaging solutions, and interactions with the supplier to develop and apply packaging to products. These cases also indicate the customer's perspective on any benefits from co-innovation other than a successful application of bioplastic packaging.

Table 9 describes the profile of companies based on the information gathered from the representatives interviewed and their company's website. The information comprises the industry sector, main product, year of establishment, location, number of employees, which is useful to show the company size, and its managerial complexity. The interview partner shows the interviewees' positions in the organisation, which also indicates the sufficiency of knowledge and information shared by the interviewee. The role in the supply chain shows whether the company is the supplier or the customer, which is important to understand any emerging patterns among roles and will be the focus of the analysis.

A benchmark consisting of professionals' opinions was also used to add robustness to the data, considering their position outside the companies involved in co-innovation, and their relevant knowledge and/or experience in the bioplastic packaging product development and the industry. Table 10 presents a brief description of the benchmark cases. The informants for this benchmark were interviewed using the same interview guide, and they answered based on their experience of direct and indirect involvement in the bioplastic product development project. The informants also gave a view that looked at complexity in the industry and supply chain comprehensively but did not side with suppliers or customers; this is due to their position being independent, i.e., outside the company, hence useful to provide an objective comparison in the analysis. A successful co-innovation in a different technology that enables using conventional plastics that are biodegradable and recyclable, just like the bioplastics, was also added to the benchmark. This case helps to understand how a different path could achieve a similar output to co-innovation in bioplastic packaging.

Table 9 The main case profiles

No.	Cases	Industry sectors/main product	Year est. (up to 2021)	Location	Employees (people)	Interview partner (ID code)	Position in the supply chain
1	SoluCo	Biodegradable, water-soluble polymers	> 10 years	UK	> 100	CTO (CTO-S-21208)	Supplier: material producer
2	ChemiCo	Bio-based, recyclable polymer	> 10 years	EU	> 100	Technical Manager (TAP-S-21209)	Supplier: material producer
3	CbagCo	Masterbatch, polymer compounds and bioplastic	≤ 5 years	Indonesia	> 100	Director/owner (Presdir-S-0211)	Supplier: material producer, converter
4	FilmpackCo	Packaging/PE and bioplastic packaging	> 10 years	UK	> 100	Technical Director (Techdir-SC-001)	Supplier: converter
5	BarrierCo	Packaging/fossil-based & plant-based, biodegradable, flexible packaging	> 10 years	UK	> 100	Technical Manager (Techman-SC-0226)	Supplier: converter
6	FoodpackCo	Packaging/packaging for food	> 10 years	UK	> 100	Account manager (Accman-SC-0304)	Supplier: converter
7	BiopackCo	Bioplastic biodegradable, compostable, water-soluble packaging	> 10 years	UK	10 to <50	Director/owner (Dir-SC-0515)	Supplier: converter
8	DrinkCo	Various food & beverages products	>10 years	Indonesia, Global	≥ 100	Sustainability Director (Susdir-C-1106)	Customer: product manufacturer
9	NutriCo	Various food & beverages products	>10 years	Indonesia, Global	≥ 100	Head of Packaging Department (HOPack-C-1207)	Customer: product manufacturer
10	CoffeeCo	Beverage product	≤ 5 years	UK	< 10	Co-Founder (Cofound-C-0107)	Customer: product manufacturer, also material producer
11	ChocolateCo	Food product	>10 years	UK	< 10	Founder (Found-C-21210)	Customer: product manufacturer
12	TeaCo	Beverage product	>10 years	UK	10 to <50	Sustainability Manager (Susman-C-21211)	Customer: product manufacturer
13	ServpakCo	Foodservice products	>10 years	UK	50 to <100	Quality Assurance (QA-C-21215)	Customer: product manufacturer
14	PharmaCo	Medicine, vaccine, healthcare products	>10 years	UK	≥ 100	Head of Packaging R&D (HOPR-C-21219)	Customer: product manufacturer
15	ConveCo	Various consumer goods	>10 years	UK	≥ 100	Sustainable Packaging Specialist (Suspak-C-21305)	Customer: product manufacturer

Table 10 Benchmark case descriptions

Cases	Descriptions	Experience in the industry (up to 2021)	Location
BioRes	University researcher specialised in biopolymer development and the industry	>10 years	UK
PackCons	Sustainable packaging consultant, also experienced in bioplastic packaging development and co-innovation	>10 years	UK
InopackDir	Sustainable packaging research project manager, highly knowledgeable in bioplastic product development and waste management	>10 years	UK
MasterbatchCo	Raw material producer, a start-up, small sized company who provide biodegradable and compostable solutions in the form of drop-in masterbatch. The participants being interviewed are CEO (CEO-A-0313); VP Innovations (InnoVP-A-0217)	≤ 5 years	UK

The following sections illustrate the data reduction process, using BiopackCo as an example to demonstrate the steps from data reduction, which included mapping the interview transcript and coding in NVivo, to the presentation of the analysis.

The data reduction process began by reviewing the interview transcript with Dir-SC-0515 (see Figure 16), followed by sorting the data according to the topic and inputting the interview excerpts into a spreadsheet.

Participant ID: P0515	*Date of interview: 15 May 2020* *Time: 14:00 - 15:00*

Interview starts after a friendly greetings

Interviewer 0:01
Yeah, I'm now recording this conversation. Okay. Yes. And P0515, please tell me in a brief about yourself and the company. Introduce yourself please.

P0515 0:17
Okay, so the company has been running since 2007. But I've been working with bioplastics since 2000 initially with water soluble plastics but then more recently with plant bioplastics based on PLA and other materials. So BiopackCo was set up basically to be a consultancy on the supply on all types of bioplastic because that's where we saw the future going. That's where we saw the future being. So that that's generally all we do.

Figure 16 An example of the interview transcript

In Figure 17, a topic on the process of co-innovation was detailed into the sub-topic: "Steps from the beginning to the implementation/real production"; then the relevant interview excerpts were copied to the column "Interview quotes/summary". Afterwards, the essential part of the quote was selected for coding using the NVivo software. For example, the statement in Figure 17 coloured in red, *"...And usually they've got a wish list of things that they require based on existing plastics. What you have to do is go through what they require, and then say… that's possible that's not possible."* was given the code "Initial assessment" in NVivo.

Mapping the information from P0515

Guidelines/Questions	Interview quotes/summary (15 May 2020)
The process of co-innovation for bioplastic packaging product development and the involvement of your customer in that process:	
Steps from the beginning to implementation/real production; how long for each stage	*Okay, so normally what happens, normally what happens, you get it you get a request from a customer or a consultant, packaging consultant or somebody who wants to try and make an existing product more often or maybe even a new product using a bioplastic.* ***And usually they've got a wish list of things that they require based on existing plastics. What you have to do is go through what they what they require, and then sort of say, Well, you know, that's possible that's not possible.*** This is what you need to do and you only work for,
	yeah, ***you do prototyping, yeah, we do, you know, small sample runs of materials. Just just to get some feedback on how the material performs...*** *a very small sample into full scale production, you always do it in small steps, to go from, you know, some some a4 sheet to roll of film to, you know, 10 rolls of film to a pallet and then you work your way up.*

Figure 17 An example of the interview map from Dir-SC-0515

Similarly, the statement in Figure 17, *"...you do prototyping… small sample runs of materials. Just to get some feedback on how the material performs..."* was given the code "Initial product prototype" in NVivo (see Figure 18). Finally, these data were presented in a descriptive narrative, as seen in BiopackCo case analysis, section 4.7. Data analysis for the remaining cases was processed in the same way and each within-case analysis is available in tabular view at the end of each case narrative.

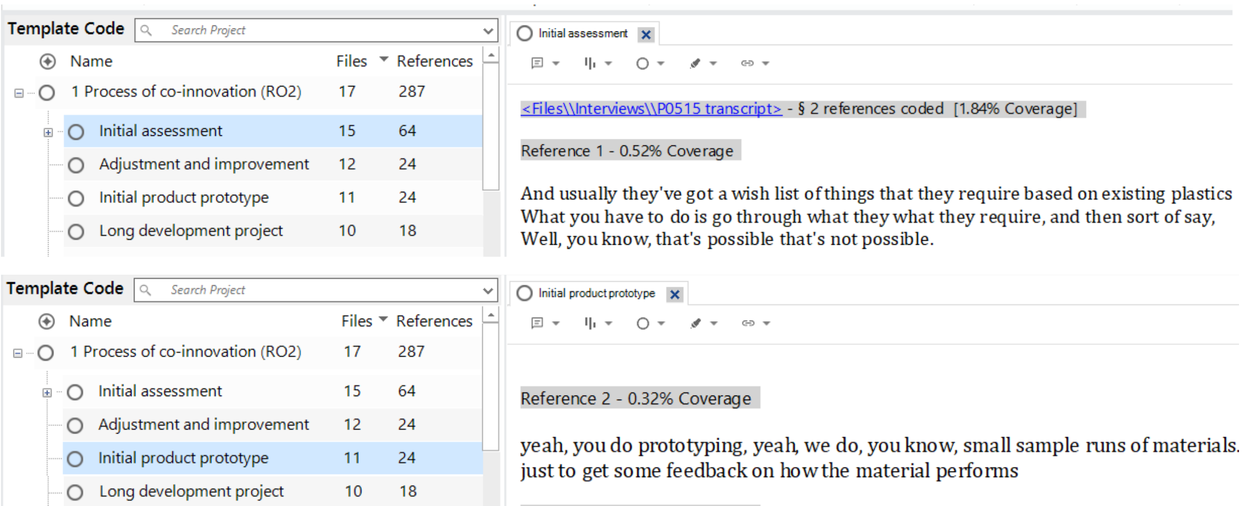


Figure 18 An example of the coding process in NVivo

4.1. SoluCo

SoluCo is a resin polymer producer, located in the UK whose product is a water-soluble polymer, which was actually a reinvention of an old polymer. SoluCo managed to improve the processing of the material, claimed its product works according to the circular economy principle and brought this material back to the industry for various specialist applications. This product has several advantages, one of which is having highly functional properties, such as clarity and high barrier properties. SoluCo's material has multi end-of-life options, which include first, easier recycling, either on its own or in combination with other things, and second, compostability or anaerobic digestion, breaks down in marine or freshwater, and is also non-toxic in the environment.

SoluCo started an internal R&D, which took about 10 years to develop the base and early stage material. Next, SoluCo started to build a factory to produce the material, and at the same time opened up discussions with the supply chain. SoluCo approached manufacturing partners, such as film manufacturers, extrusion counters, and injection moulders, to manufacture the material into packaging, and also approached the brand owner and retailers to offer packaging solutions. According to CTO-S-21208, the best mechanism of co-innovation that worked for SoluCo was by approaching the brand owner and demonstrating the potential of using SoluCo's material, including feasibility of its implementation, scale-up, and benefits, such as improving the brand owner's packaging, and other commercial benefits or addressing the circular economy. Subsequently, it is anticipated that the brand owner will ask their packaging manufacturer or other supplier to support this move and therefore these upstream supply chain members will address this demand as it came from their customer.

> *"So what we found was that the best way of doing it was to actually go directly to the brand and demonstrate. So we had to do a lot of an awful lot of demonstration." (CTO-S-21208)*

After the brand owner and SoluCo agreed on a joint development project, the brand owner was open to share confidential information, provide access to the brand owner's facilities, equipment and supply chain, such as the converter and laboratories, who already worked with the brand owner. Moreover, the brand owner opened their other development partners to facilitate more synergistic development.

"…all the information that they have all that. All Access often to their, their equipment pilot equipment test equipment, their connections…" (CTO-S-21208)

CTO-S-21208 added that mutual adaptations from the brand owner, in accepting higher costs when offset with other benefits, could be gained along the supply chain, such as multiple end-of-life options and significant market potential. According to CTO-S-21208, converters are often reluctant to work with bioplastics due to cost, conversion rate and recovery of waste, therefore, SoluCo also presents technical alternatives in the processing to address cost and recovery of waste.

"Twice the cost. But if, but if I can half the gauge of the film, and give you something that you can recover at the end of life where you currently can't…" (CTO-S-21208)

The brand owner contributed their resources after the joint development had been agreed and provided information, access to facilities and networks in the supply chain, as well as financial capital to cover part of the development cost and gain exclusivity. CTO-S-21208 added that SoluCo used the converter's machine to test the material in a real production setting to be able to demonstrate to and engage the brand owner. The important phase in the relationship management is to obtain agreement for joint development with the partner selection, in which both SoluCo and the brand owner considered partners' capability and long-term project feasibility. CTO-S-21208 emphasised that both SoluCo and the brand owner aimed for long-term close collaboration and plan to launch the final packaging in the next three to four years.

Through co-innovation SoluCo have acquired more information on the critical features of the brand owner's process. CTO-S-21208 exemplified that this valuable information includes technical and commercial, equipment, pilot equipment, test equipment, third parties' laboratories and ongoing development projects. CTO-S-21208 also added that the learning process happened through sharing information, and collaborating with the brand owner functional team and wider network.

"…all the information that they have all that. All access often to their, their equipment, pilot equipment, test equipment, their connections with independent laboratories and other development partners." (CTO-S-21208)

By sharing information and issues with a greater number of partners, CTO-S-21208 pointed out that everyone who normally focuses on their own interest, cost, development, etc., will gain a comprehensive understanding of the whole supply chain and work towards a resolution.

> *"…all of us are guilty of sitting in our own silos. You know, looking at our own costs looking at our own developments etc. But sometimes it's really difficult to put it into the context of the whole of that supply chain." (CTO-S-21208)*

These processes also enabled SoluCo to understand more about what the brand owner is exactly looking for, the direction of the project, and how the brand owner approaches and communicates the packaging to their consumers. CTO-S-21208 also added that the converter obtained a new perspective on the costs and benefits of developing bioplastic packaging, especially in offsetting increases in costs against bigger opportunities to support the brand owner's sustainability agenda.

Before co-innovation, SoluCo has got an initial product to offer. The material has several advantages such as clarity, barrier properties and more efficient processing than other bioplastic materials. It also has multiple end-of-life options, compostable, water-soluble, recyclable, and leave no harmful residue to the environment. CTO-S-21208 reflected that co-innovation not only speeds up the development and implementation, but also supports the brand owner in achieving their sustainability agenda and obtain exclusivity to use the material. CTO-S-21208 added that SoluCo is carefully managing the exclusivity and avoiding any overlapping among brand owners.

> *"So you construct a joint development agreement, and they pay an element of the costs of that development if they want that level of exclusivity …Each in different areas. And clearly, you know, you've got to be careful you don't overlap..." (CTO-S-21208)*

It was inferred from the interview with CTO-S-21208, that the key factors to co-innovate with the brand owner were to offer suitable solutions and commercial advantages, supported by comprehensive data, demonstration of proof and capability to scale-up, and the guarantee of a continuous supply. CTO-S-21208 added that often small biopolymer producers who actually do have really good products for certain applications, are unable to scale-up due to limited raw materials. Therefore, SoluCo has the advantage by developing bioplastics for which the raw material is available in millions of tonnes.

> *"I think fundamental point is scale. You've got to be able to produce material and reasonable scale reflects the demands in questions from the market." (CTO-S-21208)*

According to CTO-S-21208, different approaches are needed to push innovation, for instance driving the circular economy by providing incentives for circularity. However, applying tax on plastic might not be an effective approach because rather than working on innovation, the producer is more likely to resolve the tax burden by increasing the packaging price, which the consumers in turn have to pay.

In the SoluCo case, the biopolymer producer role is to initiate innovation through the material, and provide technology and technical expertise. The brand owner is the adopter who also has more power in selecting partners, alternative solutions and in defining the specifications. The brand owner also becomes a connector between the biopolymer producer, the converter and wider supply chain. According to CTO-S-21208, the converter is convenient with the existing conventional plastic, focused on efficiency and see bioplastics as having limitations in this area, therefore are reluctant to change. Thus, the brand owner who is the converter's customer could push the converter to become involved in a joint development project.

> *"The slowest and rate determining step the least innovative to be perfectly honest are the converters. Because they they would much prefer to carry on doing what they're doing. And it's only the pressure from the market, and therefore the pressure on the brand that is causing this shift this dynamic change…." (CTO-S-21208)*

Table 11 Within-case summary: SoluCo

Themes	Descriptions
The process	Internal R&D, fully operated production facility, approach to converter and product manufacturer, extensive co-innovation with the product manufacturer.
Joint activities	Most early works were done internally: trial, end-of-life testing and certifications. Mutual adaptations: accepting higher cost when offset with other benefits that could be gained along the supply chain operation.
Joint resources	SoluCo invested a lot of work and resources in the initial development, and to run the initial operations, testing, and certification. The product manufacturer contributed information, a network in the supply chain, and financial capital to cover part of the development cost and gain exclusivity. The converter provided access for trials on the real production facility.
Relationship management	The important phase is the partner selection, which considered partners' capability and project long-term feasibility. Co-innovation was with the brand owner bridging co-innovation with the converter.
Absorptive capacity	SoluCo acquired more information on the critical features of the brand owner's process: technical and commercial, equipment, pilot equipment, test equipment, third parties laboratories and ongoing development projects. Learning process through sharing information, collaborating with the product manufacturer's functional team and wider network. Gained a comprehensive understanding of the whole supply chain and worked towards a resolution, what the brand owner was exactly looking for, the direction of

	the project, and how the brand owner approached and communicated the packaging details to their consumers. The converter obtained a new perspective in offsetting increases in cost against bigger opportunities to support the brand owner.
Outcomes	Speeded up the development and implementation, achieved the brand owner sustainability agenda and obtained exclusivity.

4.2. ChemiCo

ChemiCo is a start-up company, a pioneer in innovative renewable and sustainable chemistry operating in the Netherlands. The company has developed a new bioplastic material for packaging of various consumers' products. The material has a unique molecule from plant-based fructose syrup, comparable to the conventional plastic PET but with a lower carbon footprint, is recyclable and degradable, and embraces the circular economy principles. ChemiCo has collaborated with several brand owners and is currently preparing for scale-up and commercialisation. ChemiCo has built a pilot plant for trials and demonstrations and another flagship plant to operate on a small industrial scale. Over time, ChemiCo has improved the material performance for many industries, including the pharmacy and food and beverage industries.

ChemiCo started with an internal development, which aimed to develop new material and create a generic prototype. The internal R&D team worked with converters to learn about the fundamental phase in packaging application, develop a prototype and produce it on a small scale. Subsequently, ChemiCo carried out further technical development with the brand owner for specific packaging applications such as design iterations, adjustments and improvements to packaging prototypes and then produced on a larger scale. The brand owner also conducted internal tests and consumer perception tests, and prepared marketing communications, then finalised the co-innovation to the commercialisation stage and any further development as necessary.

> *"The customer or brand owner would do some of their internal testing. So maybe a consumer perception test. And then we would help them prepare the storyline …start to discuss commercialisation timelines, after that. And further developments that are required." (TAP-S-21209)*

Co-innovation between ChemiCo and brand owners also involved converters and other stakeholders supporting the brand owners through various joint activities. ChemiCo explored packaging applications for their new material, shared the knowledge of the material, solutions to processing conditions and the brand owner supply chain, and also helped the brand owner in marketing communications for introducing the new packaging material. All partners were involved in knowledge sharing and sharing confidential information. Co-innovation involved many trials and mutual adaptations. The converter worked with ChemiCo in prototyping, adjusting the packaging design, changing manufacturing tools to fit the new material, and meeting the brand owner requirements. The brand owner also adjusted their brand image and prepared the consumer base along the supply chain.

> *"So, our converters, usually not usually they are always, always be expert in plastic moulding and process. So we can combine the knowledge on that side. And our knowledge on the fundamental polymer behaviour and combine those together." (TAP-S-21209)*

TAP-S-21209 explained that all partners provided equal contributions to the co-innovation by investing financial capital and sharing resources for the project. ChemiCo supported the material development, built a pilot plant and flagship plant to produce a ton of scale material, proved the scalability from lab size to small industrial scale and commercial scale, and then demonstrated the packaging application when approaching the brand owner. ChemiCo shared the technology in the project and knowledge with the collaborating partners and the converter shared their expertise in plastic moulding and process.

> *"We take that knowledge of material properties and work with the converter … they are experts in plastic moulding and process. So, we can combine the knowledge..." (TAP-S-21209)*

In addition, ChemiCo's relationship management was seen in approaching the brand owner. TAP-S-21209 explained that ChemiCo demonstrates evidence of material development that has been achieved, the feasibility of the project and future potential, by using a data-driven approach to build a business case suitable for each brand owner; thus, it managed to convince brand owners to collaborate and make an investment. The collaboration with the brand owner was managed through the partnership agreement, including a material transfer agreement and shared intellectual properties (IPs) agreement. TAP-S-21209 noted that not all companies had had the ability to collaborate and adopt ChemiCo's technology. Therefore, ChemiCo prioritised like-minded partners focusing on innovation and a high commitment to carry out good sustainability practices.

> *"Not every company would be able of co-innovate with ChemiCo … So we really look for like-minded parties that want to move forward." (TAP-S-21209)*

The ChemiCo case showed how the biopolymer producer acquired information and knowledge from the co-innovation partners, such as information on the development timeline, required material grade and quantity, and expected technical performance. ChemiCo also needed to know when the customer planned to commercialise a product and in which country to address regulations and compliance for a particular area, achieve deliverables on time, and ensure supply availability. ChemiCo showed a strong absorptive capacity; for example, ChemiCo learned from the co-innovation partner through interactions during the trial and feedback, and learned much from the brand owner about the industrial aspects and market dynamics.

> *"We learn constantly from our partners. And that's why we partner …we are right up at the upstream in the development chain, so it's really vital to work with other parties." (TAP-S-21209)*

ChemiCo learned a lot from brand owners about industrial aspects, market dynamics, and consumers' wants. TAP-S-21209 exemplified that the current industry focus is around plastic waste, and therefore ChemiCo added this aspect to the business case, presenting a compelling marketing communication and more data on recycling. Co-innovation enables ChemiCo to understand more details about the brand owner's needs and address these by improving the material; eventually, ChemiCo became more adaptive to accommodate the brand owner's specific needs. ChemiCo also learned from the wider supply chain about different methodology and technology, other than the material, such as the LCA studies, and planned to use their LCA as a basis for future technology development, grow the technology and license it.

ChemiCo shows that co-innovation outcomes were not limited to improving the material and packaging application, but also facilitated scale-up, commercialisation, further technology development and inventions. Through co-innovation, ChemiCo was able to further develop materials according to the exact need of every brand owner, thus 'fit for purpose' with excellent performance. In the long-term, the brand owner would gain exclusivity, and also expected that bioplastic packaging would address their consumers' expectations and sustainability agenda, and enhance their brand. The material developed by ChemiCo was more expensive than conventional plastics, but ChemiCo balanced the right price point with performance and other commercial benefits. TAP-S-21209 added that ChemiCo shared the IPs with co-innovation partners, providing sector-specific IPs, such as packaging design and technical application, as part of their contribution to development or discoveries.

> *"I think it's more than fair that brand owners and converters have the right to protect their discoveries as well …design aspects of the package themselves, for example…" (TAP-S-21209)*

TAP-S-21209 explained that the key success of bioplastic packaging commercialisation is the right combination of performance, commercial benefits and price. When the bioplastic packaging is offered at a higher price than conventional plastic, it is expected to meet the quality performance expected by the brand owner, and is highly relevant in supporting their sustainability agenda. Therefore, a business case is an essential tool for convincing brand owners.

> *"The performance quality has to be there …the right story, it has got the right performance, and it has to have the right price point." (TAP-S-21209)*

While partner selection is one of the key drivers for co-innovation, TAP-S-21209 noted that not all companies were capable of collaborating and adopting ChemiCo technology. Therefore, ChemiCo prioritised like-minded partners with an innovative focus, high commitment to carry out good sustainability practices and wanting to be the first to have a sustainable bioplastic product on the market. TAP-S-21209 also observed that the market is changing and this should be anticipated by biopolymer producers. For example, in the last 10 years, the focus for bioplastic materials in general has changed from biodegradability to recyclability; the market has changed as the industry used to want biodegradable bioplastic packaging but now there is concern about bioplastic material due to contamination in the existing recycling infrastructure.

> *"A little bit of a bad reputation. I mean the, what we have seen in the last 10 years. Ten years ago, everybody wanted biodegradability." (TAP-S-21209)*

Finally, the role of each co-innovation partner is inferred from the ChemiCo case. The biopolymer producer initiated the innovation by bringing a new polymer to the market with a better approach to the circular economy principle. The brand owner adopted the technology, leading brand owners to have a comprehensive requirement, be highly selective in their partnership and have the power to support complex co-innovation and influence their supply chain. One of the dynamics in the relationship with the brand owner, TAP-S-21209 recalled, was during positioning the offer, which could be challenging as there are other alternative technologies in the market, so brand owners search for suitable solutions and might co-innovate with more than one technology provider. Sometimes ChemiCo found difficulties in gaining priority from the converter to focus on the co-innovation because bioplastic packaging is only a small part of the packaging market, and the converters have to manage the co-innovation in order to work with other priorities.

Table 12 Within-case summary: ChemiCo

Themes	Descriptions
Process	Development started with an internal development aimed at developing new material and creating a generic prototype. Co-innovation in two phases: first, to develop a packaging prototype with the converter, to develop a prototype and production on a small scale. Next, further technical development for packaging applications and production on a larger scale.
Joint activities	ChemiCo explored packaging applications for their new material, gave solutions to processing conditions and the brand owner supply chain, and also helped the brand owner in marketing communications for introducing the new packaging material. All partners involved in knowledge sharing and share confidential information; the converter and brand owner give feedback to ChemiCo for improving the prototype. Many trials and mutual adaptations with the converter to achieve the desired packaging application for the brand owner. The brand owner adjusted their brand image, prepared the consumer base and supply chain.
Joint resources	All partners provided equal contributions to the co-innovation: financial capital and sharing resources. ChemiCo invested financial capital and other resources for early development, shared the technology in the project and knowledge with the collaborating partners. The converter shared their expertise in plastic moulding and the process.
Relationship management	ChemiCo approached the brand owner by demonstrating that the technology works in a fully functioning commercial scale plant. Co-innovation was managed in the partnership agreement, including selling licences for the technology, to ensure the protection of shared IPs.
Absorptive capacity	Acquired information on the development timeline, how much material is required, the grade of material, expected performance, commercialisation plan in different countries. ChemiCo learned from the co-innovation partner through interactions during the trial, feedback and participating in a research project with the whole supply chain. Accumulated new knowledge of industrial aspects, the market dynamics or what the consumers want has enabled ChemiCo to improve their approach to the co-innovation partner, improve the material and become more flexible and adaptive.
Outcomes	Further development of the materials to meet the exact need of every brand owner, ‘fit for purpose’ with excellent performance, scale-up and operation at industrial scale, implementation and exclusivity for the brand owner, technology development and inventions.

4.3. CbagCo

CbagCo is a biopolymer producer and bioplastic converter, located in Indonesia. CbagCo has developed biopolymer compounds since 2007, and was officially established in 2017 as a subsidiary of a leading polymer producer in Indonesia. CbagCo pioneered the development of bioplastic packaging in Indonesia from R&D and large scale manufacturing to the commercialisation of bioplastic packaging in the Indonesian market. CbagCo has acquired ISO certification, and several awards for its innovation and environmentally friendly product from the Indonesian government. CbagCo produced the biopolymer pellet using starch as the raw material, then converted it into flexible film used for carrier bags, electronic wraps and other packaging. CbagCo serves large and small business customers in Indonesia and has exported its product globally.

PRESDIR-S-0211 stated that the company conducted an in-house R&D supported by external experts also involving a third-party machinery workshop. Co-innovation in developing biopolymer and the packaging was carried out with the converter, a division belonging to the same parent company, but external customers were not involved in this stage. PRESDIR-S-0211 explained that the first step was designing the material formulation, followed by creating the pellet prototype on a small scale. The development process took years and was highly iterative to obtain the desired product. The most difficult part, also the critical process, was the formulation from mixtures of a large number of compatible materials that worked in the manufacturing process as well as giving an added value to the final product. After the development, the converter then functioned as a "Live Showroom" to exhibit the bioplastic packaging production, giving an overview of fully operated manufacturing to the customer.

> *"We don't actually build the packaging factory. But we build it to provide a "live showroom" to the customer." (PRESDIR-S-0211)*

Joint activities between R&D, the converter and machinery workshop were directed by CbagCo. PRESDIR-S-0211 exemplified that a machining workshop worked after requests from R&D to modify the air pressure and blowing ratios, adjust gaps for die tooling, or other requested work. Furthermore, joint activities with the converter were related to trials of materials with a larger production scale. Additionally, CbagCo provided a licensing scheme to packaging manufacturers, in which joint activities such as knowledge transfer intensively occurred between CbagCo and the customers and provided technical support to CbagCo's customers. These activities facilitated CbagCo in the introduction of bioplastic products, helping the customer to use the product, facilitating acceptance of the product as it includes its limitations, all of which helped CbagCo penetrate the market.

> *"Their technicians practiced at our facility, we trained them to run the machine, how to operate, also perform the maintenance. Then they purchased the machine." (PRESDIR-S-0211)*

When developing bioplastic packaging, CbagCo invested resources for R&D, material testing and creating a specific conversion machine, because CbagCo's bioplastic has specific characteristics that could not work straight away by using the standard conversion processes. PRESDIR-S-0211 added that CbagCo was selective in assets investment by outsourcing expensive and or rarely used assets, whilst joint resources with the customers were limited.

The relationship with the customer was limited, as CbagCo developed the bioplastic material and packaging exclusively. CbagCo received many requests for customisation or different specifications from its customers, many of which they could provide. Therefore, the customer only accepted what was available, did some trials and bought when satisfied with the result. CbagCo found that convincing the packaging manufacturer to produce bioplastic packaging was quite challenging because the price of the final product was three to four times higher than that of conventional plastic. PRESDIR-S-0211 convinced the customer to consider the future of their business when the government regulation to ban single-use plastic would be implemented, and also passed some of CbagCo's retailer customers over to the packaging manufacturer.

The CbagCo case presents a unique way to introduce bioplastic packaging and manage relationships with business customers. First, CbagCo sells carrier bags to retailers for even quite small orders of 10,000 pieces, which are valued at IDR one to ten million (approximately £50 to £500), in order to introduce the environmentally friendly carrier bag and educate the market. Secondly, after having developed the market, CbagCo would approach converters to produce bioplastic packaging by showing the demand and the growing market. CbagCo then supported the converter by supplying the pellets, production machinery, training, technical support and even handed over CbagCo’s retail customers to the packaging manufacturer.

> *“Some consumers want to use it. After that, we get more customers; we offered it to the plastic manufacturer to buy the machines. They bought pellets from us, made bags, we shifted the customers to them (the plastic manufacturer).” (PRESDIR-S-0211)*

CbagCo supplied the conversion and printing machine that works for bioplastic packaging to the converter. CbagCo allowed the converters to copy and reproduce CbagCo’s machines, modify, or create better machine themselves because CbagCo’s main objective is to introduce the biopolymer pellets and in the long-term, would then fully focus on the production of biopolymer pellets for the converters on a much larger scale.

> *“Regarding the machine, they also endeavoured to copy, and some have managed to copy even better. I said, go ahead. Our aim is not to sell the machine or the bag, but to introduce the pellets…” (PRESDIR-S-0211)*

PRESDIR-S-0211 shared that the activities and routines to acquire that knowledge barely involved the customers. For example, PRESDIR-S-0211 learned from literature study, joining or visiting packaging exhibitions and even learned material formulation from the additive suppliers. Meanwhile, the packaging manufacturers who bought a licence from CbagCo learned about the bioplastic conversion process from CbagCo through a series of training programmes at the CbagCo facility. The packaging manufacturers then combined the new knowledge with their own expertise in conventional plastic manufacturing to modify or create an entirely new machine that performed better than CbagCo's version. However, the packaging manufacturers were reluctant to share this new knowledge and instead kept the advantage themselves as they were concerned that CbagCo could share this knowledge with other customers and create competition.

PRESDIR-S-0211 explained that CbagCo's product has many disadvantages compared to conventional plastic due to the characteristics of the starch-based bioplastic, but is much better from an environmental aspect. The current bioplastic packaging is biodegradable, compostable and recyclable when sorted with waste paper. In addition, CbagCo’s bioplastic was designed to be suitable for conditions in Indonesia, in which natural soil is mostly fertile with microorganisms, but industrial composting facilities are not available. However, this product has not passed the EN13432 biodegradability standard due to its disintegration rate being slightly below the requirements.

The key to successfully persuading the customer to adopt bioplastic packaging is by educating the market and the customers to produce the packaging themselves instead of buying from CbagCo. In this way, CbagCo would create more business customers and shift their focus to supplying biopolymers to them. Furthermore, PRESDIR-S-0211 explained that the bioplastic showed a positive development; government regulation is considered a positive driver of bioplastic development in Indonesia. The packaging manufacturers noticed the changing market and were concerned about losing business in the future when plastic packaging is banned.

> *"Now they are facing a changing market; government regulations start to push towards being environmentally friendly. They are forced to think about the future because if the plastic is banned, they will lose business." (PRESDIR-S-0211)*

In the CbagCo case, the external customers tend to be adopters, who use the bioplastic packaging and adjust to its limitations, and adopt the new conversion process by learning from CbagCo how to modify their existing machines. Despite this limited dynamic, CbagCo has played a strong role in driving the technology, and pioneering the development of bioplastics and market penetration in Indonesia.

Table 13 Within-case summary: CbagCo

Themes	**Descriptions**
Process	CbagCo created design and formulation and a prototype, developed machinery for bioplastic packaging, and had a scale-up trial with the converter from the same group in the corporation. Subsequently, CbagCo operated in a small scale production, selling the packaging and licensing to produce bioplastic packaging.
Joint activities	Formulation, many trials for prototyping and scale-up with the converter, provide advice/solutions for the converter, training the customer who buys the licensing.
Joint resources	Joint resources between the converter from the same group corporation: experts, machinery/equipment, resources related to trial: production facilities, personnel. External converter buys the machine and provides people to be trained.
Relationship management	Educate the customer, convincing the converter of the potential future of bioplastic packaging, supporting the customer: training, free to copy and reproduce machinery and transfer the plastic bag buyer to the converter, more towards transactional relationship.
Absorptive capacity	Acquire information to develop the raw material: knowledge in chemistry, mechanics, additive technology; information about the existing/similar product/development from various external sources.

	CbagCo led the product development, then provided training for the licence buyer; limited assimilation with co-innovation partner. Converter learned unique characteristics of the material, how to manufacture bioplastic packaging, and maintenance of the machinery. Limited accumulation of joint knowledge. CbagCo did not provide customisation; the converter improved the conversion process and machinery.
Outcomes	Biodegradable, compostable in natural environment (bury in soil), non-toxic to the environment, recyclable with paper.

4.4. FilmpackCo

FilmpackCo is a packaging converter located in the UK. The company manufactures various flexible packaging products, such as furniture bags, waste bags, mailing bags and types of film, from plastics and bioplastics material. FilmpackCo offers a biodegradable and recyclable packaging product range from sugar cane. FilmpackCo co-innovation was initiated by a significant number of customers enquiring about compostable solutions from the company. Responding to this request, FilmpackCo then conducted an initial assessment by visiting the customers' sites to gather information on the critical features of the process, and the potential for implementation into the customer's existing manufacturing process. Next, product trials following the project agreement were conducted. In this process, FilmpackCo did not add any technical aspect to the polymer but focused its expertise on implementing bioplastic packaging at the product manufacturer, suggesting the best technical options, such as thickness, and additive chemicals without compromising the biodegradability or compostability.

> *"We will maybe make that product as a trial, using our expertise to tell them... without destroying the compostability and so on." (TECHDIR-SC-001)*

TECHDIR-SC-001 implied that FilmpackCo would try to solve the problem whenever possible but if these issues could not be resolved, FilmpackCo would involve the biopolymer producer for solutions.

Joint activities in product development are interactively undertaken among FilmpackCo, its supplier and customer. FilmpackCo gave solutions to the customer, and was involved in trials both at the customer's site to ensure the polymer grade requested by the customer works on the machine, tweaked the settings or processes when necessary and intensively communicated with the customer and biopolymer producer. The biopolymer producer will act based on the request and feedback from both FilmpackCo and its customer, then give solutions for the processing condition and, if required, adjust the polymer or even make a new grade of polymer. FilmpackCo's customer usually accommodates new film characteristics, and makes the adjustments to their process based on FilmpackCo's suggestions, e.g., changing the machine settings.

> *"They will change some settings, so maybe accommodate the different seal characteristics of the compostable versus a standard film." (TECHDIR-SC-001)*

The resources from each partner included contribution for trials, sharing expertise and providing access to the existing production facility. FilmpackCo contributed their expertise, production facilities, and machine hours, and dedicated trials using a real production scale. The product manufacturer provided access for trials at their production facilities including the operational staff, and the biopolymer producer provided the bioplastic material, dedicated their expertise to give solutions, and if required, R&D resources were allocated to create a new blend of polymer.

> *"…using our expertise to tell them, what thickness they should be using, whether there's anything we can use, more additives to make it a little bit easier…" (TECHDIR-SC-001)*

> *"…engineer another grade or do perhaps a blend of formulations to enable that to work." (TECHDIR-SC-001)*

These resources consume large capital expenditures due to the complexity of the application and the many trials required for the real production scale. Thus, they become expenses for each converter, biopolymer producer and product manufacturer.

Surprisingly, business and transactional relationships are more dominant; the converter took the opportunity to market bioplastic packaging to the customers, while the customer was looking for an environmental solution. However, the relationship between the converter and the biopolymer producer has developed over time and become closer as the biopolymer producer was very committed to supporting FilmpackCo. Eventually, the opportunity to build a close collaboration would be more apparent when the supplier has outstanding credentials in that particular innovative product

> *"It's not a close collaboration." (TECHDIR-SC-001)*

> *"…FilmpackCo has probably been one of the biggest proponents of that over the last several years; we've got a very good relationship with Supplier BK." (TECHDIR-SC-001)*

TECHDIR-SC-001 mentioned that detailed technical information was acquired for the product development, such as specifications requested, specifications previously used, certain film properties such as slip and stiffness, manufacturing processes, machine speed, and other critical features that had direct implications for implementation in the customer's existing manufacturing. TECHDIR-SC-001 acquired as much feedback as possible from the product manufacturer, and critical information and new learning were obtained when conducting real scale product trials at the customer's plants, following discussion with their technical people. From these interactions, FilmpackCo accumulated new understanding about how to make the new materials work on the customer's machine and used the solutions for other customers, which would put FilmpackCo a step ahead of its competitors, as well as having a successful customer relationship.

> *"And well, the basic thing is that with all this feedback... we ended up with a product which we know will work for those processes, which at that time, probably nobody else had." (TECHDIR-SC-001)*

At this point, the outcome of co-innovation is the packaging at an acceptable price to the customer. This is achieved through managing the grade of biopolymer used that, even though it is more expensive than the conventional polymer, when applied to the packaging with a thinner or very small spread could be cost-neutral or increase the price to a reasonable degree for the customer's product. On the performance aspect, the biopolymer must be able to work on the converter and customer's existing manufacturing machine and process. However, adjustment is possible, to a certain degree, of the feasible cost that could be applied to the final product.

> *"…also trying to make it a lot thinner at the same time to offset some of the additional costs due to the density." (TECHDIR-SC-001)*

TECHDIR-SC-001 explained that market information and rising concerns on plastic pollution encourage co-innovation in bioplastic packaging, as product manufacturers look for environmentally friendly solutions for their products and the converters need to be able to offer a packaging solution. The motives for retaining the brand and protecting market share, due to the pressure of having an environmental responsibility, are clearly driving the high demand for bioplastic packaging. The key success to co-innovation is three-way collaboration among biopolymer producer, converter and product manufacturer. This mechanism enabled all partners to overcome the critical issue of making the new material work predominantly in the converter and product manufacturer’s existing machine and process.

> *“It's a three-way collaboration in you like... downstream and upstream. And yeah, that's quite successful.” (TECHDIR-SC-001)*

The other factors are the contribution of the supplier to give sustainable packaging solutions and commercial benefits, such as enhancing the product manufacturer’s brand, sustainability programme and innovation. Thus, adoption of bioplastic packaging at the product manufacturer requires a willingness to a certain degree to accept a higher cost, a lower performance than that of the conventional plastic and adjusting the process, all of which are compensated by increased commercial advantages from using the bioplastic packaging.

> *"We might even print a little logo on it that says, all compostable. So the appearance doesn't matter, if it smells or any, it doesn't matter, because they can say that's a compostable film. So kudos is involved and brand protection and brand enhancements." (TECHDIR-SC-001)*

Inferred from the converter's perspective, the converter played important roles as both the connector between biopolymer producer and product manufacturer, and influencer in the adoption of bioplastic packaging by the product manufacturer in the converter's network.

> *"We don't really bring much to that, other than to use these particular polymer solutions and promote them to our customers." (TECHDIR-SC-001)*

The biopolymer producer is the driver of innovation, which is similar to the innovation of oil-based polymer decades ago, while the product manufacturer tends to be the adopter, which is expected to be more cooperative and understanding of the complexity of the bioplastic packaging value chain; however, TECHDIR-SC-001 reflected that the industry leader was very demanding.

Table 14 Within-case summary: FilmpackCo

Themes	Descriptions
Process	Customer demand, initial assessment, initial product prototype, trials on customer's machine, adjustment and improvement, implementation.
Joint activities	Many trials, obtain feedback.
Joint resources	Expertise, raw material/polymer for trials, dedicated team/personnel, financial capital to develop/modify the material, resources related to trial: production facilities, machine hours, personnel, financial capital.
Relationship management	Business motives, address demand from customers, closer relationship with the biopolymer producer, product manufacturer is demanding.
Absorptive capacity	The supplier acquired information for developing a polymer that would work for the converter and product manufacturer's existing manufacturing processes; feedback. The customer looks for available technology/solution in the market. Assimilation during visiting the customer's plants, learning from the biopolymer producer's technical advice, discussions with product manufacturer's production staff, regular meetings, real scale product trials at the product manufacturer's plants. New understanding on how to use the new material, make it work on the customer's machine, market developments, current situation in the industry and the future potentials. Create a workable solution and implement a type of product to a broader customer range.
Outcomes	Feasible cost, work on the customer's machine and process; developing unique expertise and customer relationship, and become a market leader.

4.5. BarrierCo

BarrierCo is a packaging manufacturer located in the UK. This company produces barrier laminates for packaging to improve the functionality of the packaging. The product range includes conventional plastic packaging and sustainable packaging made from PLA. The sustainable packaging range is compostable and biodegradable, and available for liquid packaging, processed food, fresh food, and customised film packaging. With the rising interest in greener packaging, BarrierCo started a new project by forming a new team and collaborating with new suppliers and finally developing a breakthrough product range that is also well accepted by its customers.

TECHMAN-SC-0226 explained that the co-innovation was initiated by the PLA supplier and customers looking for sustainable film packaging.

> *"So, we have two PLA suppliers. So, we, we did a trial. So, we were approached by a prospective customer; he wanted a compostable lidding film." (TECHMAN-SC-0226)*

BarrierCo then started a product development project with the supplier. After conducting many trials and having the right parameter settings, the product was taken to the customer's plant for more trials. When the bioplastic packaging was ready for implementation, BarrierCo moved to the handover stage, presented the whole operation, gave detailed explanations of the technical aspects, and machine settings, and other aspects were provided for the customer's production operations to ensure the customer understands them, is able to work on their own and is satisfied with the result.

Joint activities mainly consist of many trials and creating a feedback loop for improvement to meet the customer's expectations. During trials, the biopolymer producer gave close support and advice on material handling and troubleshooting to the BarrierCo team.

> *"And then the next critical stage is production of the material… the trial and the feedback from the trial suggest in two instances the feedback initially for the customer in engaging what they want, but the feedback and from the trial itself is absolutely key." (TECHMAN-SC-0226)*

The feedback is imperative in understanding the scope of the project, listening to what customers actually want, and setting the direction for the next step of product development. Next, the resources put into collaboration from each partner were mainly related to trial activities. On the supplier side, the resources were the technical people and their expertise to resolve problems during the trials at BarrierCo. On the customer side, the resources dedicated to the co-innovation were the personnel, at least to run the trial at the customer's production facility and the machine time.

> *"But they'd be at least there be a technical involvement from their side. And then if it was something that's been trial on the machine, a bit, at least one or two to sort of operators or operatives or operations people…" (TECHMAN-SC-0226)*

TECHMAN-SC-0226 reflected on the experience and highlighted that the critical resources in co-innovation are the technology, production facility and the machine time for the trials.

> *"So, so I think from both sides from supplier onwards… technology and machinery resource, but also for the customer as well as their resource and their machine time." (TECHMAN-SC-0226)*

The BarrierCo case illustrated that the supplier-customer relationship started with a business motive to market the product and grew into a closer interaction in technical development.

> *"So, we would have to think, initially it'd be very much a commercial-led conversation and more sales, and then there would be technical involvement." (TECHMAN-SC-0226)*

According to TECHMAN-SC-0226, the key to maintaining the relationship with the customer and supplier was to keep regular communication to ensure the timescales of the deliverables and meet the customer's requirements. TECHMAN-SC-0226 also added the importance of feedback from the customer to be underlined with honesty.

The absorptive capacity was found to facilitate the co-innovation process. Acquisition of information to develop the product and manage the collaboration includes defining clear objectives of the project, specifications, a set of requirements such as the targeted barrier performance for different applications, working parameters, the tracked progress of the product development, problems and solutions, and changes needing to be made. Moreover, the most crucial information is feedback from the customers, which helps BarrierCo to understand what they want, improve the packaging and ensure the delivery meets the customer's expectations.

> *"A standard procedure is this the trial and the feedback from the trial suggests in two instances the feedback initially for the customer in engaging what they want, but the feedback and from the trial itself is absolutely key." (TECHMAN-SC-0226)*

The activities and routines to obtain information and learn were acquired throughout all the stages of co-innovation and carefully recorded to ensure each person involved in the project had the same understanding and were working on track. The important learning activities were the trials, through which BarrierCo and the customer learned from different situations, and overcame errors and failures. Recording mechanisms were refined over time to improve the usefulness of capturing key learning and improvement, then made into parameters for different applications and challenges and solutions for troubleshooting. The information was accumulated to produce data sheets that were useful for enhancing the product dimensions and would enable sales to different customers,

> *"From this information, the BarrierCo develops parameters based on the field experiences that can be used for different situations, solutions for different troubleshooting…" (TECHMAN-SC-0226)*

The outcome of co-innovation at BarrierCo is an innovative bioplastic packaging product range, such as clear film and metallised cellulose acetate film both of which have high barrier performance, anti-fog, clarity and comparable performances to conventional plastics. Nonetheless, with their successful experiences working with the previous customer, BarrierCo was quite confident in responding to a request for new applications, such as for fresh fish packaging. BarrierCo would expect the product could become a standard product and be widely used for the new industry.

> *"They want to use that product for smoked salmon, so we've got some trials that were as a result to them, I mean set up to, to test it out. And hopefully that will then become a standard product widely used in the wet salmon industry." (TECHMAN-SC-0226)*

TECHMAN-SC-0226 explained that the factor that leads to success is creating a transformational product portfolio that then creates sales. The products were successfully accepted by customers, not only in specific industries but were also applicable to different industries. Furthermore, in the plastic manufacturing industry, the market is the main driver, and all actions head towards meeting the market demand. However, TECHMAN-SC-0226 explained that the bioplastic packaging market is very immature, reluctant to change, and uncertainties are becoming a barrier.

> *"Yeah, I think so... Yeah. And then that, and then I'll say it makes it difficult for its reluctance to, to really jump on board with it. But then that's where having a very, very good product that makes the brief... So, so breaks those barriers down, as I always suggest." (TECHMAN-SC-0226)*

The dynamics during the co-innovation were illustrated by TECHMAN-SC-0226, highlighting challenges related to openness from the customer's side, in terms of sharing information and willingness to change. For example, TECHMAN-SC-0226 found that the customer did not want the BarrierCo personnel to be present when running production. Finally, BarrierCo also played a significant role in the co-innovation, contributing their unique barrier technology to improve the technical performance of the bioplastic packaging. BarrierCo expertise complemented the biopolymer producer expertise in bioplastic technology. On the other hand, the customer plays a vital role in sharing information about their requirements, manufacturing parameters that enabled BarrierCo to develop innovative bioplastic packaging.

Table 15 Within-case summary: BarrierCo

Themes	Descriptions
Process	Approaches from PLA supplier and customers, product development with the supplier, internal trials, trials at the customer, handover to the actual production, and final review.
Joint activities	Trials, obtain feedback from the customer, provide solutions for processing the material, share confidential information.
Joint resources	Technology, dedicated team for the project, engineers, resources related to trials: personnel, machinery and machine time.
Relationship management	Agreement and commitment, business motive then turns to closer interaction, regular communication, deliverable timeline, understanding the customer's needs, honesty.
Absorptive capacity	The converter acquires information regarding the project's objectives, specifications, working parameters, problems and solutions, a lot of feedback, updates after the handover, and any changes in the operations. BarrierCo learns from trials with the supplier and customer, advice and solution from the supplier, and thorough recording and database creation. New knowledge and understanding of the product parameters for different applications, solutions for various technical problems. Improves the product performance, adds more product range for wider markets.
Outcomes	An improved bioplastic packaging with innovative metallised high barrier properties and several other performances comparable to conventional plastics. Scale-up and expand the product range and market, becoming the standard product for the industry.

4.6. FoodpackCo

FoodpackCo is a UK packaging manufacturer specialising in flexible packaging and printed tapes, such as shrink sleeves, self-adhesive labels, and die-cut lids for applications in various industries. FoodpackCo serves business customers from the food and beverage industry, supplement and nutritional products, cosmetics and beauty products. In around 2017, FoodpackCo had developed bioplastic packaging by collaborating with PLA suppliers. Despite FoodpackCo not continuing the bioplastic packaging development, this case showed the mechanism of co-innovation between FoodpackCo as a converter with a biopolymer producer and several other suppliers, and reveals issues that led to the discontinuation of the development project.

FoodpackCo was interested in developing bioplastic after hearing positive press releases and reviews about the potential future of bioplastic packaging, particularly PLA, and expecting to keep up with the competition. Subsequently, FoodpackCo approached a biopolymer producer to enquire about and test the material. There were many problems during trials with the supplier, and the end product did not meet expectations. The main problem was the difficulty of applying bioplastic material to the existing manufacturing process. Therefore, FoodpackCo further observed the market for potential demand but found no sign of interest from the customers. Therefore, FoodpackCo did not continue the project.

> *"We waited to see if there was a demand. And there was there was no… we did several exhibitions. Nobody was really asking…" (ACCMAN-SC-0304)*

Interestingly, FoodpackCo did not involve the product manufacturers in co-innovation. FoodpackCo collaborated with the suppliers to develop viable products and later showed the product manufacturer if they had something interesting or a good result. To test whether the product worked at the customer's manufacturing, FoodpackCo either did an in-house trial because FoodpackCo had similar equipment, or tested the material at the machine supplier that sells similar equipment. ACCMAN-SC-0304 explained the position of FoodpackCo, as in between the product manufacturer and biopolymer producer, machine and ink suppliers; therefore, FoodpackCo, as a converter, played the role as the supplier and customer at the same time.

The joint activities were carried out mainly for prototyping and trials on the existing production machine. FoodpackCo and the suppliers discussed the required adjustments during the trial, such as ink or other material adjustments. Suppliers also provided support during the trial by sending a technician to FoodpackCo's site or providing solutions for the material to work in the existing conversion process. ACCMAN-SC-0304 emphasised that bioplastic packaging was processed by the existing conventional plastic manufacturing, hence joint resources were limited;

> *"So the… you don't need any new. So, all the development work is to do the same process with a different material." (ACCMAN-SC-0304)*

All partners were contributing resources for the trials by using the existing resources. The supplier provided raw material without charge, technical support and sent a technician to give the required assistance during the trial at FoodpackCo's site. On the other hand, FoodpackCo contributed the machine time that included the production overhead cost. ACCMAN-SC-0304 considered these costs were more substantial than the raw material at the supplier's expense. Nevertheless, co-innovation in FoodpackCo was carried out with PLA suppliers, printers, ink and machine suppliers, and after having developed a viable bioplastic packaging, FoodpackCo planned to present it to the product manufacturer.

> *"We don't involve the product we didn't involve the product manufacturer. We tested to see if we have something interesting to show the product manufacturer…" (ACCMAN-SC-0304)*

FoodpackCo case did not exhibit a relatively strong absorptive capacity in the bioplastic packaging development. As inferred from the case, the supplier learned from trials about the new bioplastic material and its application on the existing production machine. While FoodpackCo, as the customer, gave feedback to the biopolymer producer about problems during the trials and the product outcome, which was not as expected, then asked the biopolymer producer to improve the material.

> *"…we give the feedback to the producer. One, the clarity is not so good, the printing is not as good. And the shrink was not as good… we said to them, we need a better, better material." (ACCMAN-SC-0304)*

Co-innovation with the supplier had facilitated a further understanding of bioplastic packaging. ACCMAN-SC-0304 explained that at that time, bioplastic packaging was being developed but not enough to cope with FoodpackCo's complex packaging conversion process nor deliver the expected outcome. Problems like longer processing time, printing results, seaming and clarity of the shrink sleeves, including the price, were added to the list of considerations for not continuing the development. Eventually, FoodpackCo learned that (at that time) market demand and the development state of bioplastic material were not sufficient to meet the company's expectations; and these led to the decision to discontinue.

ACCMAN-SC-0304 saw that the bioplastics worked for simple packaging, but the technology was not enough to work with complex packaging, such as shrink sleeves or layered packaging.

> *"We thought that the product was very new and not developed. So it's okay for simple packaging, but not for complicated." (ACCMAN-SC-0304)*

At that time, FoodpackCo had not yet succeeded in developing bioplastic packaging, but ACCMAN-SC-0304 shared some crucial points in developing bioplastic packaging. First, the development of bioplastic materials must pay attention to the variety of packaging features needed, the complexity of the processing and application in existing systems in different industries. ACCMAN-SC-0304 added the need to improve the biodegradability of bioplastic packaging, which not only works in industrial composting but also home composting. Another option is to improve biodegradability at the landfill, such as when trapped without oxygen, moisture, or facing different conditions.

ACCMAN-SC-0304 emphasised that the essence of bioplastic development projects is doing the same process but using new materials; hence it is also important that co-innovation enables the bioplastic to work in the same process or system.

> *"So… you don't need any new. So, all the development work is to do the same process with a different material. The new material/packaging works in the customer's existing system." (ACCMAN-SC-0304)*

Based on FoodpackCo's experience, the price factor is a driver for customers to use bioplastic. ACCMAN-SC-0304 stated that if bioplastics do not work and the price is high, the development will be slow.

Table 16 Within-case summary: FoodpackCo

Themes	Descriptions
Process	Approach to the supplier, initial assessment, internal R&D for the early product development stage, initial prototype and trials, observe demand, and discontinue the project. FoodpackCo will approach the product manufacturer after having created a successful prototype or viable sample.
Joint activities	Biopolymer producer gives solution to processing condition, many trials and feedback, converter adjusts design and manufacturing tools.
Joint resources	Biopolymer producer provides a dedicated team and supplies the biopolymer for trial free of charge. The converter buys new tooling or equipment parts, gives access to the production facility and other resources for trials, while there is no joint investment.
Relationship management	FoodpackCo did not work with the product manufacturer in testing the material and will approach the product manufacturer after having created a viable sample.
Absorptive capacity	Acquire customer's feedback and more details on the feasibility, demand and other commercial aspects. Assimilation occurs during trials; FoodpackCo learns from feedbacks. Accumulate understanding of the market situation and opportunities in the future. With these understandings, FoodpackCo determines the continuation or priority for co-innovation in developing bioplastic packaging.
Outcomes	Not successful, the bioplastic technology cannot cope with complex packaging production processes due to technical problems for shrink sleeves application, low efficiency during processing, and more expensive material cost.

4.7. BiopackCo

BiopackCo is a packaging manufacturer specialising in biodegradable, compostable and water-soluble bioplastic packaging in the UK, and was established in 2007. This company also provides technical assistance and consultancy related to product design, converting processes, trials, regulation and testing advice. BiopackCo products are made from several types of bioplastic such as PVOH, PLA, cellulose-based, and green PE from sugar cane. Water-soluble is one of the advanced features of BiopackCo products; the compostable products conform to the EN13432 standard, and some are also home compostable. BiopackCo products have an excellent performance, such as gloss, transparency, and high stretch like conventional packaging, and certain products, for example, the padded envelope made of FSC paper and with a bubble wrap lining, are considerably more durable than the ones made from conventional plastics.

BiopackCo co-innovation started from the customer approaching BiopackCo to enquire about and explore the possibility of using the available bioplastic packaging product range or developing new bioplastic packaging with BiopackCo. Next, both parties conducted an initial assessment, an essential stage of co-innovation, where BiopackCo and the customer assessed the availability of converting equipment, communicated the expectations and estimated the price before starting the development project. The development of new products at BiopackCo always started with a trial on a small scale and then gradually scaled up to full-scale production trials.

> *"How the material is going to be converted, it depends on the bioplastic. Some are easier than others, but you always have to be aware of the equipment that's going to take the bioplastic from raw material form through to the finished goods…" (DIR-SC-0515)*

Joint activities involved mainly the product trials, following an agreed trial plan. There were many problems encountered, and feedback loops were essential to resolve issues. Feedback was usually related to the technical performance during processing the material in the existing production facility. Trials in full production scale were conducted at the customer's production facility at the later development stage. Sometimes the converter and biopolymer producer were present during the trials to give immediate advice and solutions to a particular condition

“So if you’re making the product and for some reason you say that the material isn’t behaving properly or it’s not doing what it wanted to do, the supplier can come in and, you know, advise, that is also a good thing because actually they can see what’s happening.” (DIR-SC-0515)

Problems were usually related to how the material could work at the existing production facility. Accordingly, mutual adaptation occurred where the converter and biopolymer producer resolved these issues by adjusting existing production processes at the converter and product manufacturer’s plant, or adjusting the material.

Joint resources in the BiopackCo case are predominantly the resources contributed to the trials at the converter and product manufacturer’s plant, such as raw materials, people, and equipment. While the customer’s resources were quite limited and most customers were focused on deliverables instead.

“Resources from the customer? Hmm. Quite often not. They’ll go into results...” (DIR-SC-0515)

As the bioplastic packaging must run in the existing production equipment, the availability of equipment that can work with bioplastic is critical in co-innovation, but this could be complicated because equipment specifications vary depending on the type of bioplastic packaging developed. Moreover, based on the DIR-SC-0515 experience, the converter does not want to invest in a new prime machine, for example, an extruder, moulder or new press, because it requires significant financial capital.

“They may have to invest in new tooling. So a different dye bowl… the main machine the prime machine is important that they don’t have to change that.” (DIR-SC-0515)

DIR-SC-0515 explained that there is currently no shared investment to build shared facilities. However, DIR-SC-0515 added that sharing non-financial resources such as expertise, bioplastic technology, and information were crucial for product development.

DIR-SC-0515 considered the relationship between partners in co-innovation as quite a close one because there is much discussion in product development, and each partner shares confidential information. Also, interdependence was linked to their role as suppliers and customers in the supply chain.

“There is always there always is always quite a lot of discussion that goes on. So it’s quite a close relationship…” (DIR-SC-0515)

According to DIR-SC-0515, some customers are willing to work together to face problems during product development, but others are quite demanding. At the beginning of the project, excellent communication with customers was needed to educate users and manage expectations. Customers needed to know about the bioplastic packaging in the market and which one is commercially available to meet their needs. In addition, a confidentiality agreement is needed to regulate the sharing and use of specific information and IPs created from the project.

Furthermore, BiopackCo's absorptive capacity was present during co-innovation. DIR-SC-0515 explained how BiopackCo connected detailed packaging specifications requested by the customer with material specification information from suppliers, such as technical properties, food contact approval, biodegradability, degradation process, and degradation time.

> *"From the supplier, what you need is the data on the raw material …By acquiring all that information, then you can put the two together and see what's suitable and what isn't." (DIR-SC-0515)*

Further information from the customer included the critical features of the customer's manufacturing process and equipment, which was acquired through a standard questionnaire. As a result, BiopackCo accumulated experience to meet the customer's detailed specification, further understanding the various parameters that include suitable equipment for each bioplastic material and material characteristics needing to be more manageable to process. This knowledge was implemented for the next product development to improve the existing product and serve a broader customer base.

Through co-innovation, BiopackCo created a variety of packaging, ranging from simple films and bubble wrap to complex, layered bioplastic packaging with performance similar to conventional plastic that were easily processed by the customer's existing standard equipment. However, the final price was still a concern as the price of bioplastic packaging was around three times that of regular packaging.

Based on the experience of DIR-SC-0515, the key to successful co-innovation was to have a bioplastic material that was easy to use in the customer's production process.

"That's really the main focus is to try and get a bioplastic to run on existing equipment rather than having to design a new piece of equipment. That really doesn't work." (DIR-SC-0515)

"So the key to success is producing something that the consumer can easily use and easily understand. So you don't want to make anything that's too difficult to deal with at the end of the day." (DIR-SC-0515)

DIR-SC-0515 added the importance of a willingness from the customer to understand the limitations of bioplastic, work towards resolutions and accept a reasonably higher price. Despite some business customers wanting to develop bioplastic packaging just because they want to show some contributions to the environment, DIR-SC-0515 also added that currently, the general public is interested in bioplastic packaging, which could be the driver of further development.

"…it's tick their environmental box. Really, they're not that keen about doing it, rather not have it at all." (DIR-SC-0515)

The role of each partner in co-innovation is related to their position in the supply chain. BiopackCo is a converter playing the role of a connector to fit in between the available biopolymer material from the supplier and what the product manufacturer wants. DIR-SC-0515 explained that a biopolymer producer often did not know what the converter and product manufacturer want, whilst the product manufacturer did not know what commercially available bioplastics there were to fulfil their needs, expectations and production capacity.

"The resin manufacturers don't always know what converters want or that the customer wants. From the customer, they don't know what's available and how to get that. So really we try to fit in between…" (DIR-SC-0515)

Table 17 Within-case summary: BiopackCo

Themes	Descriptions
Process	Request from the customer, initial assessment, initial prototype and trials, feedback and improvement, trials at the customer's facility
Joint activities	Many trials following an agreed trial plan, feedback loop, provide advice/solution to the product manufacturer, mutual adaptation.
Joint resources	Share expertise, resources related to trial: access to production facilities, personnel, machine hours, raw material/polymer from the biopolymer producer. It is crucial to ensure the availability of equipment/machinery that works with the bioplastic material.
Relationship management	Agreement and commitment to the project, intensive communication at the beginning of the project, managing expectation, educating users, openness, a relatively close relationship. Some product manufacturers are quite demanding.

Absorptive capacity	Acquire detailed information about the material specifications, critical features of the customer's existing processes, technical working parameters, also regular updates about the existing/similar product/development from various external sources. Assimilation occurs during many trials and implementations, especially when all partners are present. Learn from feedbacks. Accumulated understanding and experience to meet customer quality standards, work with the bioplastic material/packaging in various parameters: equipment, material characteristics, various problems and solutions. Improve the existing bioplastic packaging and product offering for the customers, plan for the next product development.
Outcomes	Improve the packaging quality: high gloss and transparency, layered packaging. The product manufacturer is willing to accept a higher cost of the packaging within a reasonable/affordable price range.

4.8. DrinkCo

DrinkCo is a multinational producer of food and beverage products, operating globally, including in Indonesia. DrinkCo is one of the market leaders for food and beverage products in Indonesia, with superior products such as bottled drinking water, fresh milk and essential nutrition. DrinkCo set a roadmap to sustainable development and circular economy, which included increasing recycling and moving towards net-zero carbon. DrinkCo has an ongoing co-innovation with a biopolymer producer, developing recyclable bio-based packaging, PEF, or Polyethylene Furanoate for PET-based packaging such as water bottles.

SUSDIR-C-1106 explained that the objective of the development was to acquire 100% access to bioplastic technology; therefore, they formed a dedicated team to search for and understand the bioplastic technology available in the market; then made a collaborative approach to several potential partners.

> *"... the team tries to understand the available technology ... what's available in the market ... our target is to have 100 percent access to the material ..." (SUSDIR-C-1106.Quo1)*

Furthermore, DrinkCo conducted an initial assessment of the potential development of bioplastic materials with several partners, i.e., start-up companies in the US and Europe. The next stage was to develop an initial product prototype, which involves a lot of trials with partners. The overall development of bioplastic material is quite long, approximately between three and five years, broken down into shorter stages. In the end, DrinkCo would manufacture the packaging, and the external converters, which were in partnership with DrinkCo, would be able to access the biopolymer only when needed to cover DrinkCo's capacity.

> *"Because the output will be in the form of resin. The option for us is to produce ourselves ... if we don't have the capacity, enough capacity, we will be partnering with other companies; therefore they can also access the raw materials." (SUSDIR-C-1106.Quo6)*

Joint activities between DrinkCo and the biopolymer producer in developing a breakthrough material includes many trials, starting from lab-scale then gradually increasing to industrial scale. SUSDIR-C-1106 explained that DrinkCo provided information and feedback regarding the application of the material to meet DrinkCo's industrial standards.

> *"How the materials that they developed when applied for industrial ... Does it meet the specifications defined by DrinkCo as an industry?" (SUSDIR-C-1106.Quo8)*

The mutual adaptation from DrinkCo could be seen in the tolerance given when the overall impact is minor and to a certain extent offset with other benefits, such as reduced carbon emissions.

Co-innovation between DrinkCo and the biopolymer producer involved investment from both parties. SUSDIR-C-1106 explained that DrinkCo's partner is a biotechnology provider, a start-up company; therefore, their resources are technology and expertise in biopolymer development. SUSDIR-C-1106 stated that DrinkCo provided significant financial capital to fund research, built lab and trial facilities specifically to develop this material and this was sufficient to bind each party to maintain cooperation. Another resource from DrinkCo was to provide a pilot plant for testing the conversion of small-scale biopolymers into plastic bottles and a man-hour for trials.

> *"The facilities are specially built… definitely, to develop at the lab scale, there must be dedicated facility built for that." (SUSDIR-C-1106.Quo13)*

> *"It has to bring the advantage that we can convert to commercial, to be honest ... convert via carbon trade or something ...but at the end, it has to be competitive." (SUSDIR-C-1106.Quo24)*

From the environmental side, SUSDIR-C-1106 explained DrinkCo's commitment to packaging using recyclable, reusable or compostable in 2025. In line with this, SUSDIR-C-1106 explained that co-innovation in developing bioplastic packaging would look for innovation in plant-based or non-fossil-based materials, which would later have similar technical properties to PET, recyclable, but not compostable or biodegradable. According to SUSDIR-C-1106, one of the materials used was derived from used paperboard and from biogas, molasses.

Furthermore, the relationship between DrinkCo and its partners was managed through a framework agreement, which SUSDIR-C-1106 considered to be the key factor, governing a fair collaboration mechanism, compliance with regulation, joint ownership of IPs, scaling-up plans, and the possibility of engaging with other partners. SUSDIR-C-1106 explained that partner selection is crucial, where DrinkCo will identify collaboration partners based on assessment criteria for scalability, readiness, cost, investment in the project, the right to access and use the material, compliance with various regulations and the market potential of this material in the future.

The DrinkCo case shows supplier-customer absorptive capacity, especially in accumulating joint knowledge that benefits both partners. Learning between partners occurred through discussion and trial. DrinkCo learned a lot from partners about the options of new materials, new technology, and material characteristics that include machinability, properties, and comparison with existing material.

> *"Then from our side, off course we learn this is new technology, new material, which we will always compare with the existing." (SUSDIR-C-1106.Quo8)*

On the other side, the biopolymer producer learned about the industry, such as applying the material at DrinkCo's industrial manufacturing site, producing the material on a bigger scale, commercialising the material, logistics, and supply chain.

> *"... they will learn more about ... industrial related topics ... what would it be at the industrial application ...Does it meet the specifications defined by DrinkCo as an industry ..." (SUSDIR-C-1106. Quo8)*

SUSDIR-C-1106 emphasised that both DrinkCo and partner learned equally and the new knowledge is then used as a reference to explore new technology; the potential is for DrinkCo to have access to such technology, also to improve the material being developed.

Co-innovation is currently underway, and DrinkCo has targeted the technical performance to be as good as that of conventional plastic, and most importantly, the new bioplastic packaging must not affect the product quality.

> *"We're not letting the new material after being developed affect the product quality. We can say that that is a failure... "(SUSDIR-C-1106.Quo9)*

SUSDIR-C-1106 emphasised that cost is crucial and a key indicator of the success of co-innovation. If the target cost is not achieved, then there must be an offset with other benefits that can be commercially equalised, such as reducing carbon emissions, which is also pursued by most companies.

SUSDIR-C-1106 emphasised that the first key to success is partner selection and officially agreeing on the terms and conditions as well as the target deliverables in the co-innovation. In addition, SUSDIR-C-1106 explained the importance of delivering the expected technology and aligning the packaging cost as the key success to co-innovation. Moreover, from the interview with SUSDIR-C-1106, it can be concluded that regulation is the driver for bioplastic packaging development, especially the one that encourages the use of bioplastic materials as packaging materials, for example, a mandatory or recommended requirement for carbon reduction in Indonesia. SUSDIR-C-1106 also added the need to develop end-of-life packaging standards that suit the infrastructure of a country.

> *"We must ensure that it is degradable to nature… considering the infrastructure available in a country ...for example, PLA; that is possible in Europe..." (SUSDIR-C-1106.Quo26)*

And ultimately, the material must be competitive in the market in the long-term, for example, ten years, and provide a commercial advantage, not limited to cost, but in a broader sense in the form of other environmental contributions.

From the interview with SUSDIR-C-1106, it can be concluded that the biopolymer producer as a DrinkCo partner acts as the technical expert, who also drives the innovation for DrinkCo. On the other hand, as indirectly inferred from SUSDIR-C-1106's statement, DrinkCo as a product manufacturer and industry leader, guided the R&D, set expectations and specifications to be met, then developed the material with the biopolymer producer.

Table 18 Within-case summary: DrinkCo

Themes	**Descriptions**
Process	Approach to supplier, initial assessment, partner selection, partnership agreement, product development and trials: lab scale, pilot, scale-up, and implementation.

Joint activities	Many trials and give feedback to the biopolymer producer, mutual adaptation and tolerance in several aspects with exception to those affecting the main product quality.
Joint resources	Complementary expertise, financial capital for running the co-innovation research, and building new infrastructure: lab, pilot plant; machine hours; personnel: multi-functional team, resources related to trials in the company and customer's plants.
Relationship management	Agreement and commitment, non-disclosure agreement. The product manufacturer invites other partners to support the project, defines comprehensive requirements for bioplastic packaging and relatively demanding.
Absorptive capacity	The biopolymer producer acquires information on the industrial aspects, which is highly relevant for improving the material and scale-up. The product manufacturer gathers updates on the recent technology and solutions, regulation and law, thorough information on potential partners and their scale-up capability. Assimilation occurs through regular meetings, discussions and trials. The biopolymer producer has a new understanding of the industrial aspects, scale-up, how to make the new materials work on the converter and product manufacturer's machine. The product manufacturer has a better understanding of the new technology, market situation and opportunities in the future. Possibilities for innovation, explore more advanced technology.
Outcomes	Improve material and packaging that suits product manufacturer complex requirements, implementation at the product manufacturer, align the higher packaging cost with commercial benefits. Other outcomes: joint intellectual properties, unique expertise/innovation, exclusivity, scale-up, sustainable agenda, to be the market leader.

4.9. NutriCo

NutriCo is one of the largest food and beverage producers running a global operation, and one of its business units operates in Indonesia. NutriCo's products include infant formulas, cereals, dairy products, chocolate, coffee, ready to drink & bottled water, health nutrition, pet care and many more, marketed using various brands. NutriCo is strongly focused on achieving 100% recyclable or reusable packaging and zero waste as part of its sustainability commitment. NutriCo invested considerable resources in development projects for developing bioplastic packaging from a mix of plant-based material for PET bottles, which was then launched as one of its premium products in Italy. NutriCo also collaborated with an external biotech start-up and two other product manufacturers in developing bioplastic packaging to replace conventional PET bottles planned to be launched in several countries for drinking water units.

HOPACK-C-1207 added that business units, such as NutriCo Indonesia were not directly involved in the development of bioplastic packaging, and described the packaging development process that applies in general at NutriCo, starting from initial assessment and partner selection, technical development, lab scale, scale-up to industrial scale, manufacturing materials and implementation into manufacturing. Validation and a rigid quality check is included in each process. All partners involved in development are bound by a non-disclosure agreement (NDA). NutriCo owns an in-house packaging R&D centre capable of developing materials and has a broad understanding of material science, sustainability, and environmental impact. Hence co-innovation was carried out with partners who complement NutriCo's capability, closing the knowledge and technology gap.

> *"A partner who can close the gap on the knowledge or technology that we've got, because we also have an in-house knowledge, we want complementarity from the external partners." (HOPACK-C-1207.Quo10)*

HOPACK-C-1207 explained that the ongoing material development project started from concept and ended with materialisation and thus required enormous resources; therefore, NutriCo collaborated with other product manufacturers to provide significant financial capital for the development project.

> *"Moreover, this is starting from scratch ... So it will need substantial funds to develop until it can be materialised, that's why engage with partners that can provide funds." (HOPACK-C-1207.Quo11)*

NutriCo Indonesia once explored partnerships with local start-ups to develop bioplastic packaging in Indonesia. NutriCo conducted internal research and an initial assessment of one of the start-ups that has achieved international recognition. The factors considered in partner selection were the suitability of the product concept to NutriCo's vision and mission, and the partner's capability to meet the required performance. However, the assessment revealed that, despite the packaging being edible and biodegradable, the seaweed-based packaging to be developed was difficult to convert, did not meet the protection requirement, and did not quite fit the NutriCo packaging roadmap, which prioritised recyclable or reusable packaging.

> *"From Indonesia, there are those who develop material from seaweed, to become plastic, but it is still in a very early stage..." (HOPACK-C-1207.Quo5)*

> *"Cross-checked with our R&D, it turned out not quite positive in the sense that seaweed is difficult to be made into plastic for packaging, it's difficult. Because we are targeting recyclable or reusable..." (HOPACK-C-1207.Quo6)*

HOPACK-C-1207 was involved in the trial of PLA shrink wrap for NutriCo Indonesia following direction from HQ but did not involve the partner directly in co-innovation.

HOPACK-C-1207 explained that the business unit was involved in the development to provide information about existing material and machine specifications, thus enabling the materials to be developed, to work within the existing manufacturing process and perform as well as the existing plastic films. Feedback was submitted to the head office at the beginning of the development stage, then forwarded to the material supplier. After reaching a certain stage, the business unit received instructions from the head office for a trial. HOPACK-C-1207 described the adaptations made by NutriCo included adjusting engine settings and operating parameters, and replacing spare parts.

HOPACK-C-1207 was also involved in the PLA shrink wrap trial phase at the business unit level and recalled several constraints, such as procurement of material samples, which took a long time because the material was still under development. According to HOPACK-C-1207, the biopolymer producer did not have a standard material ready for trial and was at the same time learning to produce the sample following the requirement and specifications from NutriCo. When the sample was finished and tested, the material did not perform well, even though NutriCo had made adjustments.

> *"... They were still learning to produce the sample according to the expected performance." (HOPACK-C-1207.Quo12)*

HOPACK-C-1207 noted several factors as causing the failure of co-innovation. First, the material failed to reach key technical performance requirements due to technological limitations. The PLA shrink did not produce barrier properties, which were vital to protect the product. This was non-negotiable for NutriCo because the PLA's failure to protect the product will risk the quality of NutriCo's products, which are mostly known as the market leaders. Second, the material was difficult to process on existing machines. Finally, the industry in Indonesia was not ready for bioplastic packaging due to several challenges, such as price and market, infrastructure for collection, waste sorting and regulations.

According to HOPACK-C-1207, a higher cost was actually acceptable for NutriCo because the new packaging contributed to the sustainability agenda. However, it would be difficult for most businesses in Indonesia to accept higher costs because consumers were sensitive to price and prefer cheap products in small packaging, such as instant coffee in sachets, which are priced at IDR 1,000 or approximately GBP 0.50. The other challenges in Indonesia are the regulations and limited infrastructure. HOPACK-C-1207 described how Indonesia prioritises waste and recycling issues, but there was no specific agenda for bioplastic packaging. HOPACK-C-1207 added that NutriCo carefully considers developing bioplastic packaging, especially biodegradable ones and constantly compares the LCA with previous plastic packaging.

> *"NutriCo is very cautious to develop biodegradable materials including bioplastics… we should always consult to central office." (HOPACK-C-1207.Quo10)*

NutriCo case presents the biopolymer producer role as the expert who drives innovation at the early stages of material development, such as concept development and lab-scale trials. NutriCo, as an industry leader, indirectly drives material development by setting expectations to be met, such as quality and performance specifications and the capabilities of partners who can serve needs on an industrial scale.

Table 19 Within-case summary: NutriCo

Themes	Descriptions
Process	Partner selection, initial assessment, initial product prototype, adjustment and improvement, validation and quality check.
Joint activities	Concept exploration of the packaging, mutual adaptation: product manufacturer would change the machine spare parts and settings, involvement in an extensive co-innovation project from the material development to scale-up of the packaging production.
Joint resources	Share complementary expertise and capabilities, dedicated team. In the extensive co-innovation project, the biopolymer producer shares expertise and technology, while the product manufacturer provides financial capital to develop or modify the material.
Relationship management	Agreement and commitment, non-disclosure agreement. The product manufacturer invites other partners to join in the extensive co-innovation project.
Absorptive capacity	The product manufacturer acquires details of the potential partners: feasibility and capability to scale-up; the biopolymer producer needs to know the critical features of the customer's process. Assimilations occur during the discussion and feedback loop. The product manufacturer learns how to work with the new material. The biopolymer producer could develop or improve the material.
Outcomes	Unsuccessful implementation for shrink sleeves due to technical limitations, lower performance than conventional plastics whilst the cost was not feasible. From the extensive co-innovation project, the product manufacturer expects to receive a bio-based packaging with similar performance to the conventional plastic bottle, higher cost but counterbalanced with commercial benefits and contributions to the product manufacturer's sustainability agenda.

4.10. CoffeeCo

CoffeeCo is a UK-based start-up which at the beginning, sold compostable coffee pods from a third-party supplier, then started to develop new home compostable materials made from the coffee husk, bamboo and rice husk. The CoffeeCo case presents a unique view, illustrating a product manufacturer as a business customer, expanding to bioplastic technology development through co-innovation with its suppliers.

In the beginning, internal R&D processes were conducted for concept development and initial prototypes. CoffeeCo founders started to leverage knowledge about coffee, food packaging, compostable material alternatives, defined material specifications and building a network. COFOUND-C-0107 explained that this process was challenging as there were limited materials available in the market that could tick all the required specifications, including technical, engineering, production, logistics and final product specifications. Therefore, CoffeeCo viewed this as an opportunity and started developing innovative bioplastic material to fill the gap.

> *"And not all of them have, for example, low oxygen permeability, water resistance, or temperature resistance, all of which you need for food packaging product, and that includes coffee pods. And so what we started doing is working with blends of materials …and to try and address that." (COFOUND-C-0107).*

Subsequently, CoffeeCo started with a small-scale initial product prototype, experimenting with single and blends of materials, including coffee husk, bamboo, rice husk, and combinations. Additive materials were also used in the blends to achieve desired material properties to make it work in the conversion process and at the consumer's coffee machine.

COFOUND-C-0107 explained joint activities in the current partnership with the polymer producer and converter covered the main activities such as trials, improvements and production. The biopolymer producer supplied the raw material and provided support during the development process regarding the compatibility of the material with the packaging production machinery and consumer's coffee machine. They also helped modify the material compound that improved the material properties.

> *"When we want to make the product or tweak the material, we consult our manufacturing partners." (COFOUND-C-0107)*

COFOUND-C-0107 confirmed that CoffeeCo did not have any joint investment with the supplier. The resources for the material development were mainly from CoffeeCo, and the supplier leased the production machine and the injection moulding. The partnership started as transactional, where the machine supplier provided access to the machine for testing the prototype; CoffeeCo provided the material specification and design to the supplier to produce, then CoffeeCo would pay as per contract and agreement.

> *"We lease their equipment or we contract out some production work to them, and mostly for prototyping recently." (COFOUND-C-0107)*

The partnership was made following a partnership agreement, such as a leasing agreement, which includes the production work, non-disclosure, non-solicitation, non-circumvent and non-competing agreement; all responsibilities from both sides were regulated. CoffeeCo acknowledged that the partnership has grown closer over time, and CoffeeCo plans to build a joint venture to develop CoffeeCo new material as joint IP.

> *"We don't have any joint investment with the suppliers, we do have manufacturing partnership contract contracts. So these are sort of a, an agreement to enter in on to this project collaboratively…" (COFOUND-C-0107)*

> *"…we may be launching* a *joint venture, and we might be filing for joint intellectual property rights as well. And since we're working on this product together..." (COFOUND-C-0107)*

CoffeeCo had limited understanding when starting the business because the founders did not have backgrounds in sustainable packaging and coffee. COFOUND-C-0107 explained that the founders first acquired knowledge about the material, such as the material available in the market, its performance and the extent to which it suits food packaging, and that the best way to learn is from trials and iterations. Failures were inevitable, and each iteration meant that CoffeeCo accumulated an understanding of the design and material features, concluding with the impact of changes and modifications to the design and other parameters. CoffeeCo also learned about the market situations and opportunities in which only a few home-compostable materials actually work, but not all of them were compatible with food packaging.

CoffeeCo targeted the outcome from bioplastic packaging co-innovation as being to create innovative coffee pods from plant-based materials, coffee husk, bamboo, rice husk or combined material, that are also home compostable, taking up to 20 weeks to degrade completely. From the performance aspect, the material must have several key properties, such as mechanical properties and heat resistance, which enable efficient processing in both the injection moulding machine and the consumer's coffee machine. For food packaging, barrier properties and low oxygen permeability are essential to protect and maintain the freshness of the product. In addition, cost efficiency was achieved through efficient processing by selecting materials that can be extracted from plants without a lengthy process and choosing the most efficient packaging conversion. COFOUND-C-0107 explained that injection moulding was chosen because it is considered the most feasible for efficient processing and mass-scale production; therefore, the material is developed to be compatible with this manufacturing process.

> *"And so we can get our unit costs really, really low. And we can make, you know, we can go from hundreds of 1000s of units to 10s of millions of units quite quickly and quite cost effectively as well." (COFOUND-C-0107)*

COFOUND-C-0107 mentioned that the collaboration with CoffeeCo's manufacturing partners was also intended for scaling-up, which was planned to reach several million units within a couple of years.

The key to success in material development is creating innovative bioplastic materials that, according to COFOUND-C-0107, 'tick all the boxes' to meet comprehensive work specifications, including working on conventional plastic injection moulding, compatibility with several coffee machine brands, having high protection properties that preserve the product quality until it reaches the consumers, and being home compostable within the targeted time. Furthermore, markets and growing demand are the main drivers for the development of sustainable products, including bioplastic packaging. In fact, according to COFOUND-C-0107, using sustainable packaging is not a selling point, even though there is currently massive growth for sustainable products and packaging.

> *"… We've found that, that sustainability isn't really a big selling point for a lot of customers… But I think ultimately, people act in their self-interest. And that means that what will really help you sell product is a good quality, and things like consistency as well." (COFOUND-C-0107)*

According to COFOUND-C-0107, most consumers prioritise quality and price; hence to increase sustainable packaging growth, products that use bioplastic packaging must still prioritise these aspects to encourage more consumers to use sustainable products on a large scale and thus create a positive impact on the environment.

This case presents CoffeeCo as a product manufacturer or business user who uses the bioplastic packaging for the product, has comprehensive requirements and specifications to be met. However, CoffeeCo expanded its operation to develop bioplastic material due to the limited material availability that fulfils their need, and therefore CoffeeCo also plays the role of biopolymer producer. The dynamics in the bioplastic packaging development were illustrated during the process, especially during iterations in developing bioplastic coffee pods. CoffeeCo has two partnerships with the supplier, both started as transactional, where the suppliers supply the material and lease the injection moulding machine. The collaboration with the biopolymer producer grew closer as the supplier intensively helped CoffeeCo during the material development process. Accordingly, CoffeeCo considered establishing a joint venture and arranged a joint intellectual property right for the new bioplastic material developed with the material supplier.

Table 20 Within-case summary: CoffeeCo

Themes	Descriptions
Process	Approach to the supplier, initial assessment, partner selection, validation & quality check. Expand its operation to material development, conducting an internal R&D for the early material development.
Joint activities	The biopolymer producer gives solutions to processing conditions during internal development, mutual adaptation: biopolymer producer adjusts the polymer; the product manufacturer would not tolerate packaging that affects the main product’s quality.
Joint resources	The biopolymer producer’s expertise, the converter’s machine for trial, financial capital to develop or modify the material, no joint investment for tangible assets.
Relationship management	Agreement and commitment, co-innovation started as a transactional relationship and grew into a joint venture, formal contract, non-disclosure agreement.
Absorptive capacity	Acquire information about available technology or solution in the market, information for designing the packaging and its commercial aspects. Assimilation occurs during trials, learn from literature or previous research to obtain ideas for developing the material.

	Product manufacturer learns how to work with the new material, the importance of quality control, and better understand the market situation. To optimise quality control, to develop or improve the material.
Outcomes	New material derived from a renewable source, biomass, is designed to be cost-effective through efficient processing, compatible with the business customer and the consumer's machine processing, also would reduce carbon footprint. Other outcomes: expected to scale-up to an industrial scale.

4.11. ChocolateCo

ChocolateCo is a small business in the UK that produces and sells premium hand-made chocolate bars. ChocolateCo was founded in 2009 by an entrepreneur who has a strong interest in healthy food and the environment. Accordingly, ChocolateCo products are vegan, made from raw cacao from an ethically grown source, and use plastic-free packaging as ChocolateCo uses plant-based compostable packaging. ChocolateCo products are sold online on the company's website and several other websites, mostly selling vegan, healthy food, plastic-free, eco-friendly or natural products.

ChocolateCo packaging consisted of an inner packaging made of a flexible film bag to wrap the chocolate bar and the outer packaging is a carton. ChocolateCo worked with a converter to supply the film, which is plant-based, 100% industrial and home compostable. FOUND-C-21210 explained that the converter provides bespoke packaging following ChocolateCo's request. In this case, ChocolateCo set the desired design, colour and size. Even though ChocolateCo ordered a flexible packaging bag with a quite generic model, obtaining the packaging as expected was not easy and faced many obstacles. ChocolateCo produced vegan chocolate bars on a small scale and mainly processed manually. FOUND-C-21210 revealed that the converter supported the design process, such as suggesting more suitable materials and how to process them. The converter also provided feedback and advice on how to overcome obstacles and improve the packaging. For example, ChocolateCo designed a transparent plastic bag with a brand name printed on it, but the results were not satisfactory when applied to bioplastic packaging. Hence, FOUND-C-21210 was also advised to change the design, and the converter conducted several iterations, and produced several samples for FOUND-C-21210 to select from.

"They have any suggestions on better material, or perhaps how to work with the material well …So it's very important to get feedback from the converter. And if they have any advice for improving things." (FOUND-C-21210)

The ChocolateCo case showed limited joint resources in the collaboration as ChocolateCo, and the converter do not engage in a shared investment in machinery or equipment. Currently, the converter provides ink and a sample of packaging for trial, and their expertise to support the customer's packaging application. Furthermore, FOUND-C-21210 described that the relationship with the converter is built for long-term collaboration. ChocolateCo noticed commitment and sincere support from the converter, even though ChocolateCo is a relatively small business. FOUND-C-21210 expressed a gratitude for the converter who tries to give the best support to ChocolateCo, even though currently buying only a limited quantity and FOUND-C-21210 being quite demanding regarding colour and sizing. Nevertheless, a small business such as ChocolateCo considers several factors, such as price, flexibility and service, when selecting a supplier. FOUND-C-21210 explained that the supplier was reliable, offered a competitive price, and accepted small orders from 5,000 units, which was often impossible with other converters who required larger minimum order units, approximately 50 to 100 thousand per order.

> *"It's definitely not just transactional there's been some genuine support. They really, for the small size board I put in, they went above and beyond…" (FOUND-C-21210)*
>
> *"…sometimes my supplier, they can be a bit slow but they're reliable and good price as well, and they can do relatively small orders, like 5000 or 10,000 packs…" (FOUND-C-21210)*

In this co-innovation, the supplier-customer absorptive capacity facilitated adaptation and improvement, leading to implementation for the business customer and cultivating a long-term relationship. FOUND-C-21210 received a lot of feedback and advice from converters, then learned from these experiences to adapt to the bioplastic packaging limitations. Later FOUND-C-21210 would adjust the packaging design to work better and be more compatible with the material, improving the text printed on the packaging to enhance the sharpness or aesthetics. FOUND-C-21210 planned to communicate more about compostable packaging to consumers explaining the material and disposal of the packaging.

The bioplastic packaging used by ChocolateCo was quite simple, but ChocolateCo specifically required functionality for food contact and good barrier properties. FOUND-C-21210 explained that chocolate products are sensitive and easily affected by the external environment; therefore, moisture and odour barriers were crucial to protect the product freshness.

> *"Chocolate picks up other smells odours, very easily, strong odours. So if you store it next to onion or garlic or something it'll go into the chocolate. So it's very important to have odour barrier, moisture barrier…" (FOUND-C-21210)*

FOUND-C-21210 also described some problems due to the limitation of the bioplastic packaging performance. ChocolateCo used a manual impulse sealer typically used for conventional plastic packaging; however, when applied to bioplastic packaging, it often causes the bioplastic packaging to burn or does not stick properly, and needs rework. These problems slowed the processing, and ChocolateCo had to bear higher costs due to damaged packaging and rework.

Inferred from the discussion, ChocolateCo has a genuine concern for the environment, willing to pay for the higher bioplastic packaging price and adapt to its limitation. ChocolateCo will continue using compostable packaging and expect improvements to the packaging capability, where bioplastic packaging must have the expected specifications, primarily to protect products and be easy to compost in a relatively short time. The customer was also an important factor, and FOUND-C-21210 appreciated that the end-users and retailers who become ChocolateCo customers are those who have a high awareness of sustainability and the environment. However, FOUND-C-21210 received feedback from customers regarding difficulty at the packaging disposal because some councils do not take compostable products in the compost bin. At the same time, consumers cannot put the compostable packaging into the recycling bin either, and other customers were concerned if the packaging ends up in the landfill as it might not compost.

> *"So my customers who are very environmentally aware and retailers… they, they find compostable products a problem, because some councils won't take it." (FOUND-C-21210)*

ChocolateCo case demonstrates supplier-customer collaboration for the application of bioplastic packaging in small businesses. ChocolateCo is the adopter, as this case shows the ChocolateCo owner wanted to use compostable packaging because of a genuine concern for sustainability and the environment. Furthermore, the converter played a role in promoting and facilitating the use of bioplastic packaging by providing support and advice for the customer to work with the bioplastic packaging.

Table 21 Within-case summary: ChocolateCo

Themes	Descriptions
Process	Product manufacturer approaches the supplier, initial assessment: cost and feasibility, partner selection, trials on the customer's machine, adjustment and improvement.
Joint activities	The converter gives solutions to the customer, mutual adaptation: converter works hard to ensure the ink colour and size is as specified by the product manufacturer, who in turn accommodates new film characteristics in the processing.
Joint resources	Converter's expertise, resources for trial at the customer: converter provides samples. There is no joint investment in assets.
Relationship management	Agreement and commitment; the converter is highly supportive despite the product manufacturer being a small company: reasonable minimum order; the product manufacturer wants a precise design. The relationship grows in the long term.
Absorptive capacity	Acquire info about available technology or solution in the market, material specification, cost and other information for designing the packaging: colour, size, and printing. Assimilation through regular communication and feedback. Product manufacturer learns how to work with the new material. Adjust the packaging design to work with the bioplastic material.
Outcomes	Improve packaging design for a specific application. The customer expects to gain environmental benefits from bioplastic packaging, accepts the higher price and technical limitations that do not affect the main product.

4.12. TeaCo

TeaCo is a UK-based company founded over a decade ago; it manufactures and sells a leading premium tea brand. TeaCo's distribution covers all over the UK, targeting food stores, cafés and pubs, restaurants, hotels, major retailers, and online customers. TeaCo has expanded its operation in the US and distributes worldwide. TeaCo ethically sources tea from many countries; its production includes tea filling, packaging, and distribution handled by a manufacturing partner with whom TeaCo has been working in close collaboration for a long time. TeaCo uses a tea temple, a pyramid-shaped teabag made from corn starch that is compostable in industrial composting. In addition, TeaCo uses a plant-based film bag to put the tea temples in and mixed carton and plant-based film for the outer packaging. TeaCo's current packaging is plastic-free and has obtained a plastic-free trust mark from an independent organisation in the UK.

SUSMAN-C-21211 explained that the first activity with suppliers was to discuss TeaCo's requirements with the biopolymer producer, mainly to ensure that the material met food and beverage packaging specifications. Next, TeaCo described the material sample and packaging design, and asked about the material's compatibility with the converter's process.

> *"…we would then get a sample of the packaging that we would like to use going forward to get a sample, send it off to the to the manufacturer or the converter, and just see how it goes." (SUSMAN-C-21211)*

TeaCo took the design to the converter and asked that it be used for all TeaCo's products onward. Next, the converter sent the initial packaging prototype to be validated by TeaCo and then proceeded to implementation. The application of bioplastic packaging to TeaCo's product was relatively straightforward. SUSMAN-C-21211 stated that bioplastic material is not always fit for the product or compatible with the production machinery. However, that was not the case at TeaCo, because the bioplastic packaging was used for a simple application, and TeaCo's product did not require very high protection from the external environment.

The converter was very supportive of accommodating TeaCo's demand for changing to bioplastic packaging because TeaCo had a close relationship with the converter for many years. For example, although it was not easy when changing to bioplastic packaging, the converter could solve problems during the trial or application of bioplastic packaging without burdening TeaCo. P21211 also exemplified that the converter would share information on new sustainable packaging or alternatives that might work on TeaCo's packaging and send the packaging sample, and TeaCo would be happy to discuss this new opportunity further.

> *"So instead of coming to us with loads of problems, they would come to us with like, oh, this happened, but we fixed it, don't worry." (P21211)*

The TeaCo case showed limited joint resources between partners; TeaCo and its suppliers did not build joint facilities such as special machinery because TeaCo uses a simple design and does not require a particular machine.

> *"…the materials that we use, or the style of packaging that we use isn't overly complicated. So the machinery that they would need in order to manufacture our product …that is quite normal…" (SUSMAN-C-21211)*

As inferred from the interview with P21211, the supplier's resources included sending samples to TeaCo, such as samples of material resources from the biopolymer producer, samples of packaging from the converter, and the use of existing machinery production lines. Converter expertise was also crucial in overcoming problems during the transition to bioplastic packaging.

> *"We would then get a sample of the packaging that we would like to use going forward to get a sample, send it off to the manufacturer or the converter, and just see how it goes." (P21211)*

TeaCo has had a long-tracked relationship with the converter for over a decade and showed a strong engagement. The converter showed commitment to accommodating the transition to bioplastic packaging and suggesting sustainable packaging alternatives. TeaCo was also committed to working with the same converter and maintaining their well-established relationship. SUSMAN-C-21211 gave an example: if the selected bioplastic material at that time was not compatible with the converter's machinery, TeaCo would look for alternative materials suitable for the converter's machines or might delay the application of bioplastic packaging until the converter was able to produce it.

> *"We're just, it's just such a nice relationship that we've built with them over the last 15 years; there would be no reason for us to go anywhere else." (SUSMAN-C-21211)*
>
> *"You know, if there's huge issues in the beginning, we'll either work really hard to try and rectify those issues, or just find another solution. So we'll find another material." (SUSMAN-C-21211)*

The TeaCo case showed the supplier-customer absorptive capacity started to grow when TeaCo decided to use bioplastic packaging more than 15 years ago when this type of packaging was very new to both TeaCo and the converter. The converter shared their learning from a production point of view, and TeaCo also shared anything learned from a customer point of view. SUSMAN-C-21211 also noted that this process helped both sides have the same vision and direction, and built the same understanding of packaging innovation.

> *"… it's kind of a constant learning for both of us really, because in the beginning, when we decided to go down the bioplastic route that was very new to them, as well. So we were kind of learning together." (SUSMAN-C-21211)*

The co-innovation facilitated TeaCo to understand that the application of sustainable packaging was not limited to the product packaging but also the packaging used for the logistic or tertiary packaging. SUSMAN-C-21211 added that TeaCo planned to extend the application of bioplastic packaging to its tertiary packaging.

Co-innovation between TeaCo and the converter aimed to apply bioplastic material to TeaCo's packaging but did not include improvements to the material or production process. SUSMAN-C-21211 explained the importance of choosing packaging materials that are safe for food products and have good barrier properties. The new material must also be compatible with the converter's machinery because TeaCo's filling and packing processes were at the converter's site.

> *"So it has to be food safe. The material on the inside has to be airtight. Stop any sort… any bugs and stuff getting in." (SUSMAN-C-21211)*

SUSMAN-C-21211 explained that TeaCo accepted that the cost of bioplastic material was more expensive than conventional plastics because TeaCo considered plant-based packaging to be more eco-friendly or sustainable for TeaCo products. Besides, this option was also suitable for TeaCo's customer base and reciprocated the customers' expectations.

> *"We're more than happy to spend a little bit more on a packaging solution that is more eco-friendly." (SUSMAN-C-21211)*

SUSMAN-C-21211 recalled that as the converter strived to improve its sustainability credentials, it can be concluded that the success of co-innovation with TeaCo would increase those credentials, which would also benefit the converter commercially.

> *"…they strive themselves to be a little bit more eco-friendly, a little bit more sustainable. So the two ideas kind of aligned really nicely." (SUSMAN-C-21211)*

TeaCo initially chose the plant-based tea temple because the founders felt it was right for their premium market. SUSMAN-C-21211 considered innovation and change to use more environmentally friendly packaging in the industry is customer-driven. SUSMAN-C-21211 noticed that customers would voice their opinion on social media, influencing consumers' buying intention.

> *"… it's mostly customer driven… customers are going to social media to voice their outrage and if you're seen to not be making any changes people just aren't going to buy your product." (SUSMAN-C-21211)*

Accordingly, SUSMAN-C-21211 shared that even though the customers had chosen eco-friendly products and intended to dispose of the waste properly, there were still challenges in the waste stream. Some of the problems were limited infrastructure at the end-of-life, some consumers did not have access to recycling, or certain councils did not collect food waste. Therefore, more communication and lobbying of the government were needed in order to bridge this gap.

> *"…what the customer really wants to do and what the company is trying to do, and then there's a bit of a gap …The infrastructure is not there." (SUSMAN-C-21211)*

Last, the TeaCo case showed that the brand owner initiated adopting bioplastic packaging as a more eco-friendly material for the teabag. The converter, also TeaCo's manufacturing partner, had gained TeaCo's trust and could influence their packaging decision by giving suggestions on new material or extending the packaging application.

Table 22 Within-case summary: TeaCo

Themes	Descriptions
Process	Approach to the converter for bespoke packaging, partner selection, initial assessment, design phase and packaging prototype, validation and quality check. Straightforward process for simple packaging application.
Joint activities	Working with the converter, mutual adaptation: the converter accommodates the product manufacturer's requirements, and the product manufacturer accepts a higher price. The converter gives solutions and highly supportive.
Joint resources	The converter provides samples for bespoke packaging. There is no joint investment in assets.
Relationship management	Agreement and commitment, considering supplier with 'eco-credential', regular meetings, communication, honesty, openness, close and collaborative, long tracked relationship with suppliers.
Absorptive capacity	Acquire info about available technology or solution in the market, material specifications for a specific application. Assimilation occurs relatively intensively as the biodegradable teabag was very new to the converter and product manufacturer. Sharing to obtain the same understanding, feedback. Learning from both sides: the product manufacturer learns how to work with the new material, the converter learns about the customer/consumer's point of view. To adjust the packaging design to be compatible with the bioplastic material. Implementing bioplastic packaging to the customer's product and potentially expanding to logistics operations.
Outcomes	Implement the biodegradable teabag and a set of plastic-free packaging, aligning cost and commercial aspects. Other outcomes: achieve business customer's sustainability agenda and improve the converter's sustainability credentials.

4.13. ServpakCo

ServpakCo is a UK-based company and one of the pioneers in the compostable packaging market with a global customer base in the US, New Zealand, Australia and Hong Kong. ServpakCo provides a full range of compostable packaging products made from bioplastics and paperboard for the foodservice business, such as cups, cutleries, plates, salad containers, straws, napkins, takeaway boxes, and bags. These products are sold to distributors, contract caterers for offices, hospitals or schools, and other businesses in hospitality, such as cafes, hotels, and restaurants. ServpakCo's co-innovation is not limited to developing packaging but includes managing proper disposal for the compostable packaging. ServpakCo is positioned between the converter and the business user and manages co-innovation with suppliers and customers separately. Co-innovation with the suppliers is aimed at developing a set of foodservice packaging, such as cups, salad boxes, food trays and supplementary products that use bioplastic packaging, such as napkins and sugar wrapped in bioplastic packaging. Meanwhile, co-innovation with customers is aimed at managing the packaging at the end-of-life, and routing the packaging to the industrial composting facility.

ServpakCo works with converters as their manufacturing partners to produce the products, and their collaboration has grown very well since the company started. ServpakCo selected leading bioplastic material producers and converters experienced in producing bioplastic packaging. QA-C-21215 explained that ServpakCo determined the design and requirements and, together with the converter, developed the design to be implemented in the actual production. At the development stage, multiple iterations were required to fulfil ServpakCo products' quality standards, stressing the functionality and visual appearance received by the customers, then ServpakCo would give the converter approval to continue to actual production.

> *"You will have to make sure that you go through various iterations of the design process, and make sure that everything meets our standard and, and is approved by us. So, yeah, it's a long process, and sometimes it works seamlessly." (QA-C-21215)*

The ServpakCo case showed limited joint activities with the biopolymer producer and relied more on the converter to manufacture the packaging. Inferred from the conversation with QA-C-21215, ServpakCo communicated with biopolymer producers on a limited basis to explore new materials and technology. The joint activities carried out with the converter showed that ServpakCo first determined the overall design and packaging requirements to be produced, then iterated on the design and quality with the converter to align with both ServpakCo's and the converter's standards.

“You will have to make sure that you go through various iterations of the design process, and make sure that everything meets our standard and, and is approved by us. So, yeah, it’s a long process, and sometimes it works seamlessly.” (QA-C-21215)

In addition, QA-C-21215 explained that ServpakCo provides services, such as socialisation and training to the customer’s staff to understand compostable packaging, and provides marketing communication materials and manages food waste into a closed-loop as in the circular economy for customers operating in close environments, such as cafeterias.

“We also offer lots of other services relating to our brand, and that’s including composting service, and marketing materials …Like a way to get rid of all the waste in an environmentally friendly and sustainable way.” (QA-C-21215)

Joint resources appeared in sharing knowledge and expertise between ServpakCo and the converter. However, at the very beginning of the collaboration, ServpakCo purchased the standard product range from the converter. Over the years, ServpakCo co-invested with the converter in tooling and specific machinery to develop specific products, now reaching up to 60% of ServpakCo products.

“We’ve opened and invested in tooling with our converters and bought production machinery if the converter didn’t have it … I’d say that was probably about 50 to 60% of our products have got our investment in them in some way.” (QA-C-21215)

ServpakCo had a long-tracked relationship with the suppliers and strived to build a long-term relationship with the converter to keep producing innovative products in the market. However, the ServpakCo case showed how the relationship management with the suppliers and the customers were managed in varying degrees, avoiding three-way communication. The converter usually did not like ServpakCo to communicate directly with material producers; similarly, ServpakCo will manage the project and communicate directly with the customer without directly connecting to the converter.

“…there’s varying degrees of communication. Sometimes converters don’t really like you talking to the material manufacturer…” (QA-C-21215)

Absorptive capacity was apparent in the ServpakCo case. ServpakCo acquired information regarding updates on new material, functionality, or development from the material producer. Assimilation between ServpakCo and the converter occurred through intensive communication with the converter and customer. Accordingly, ServpakCo learned from the converter about the packaging or design possibilities to be manufactured, and worked on the alignment of the standard quality of packaging. The converter would understand the customer's quality requirements and be more capable of working with bioplastic materials. ServpakCo managed good relationships with customers and acquired *valuable* feedback to improve the product range or meet the customer's needs, and became aware of the changing market and regulation, such as the EU single-use plastics directive *that includes banning* plastic cutlery. ServpakCo used up-to-date knowledge about new materials, technology, new functionality, changing markets and regulation to continuously improve their products, offering a new range to the market to adapt to customers' requirements, the changing market and regulation.

Co-innovation at ServpakCo focused on developing a complete range of packaging applications for a food service business without involving material development. QA-C-21215 explained that co-innovation did not lower the costs, as these depended on the packaging features requested by the customer, and the cost might increase when the customer asked for a specific type instead of the standard range. Nevertheless, ServpakCo managed efficient costs from operations, one of which minimised shipping by bringing production closer to the market. Moreover, ServpakCo worked closely with customers to properly manage compostable packaging waste; thus, co-innovation with ServpakCo would improve customers' sustainability or circular economy practice.

> *"But we also make sure that we focus on the waste side of things, and try and put it on our own waste streams where possible…" (QA-C-21215)*

Co-innovation with ServpakCo is also beneficial to converters as they would continuously produce innovative sustainable packaging widely used in the foodservice business.

> *"Our relationships with converters are long-term enduring relationships. We work together to make sure that the products that we produce for them, are right for us and innovative and first to market." (QA-C-21215)*

QA-C-21215 explained that the key factor in co-innovation was the material's availability and continuous supply following the customer demands. According to QA-C-21215, some bioplastic materials were currently experiencing limited supplies, whilst ServpakCo must avoid shortages and ensure the key customers' supply targets are achieved. Customer demand is also an important factor that encourages co-innovation. ServpakCo serves the global market, in which different regulations are applied in different countries. Therefore, QA-C-21215 emphasised the importance of following changing markets and regulations because the customers must follow the regulations in their operational areas. ServpakCo also considered the end-of-life and infrastructure at this point as key factors for the wide adoption of compostable packaging and the government support needed to increase industrial composting facilities.

The ServpakCo case demonstrated the business customer's role in defining the packaging specification, as shown when ServpakCo determined the design and standard quality and thoroughly communicated these to the converter. ServpakCo built engagement with a broader supply chain, as it built co-innovation with foodservice industries and local waste services to overcome the challenges in compostable packaging waste streams. The converter plays a vital role in this case as they are the key manufacturing partner. ServpakCo considered the converter to be a technical expert in bioplastic packaging manufacturing, very well informed about bioplastic, and highly capable of working with the material. Nonetheless, collaboration with more stakeholders around ServpakCo's value chain was limited as each player protected the relationship with their immediate supplier or customer.

Table 23 Within-case summary: ServpakCo

Themes	**Descriptions**
Process	Product manufacturer looks for alternatives of material and supplier (biopolymer producer and converter), initial assessment, partner selection, design phase, adjustment and improvement, validation & quality check, product launch.
Joint activities	Explore packaging application and requirement, many trials and feedback, provide supporting services for the customers including waste management, mutual adaptation: balancing the supply of the material and packaging for sale, accommodate product manufacturer's quality standard.
Joint resources	Converter's expertise, sustainability credentials; product manufacturer's environmental knowledge, resources in waste management, HR training. Co-investment in the production unit occurs with the converter.
Relationship management	Agreement and commitment, regular communication to track product development progress, building long term and close collaboration, long tracked relationship with the converter, communication boundaries with the material producer and converter.
Absorptive capacity	Info about available technology or solution in the market, possible packaging to be developed, details of the potential partners, updates on the regulation, law and changing market. Assimilation occurs from discussion and meeting, getting loads of feedback, and building the same understanding.

	Converter learns the customer's quality standard and how to work with the material, and with the product manufacturer, becomes aware of changing regulations in different regions, market situations, opportunities in the future. To improve product offering for customers, comply with the (upcoming) regulation.
Outcomes	Higher cost and adjust the operations to improve cost-effectiveness, embrace the circular economy principle. Other outcomes: accommodate business customer's expectations for sustainable packaging.

4.14. PharmaCo

PharmaCo is a pharmaceutical company that operates globally, including in the UK and Indonesia. This company is an industry leader in the production of medicines, vaccines and other healthcare products. Like other companies, sustainability is also a concern of PharmaCo, which tries to address various agendas, including eliminating single-use packaging, reducing environmental impact and achieving zero waste, prioritising recyclable and reusable packaging, and eliminating problematic single-use packaging when possible. PharmaCo has an ongoing co-innovation with a biopolymer producer to develop bioplastic for applications with various products, such as medicines for allergies, pain and critical illness, and other healthcare products. The following analysis is based on the interview with HOPR-C-21219, which was documented in a manual note; hence direct quotes are not available.

PharmaCo did not collaborate to develop a new material from the start but looked for a material supplier with a product prototype. The biopolymer producer on the other hand approached PharmaCo to engage in co-innovation after having an initial product prototype, which had been tested and developed to reach a pilot-scale capacity. An important phase before both partners engaged in co-innovation was the initial assessment, in which PharmaCo applied stringent selection mechanisms.

The co-innovation between PharmaCo and the biopolymer producer aimed to develop the material further to meet PharmaCo's specific needs. Inferred from the discussion, joint activities between PharmaCo and the biopolymer producer partner mostly covered exploration and shared information, which helped the biopolymer producer to carry out material development. The biopolymer producer's current material has several gaps; for example, the biopolymer producer's early development, which was for a product with a shorter shelf life, might need to be modified to fit PharmaCo's pharmacy products with a long shelf life. The crucial aspects to be resolved between

PharmaCo and the partner included the packaging compatibility, its application in different countries, cost and supply chain sufficiency.

Most contributions from PharmaCo were in financial capital for the biopolymer producer to cover the development cost and scale-up in exchange for agreed deliverables and exclusivity. The amount of investment depends on scale, and considering the benefits of exclusivity to leverage the PharmaCo brand. HOPR-C-21219 stated that there is no joint investment in building a plant or special equipment in the co-innovation. Partner selection is an important part of relationship management, and the relationship is mainly arranged in a formal contract agreement. PharmaCo filtered and selected a shortlist of potential partners considering the biopolymer producer's early investors in order to gauge the potential of the company, its capability to meet PharmaCo's expectations and deliver the result, the biopolymer producer's initial research, data transparency, additional third parties to be involved in the co-innovation, ethics and compliance. HOPR-C-21219 also recalled that it took a long negotiation to have an agreement on the joint IP ownership. PharmaCo has to consider its existing patents, whether a new patent with the biopolymer producer will be joint or separate. So far, PharmaCo has found it difficult to collaborate with some providers, including early, small start-ups.

The PharmaCo case showed strong absorptive capacity from the PharmaCo and biopolymer producer side. PharmaCo had started looking for available technology and solutions in the market a year earlier. The assimilation between PharmaCo and its co-innovation partners occurred through sharing information and expertise. The biopolymer producer learned how to reach commercialisation, generate revenue, learn the industrial aspects, create viable business propositions and understand precisely what brand owner's need from PharmaCo's feedback. On the other side, the brand owner also learned the new technology and its potential application to the product and understood the early development process without doing the R&D themselves. Eventually, this new understanding will be used to develop the material further for packaging applications at PharmaCo.

The biopolymer producer had developed an innovative material from renewable resources. The biopolymer is derived into a new class of material that works similarly to the conventional plastic PET and is recyclable at the end-of-life. The co-innovation with PharmaCo aims for further development of the material for packaging applications at PharmaCo. PharmaCo highly prioritised protection for the product, and strict health and safety standard for medicines; therefore, the packaging needs to be further developed to fit PharmaCo's packaging specification and must not affect the product quality. Cost is essential; it has to be aligned with the commercial aspect and profit for the company, which can be extremely challenging for medical products. HOPR-C-21219 explained that a limitation is the higher price the consumer is willing to pay for medicines, unlike luxury or hi-tech products. Eventually, PharmaCo selected a co-innovation partner who can provide a new packaging material that contributes to PharmaCo's sustainability goals, including net-zero, minimising waste, increasing circularity and improving the product's environmental performance throughout the whole life cycle.

Inferred from the interview with HOPR-C-21219, the key factors are related to cost, customer's expectations on sustainability, the commercial advantage from using the new material, and compliance with regulations in the regional markets where the packaging is used. Another key success in developing bioplastic packaging is ensuring availability and a continuous supply of the raw material and the packaging on an industrial scale. The biopolymer producer must consider the supply chain, ensure the raw material and biopolymer availability to cover PharmaCo's global operation or commercial needs and avoid shortages, such as the one with recycled material, as more recycled packaging is used globally.

As concluded from the interview with HOPR-C-21219, the biopolymer producer plays the role of the expert in material development by creating new material claimed to be more innovative than other bioplastic materials, while PharmaCo as the product manufacturer, plays the role of adopter as their main intention is to use the new bioplastic material for packaging applications. PharmaCo is also an industry leader that is powerful in directing the development to meet their requirements and is quite demanding. The product manufacturer also plays the role of a connector to a wider supply chain, such as involving more experts or testing labs to address gaps that cannot be resolved by either the brand owner or the biopolymer producer.

Table 24 Within-case summary: PharmaCo

Themes	Descriptions
Process	Internal R&D up to the initial product prototype at the biopolymer producer, approach between the product manufacturer and biopolymer producer, initial assessment, partner selection: compliance with law and regulations, scale-up potential, the feasibility of the project for industrial-scale implementation.
Joint activities	Extensive mutual adaptation at all partners to enable implementation, product manufacturer tolerates reasonably higher cost, share confidential information.
Joint resources	Financial capital to cover the biopolymer producer's development cost, improve the biopolymer up to the final bioplastic packaging. There is no joint investment in assets.
Relationship management	Agreement on cost, outcomes, exclusivity, IP. The product manufacturer is relatively demanding: stringent partner selection, complex requirements. The product manufacturer engages other partners to support the co-innovation project.
Absorptive capacity	Acquire info about available technology or solution in the market, potential partners' capabilities, regulation and law, scale-up potential, price of the final packaging. Assimilate through a feedback loop, sharing expertise. Biopolymer producer understands the product manufacturer's complex needs, industrial aspects, and commercialisation. Product manufacturer learns the technology and its potential applications. To achieve implementation at the product manufacturer on an industrial scale.
Outcomes	Reasonable higher cost aligned with commercial benefits. Other outcomes: achieving business customer's sustainability agenda, exclusivity, joint intellectual property.

4.15. ConveCo

ConveCo is a multinational company based in the UK, also a global industry leader in consumers good, selling a fast range of beauty and personal care, food, beverages and household products. ConveCo sells and manufactures the product, including in Indonesia. ConveCo sets its agenda on sustainability in diverse areas and has a specific target on the packaging, focusing on using less plastic, optimising recycling by increasing the recycling rate and using recycled plastic, and developing reuse and refill schemes. Moreover, ConveCo prioritises bioplastic packaging materials that would not conflict with food stocks and contaminate the recycling stream. ConveCo has used bioplastic packaging in a few products, such as ice cream and tea, and launched it in a few different countries but it has not yet been available globally. The following analysis is based on the interview with SUSPAK-C-21305, documented in a manual note; hence direct quotes were not available.

Co-innovation in ConveCo aimed to develop further the packaging for application by the product manufacturer, involving collaboration with the material producer, converter and other partners in the value chain. SUSPAK-C-21305 explained that first, the product manufacturer undertook an initial assessment of several alternatives of material, then reviewed potential partners considering the solutions offered by these potential partners. SUSPAK-C-21305 mentioned that the concept development and exploration for packaging application happened during the initial assessment and partner selection. Next, the product manufacturer worked with the partners, including the converter and the material producer, to further develop the packaging, then validate and launch the product using new bioplastic packaging. According to SUSPAK-C-21305, the product manufacturer did not co-innovate for the material development, which started from a lab-scale, because this project usually takes a long time and process

The ConveCo case showed that joint activities in concept development with partners occur before engaging in collaboration. At this stage, the product manufacturer and supplier explored the use of bioplastic materials for specific packaging applications and developed the material's functionality. In addition, the product manufacturer also discussed the project's timelines, when to work and what will be delivered. Mutual adaptation at the product manufacturer's side appeared when the product manufacturer accepted a higher cost than conventional packaging by considering the offset to other benefits. The product manufacturer understood that the bioplastic material would not be instantly compatible with the existing infrastructure, and changes were needed to accommodate the new material. SUSPAK-C-21305 shared an example: when changing to biodegradable teabags, ConveCo had to replace the machinery because the new packaging uses adhesive for sealing, where this process is different from the heat sealing process used on the previous teabags.

In the co-innovation, joint resources were limited to using the existing resources for trialling the new bioplastic packaging at ConveCo's plant or changing machinery when necessary. SUSPAK-C-21305 added that some infrastructure changes were required in order to work with the new material, such as changing the mould or other equipment for the ice cream tube and changing the machinery to process the new teabag. Furthermore, the relationship with the biopolymer producer was considered a long-term collaboration. Partner selection is a crucial step for engagement, and the product manufacturer carefully reviewed a comprehensive business case from the biopolymer producer, such as how the bioplastic packaging meets functionality specifications that included technical properties, end-of-life and source of the material; fit for the brand purpose; brand and sustainable strategy. The product manufacturer also checked the sustainability credentials of the biopolymer producer's material, such as home composting certifications. The co-innovation relationship was preserved based on agreement on the project's timelines, deliverables and commitment to supporting the product manufacturer, and being flexible and adaptive to the product manufacturer's requirements, such as changes at a later stage. However, developing a bioplastic material required a lengthy development, and there would be a risk that the material would no longer suit ConveCo's interests. In this situation, ConveCo would have to stop the collaboration and look for a new partner.

In this case, a higher absorptive capacity is required at the biopolymer producer's side to cope with ConveCo's requirements. SUSPAK-C-21305 conveyed the importance of supplier assimilation with ConveCo through discussion and responsiveness to ConveCo's needs. SUSPAK-C-21305 explained that even though the supplier has produced packaging according to the agreed requirements, there could be problems when implemented in the value chain. From this process, the biopolymer producers and converters could better understand the product manufacturer's needs and how materials worked along ConveCo's value chain. Eventually, the biopolymer producer and converter supplier could have more capability to provide solutions to ConveCo, and be more responsive and adaptive when collaborating with product manufacturers, especially the industry leader.

As the co-innovation was intended to apply the bioplastic packaging to one of the product manufacturer's product packaging, SUSPAK-C-21305 emphasised that the functionality requirement must be met. The packaging must have the desired technical properties that work at the production site and are convenient when the end consumers use the packaging, such as opening an ice cream tube, squeezing a bottle, or drinking tea. ConveCo considered many scenarios to ensure the bioplastic packaging was fit for purpose. SUSPAK-C-21305 exemplified the biodegradable packaging as an excellent option for teabag application because used tea grounds are difficult to separate from the teabag; thus, recycling was impossible. Furthermore, SUSPAK-C-21305 stated that the product manufacturer managed to offset the higher material cost with commercial benefits, such as enhancing the brand through sustainability. SUSPAK-C-21305 explained that the source of material and end-of-life options were also important considerations; bioplastic packaging from renewable sources, such as that used for plant-based biodegradable teabags, was more likely to reduce the carbon footprint. Finally, SUSPAK-C-21305 noted that ConveCo was cautious about claiming exclusivity or IPs from the co-innovation and considered it on a case-by-case basis. ConveCo would allow the widespread application of bioplastic packaging because innovation in sustainability should be widely available for the future.

According to SUSPAK-C-21305, the key factor for changing to sustainable packaging and using bioplastic material is communicating sustainability to the consumer. ConveCo has created excellent marketing communication, explaining the story on sustainability and how ConveCo's new packaging would contribute to sustainability. Furthermore, SUSPAK-C-21305 emphasised the importance of co-innovation for developing bioplastic packaging to involve a wider supply chain, NGOs and government, to facilitate the understanding of a more comprehensive view representing the whole value chain. In the end, ConveCo as the product manufacturer and global industry leader is considered to be the central part that connects the packaging supplier and consumers. The product manufacturer would adopt the new material, which was ready to be further developed for specific packaging, and collaborate with the whole value chain. The product manufacturer played an essential role in communicating sustainability and change in the packaging to the consumer.

Table 25 Within-case summary: ConveCo

Themes	Descriptions
Process	Approach between the product manufacturer and biopolymer producers, initial assessment and partner selection: review the material sustainability credentials, project feasibility, further packaging development for the product manufacturer's specific application, trials, customer testing, validation and quality check.
Joint activities	Concept exploration, mutual adaptation: the converter adjusts design and manufacturing tools, gives solution to packaging processing; the product manufacturer accommodates new film characteristics changes the machine, process, accepts a higher packaging cost.
Joint resources	Resources for trial at the customer. There is no joint investment on assets.

Relationship management	Agreement and commitment to meet the project timelines and deliverables, build a long-term relationship with the biopolymer producer, emphasise suppliers who give extensive support and solutions. Product manufacturer is relatively demanding.
Absorptive capacity	Acquire info about available technology or solution in the market, feasibility, commercial aspects, material specification and detailed check on partner capabilities. Assimilation occurs from discussions and meetings. Biopolymer producer understands the product manufacturer's complex needs and the supply chain. To make solutions for implementation at the product manufacturer, be more adaptive, responsive to fulfil the product manufacturer's requirements.
Outcomes	Reasonable higher cost aligned with commercial benefits. Other outcomes: achieving business customer's sustainability agenda, exclusivity.

5. Cross-case analysis

The following sections present the cross-case analysis and are arranged to address the ROs of this study, in particular, RO2 to RO5, which are explained earlier in section 1.4, see page 8. The cross-case analysis was conducted by comparing the codes among companies with the same role in the supply chain: the biopolymer producer, converter and the product manufacturer, then describing the co-innovation mechanism in each dyad. This step enabled a clearer view of the mechanisms and consequences for each company, i.e., whether similar mechanisms create similar or different results. This step also helped in the identification of impactful mechanisms and generated an understanding of the underlying mechanisms at the biopolymer producer, converter and product manufacturer. Subsequently, the supplier-customer relationship in the co-innovation was identified based on the co-innovation process of the biopolymer producer, converter and product manufacturer. This would ascertain the dynamics among partners representing the supplier-customer role in the co-innovation, which derived from common issues of each role. Finally, a comprehensive co-innovation mechanisms were generated, including any gaps in those mechanisms from the different views of the biopolymer producer, converter, and product manufacturer.

5.1. The process of co-innovation in developing bioplastic packaging

This section reconstructs the process of co-innovation, which involves the biopolymer producer, converter and product manufacturer, and eventually fulfils RO2. The supplier in this study is the biopolymer producer or the biopolymer producer and converter together, who process the material into packaging. The converter is the supplier of the product manufacturer and retailer but also the customer of the biopolymer producer. In this case study, the customer is the product manufacturer who uses the packaging from the converter for their product or sells the packaging as part of their product range. In all cases, the converter, which fabricates biopolymers or polymers into bioplastic packaging, is unlikely to be eliminated in the co-innovation. The converter plays an important role in the existing plastic packaging supply chain and remains vital in the bioplastic packaging supply chain.

5.1.1. Initial development and co-innovation for developing a packaging prototype

In Figure 19, the initial stage of the product development is the internal development undertaken at the biopolymer producer. When the material is deemed viable, it is introduced to the converter for development into a packaging prototype of a particular product application and trialled using the existing real production system. Next, the biopolymer producer works with the converter to create a bioplastic packaging prototype or viable product to sell; the product manufacturer is not involved in this process because the product manufacturer is interested only when the product is ready to use with perhaps a few adjustments needed or is able to be produced on a small scale. In ChemiCo, the packaging prototyping was carried out by involving an external converter as collaborating partner, while CbagCo worked with the converter, who is also part of the same corporation. CbagCo's converter operated as a pilot plant, which supported the packaging R&D, produced bioplastic packaging on a small scale, and became a showroom or demonstration plant.

At this stage, problems occur when trialling the material at the converter's manufacturing facility, and all partners work on a solution and are willing to adapt. Many failures and iterations occur before achieving the desired results because the new material developed on a small scale cannot be applied straight away on a real production scale. This situation provides an opportunity to learn the operationalisation of bioplastic packaging in the existing production system. The converter, as the customer, adapts by either adjusting the process, tools, setting or even adjusting their required specification and accepts the limitations; on the other hand, the biopolymer producer, as the supplier, adapts by improving the material. The subsequent development is to apply the bioplastic packaging to the product, in which the product manufacturer, converter and biopolymer producer are involved in co-innovation. Many trials and adjustments are needed to resolve the problems, and the adjustment could occur at the product manufacturer or go a step back to the converter and the biopolymer producer.

Figure 19 shows how the development flows from the biopolymer producer, converter and product manufacturer, creating the material, packaging and application at the latter. However, co-innovation for bioplastic packaging does not happen straightforwardly. Co-innovation follows two stages: the first is co-innovation between the biopolymer producer and converter to create a packaging prototype; the second is co-innovation for further development, which involves the product manufacturer.

5.1.2. Further development with the product manufacturer and implementation

The next stage of co-innovation aims to further develop the packaging into the final product that has qualified for the product manufacturer's use. In this stage, the co-innovation mechanism varies depending on the complexity of the packaging application. Co-innovation to develop more complex packaging with extensive application requires a long development period and involves biopolymer producer, converter and product manufacturer. In this co-innovation, improvement and adjustment are made through material and process (see Figure 19). Moreover, most co-innovations between the small/medium product manufacturer and the converter exist for simple packaging applications. They could generally manage to develop and improve the packaging requested by the product manufacturer and involve the biopolymer producer when needed to assist in trials.

Extensive co-innovation aims to develop materials to be manufactured into packaging that meets the product manufacturer's comprehensive requirements. In this co-innovation, it is interesting to note the biopolymer producer approach to engage a co-innovation partner, as shown in the CbagCo and SoluCo cases, is that introducing the new biopolymer and collaborating for further development with the product manufacturers seemed to be more effective than approaching the converter, who was supposed to be the direct user of the bioplastic material. The biopolymer producers saw the converters as being reluctant to develop or produce packaging bioplastic because the price was higher than conventional plastic, and because of differences in the production process, and also that they had not yet seen the potential market for bioplastic packaging. Therefore, biopolymer producers approached the product manufacturers to use bioplastic packaging in their products and from there, the product manufacturers involved the converter to support the project. In line with that, in the FilmpackCo, BarrierCo and BiopackCo cases, the product manufacturer approached the converter to provide a sustainable packaging solution and to meet this demand, the converter approached the biopolymer producer.

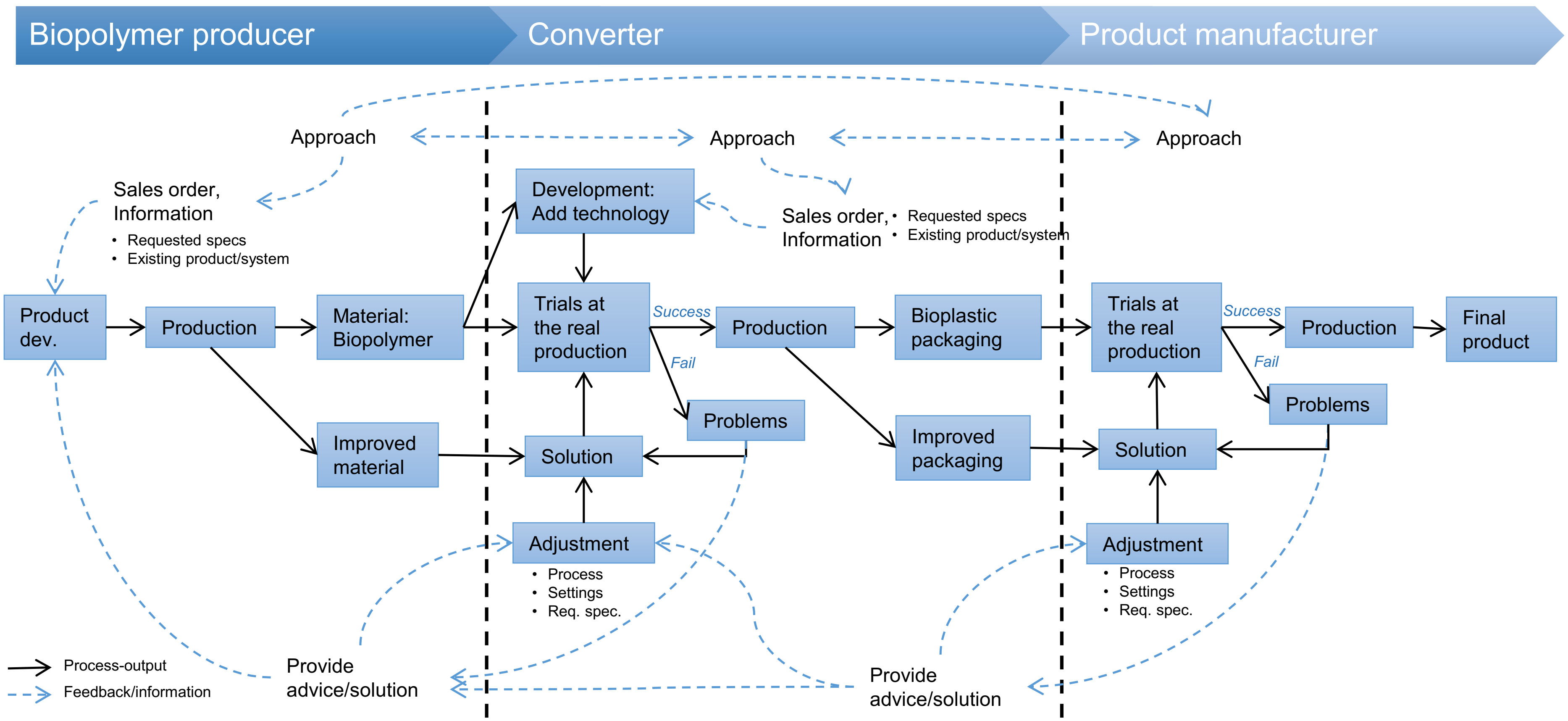


Figure 19 The process of co-innovation in developing bioplastic packaging

Co-innovation in the extensive and complex co-innovation project involves industry leaders, and partnership development is challenging for the biopolymer producer, who must put substantial efforts into demonstrating the co-innovation project potential to the product manufacturer. Industry leaders use a rigorous filtering mechanism and an initial assessment of the project's feasibility and the partner's capability. Industry leaders carefully select co-innovation partners, considering rigorous selection criteria starting from the technology, the state of the material development, sustainability credentials and material certification. The most important aspects require the material to have been successfully developed in small stages and be ready to scale-up. The product manufacturer will then assess the partner's ability to demonstrate the feasibility of the development project for industry leaders, such as commercial benefits for product manufacturers, the capability to scale-up and further develop the materials following comprehensive requirements from technical and logistics points of view, and ensuring compliance with regulations in different countries.

Before engaging a co-innovation partner, the biopolymer producers have built a pilot plant and operate on a small scale, therefore are capable of demonstrating the new material's readiness to be manufactured into bioplastic packaging. SoluCo and ChemiCo presented a comprehensive business case to show the potential long-term material and commercial benefits that can be achieved by the product manufacturer and the feasibility of the project, including the required investment and the projected cost of the material to the product manufacturer. These companies also demonstrated their readiness to scale-up, then, with product manufacturers who are also industry leaders, explored the packaging application and further development, which will accommodate the very comprehensive needs of the product manufacturer. CbagCo used a live showroom to show a smooth production process and the finished product to potential customers, predominantly converters. With this reality, not all companies have the capability for co-innovation; for example, start-ups that develop potential bioplastic materials or packaging present only a small-scale prototype and have difficulty demonstrating the readiness of materials to scale-up and meet industrial-scale needs.

Co-innovation carried out by industry leaders, such as DrinkCo, NutriCo, PharmaCo and ConveCo, was done through material development and working with biopolymer producers. In contrast, small and medium-sized companies engaged in a simple and narrow co-innovation. Small product manufacturers such as ChocolateCo, TeaCo and ServpakCo looked for converters offering a bioplastic packaging product range then requested bespoke packaging that required less complicated adjustments to the specifications, such as design, size, thickness and functionality. CoffeeCo is a start-up company that started its business as a product manufacturer then expanded its project by developing new material through co-innovation with biopolymer producers. Eventually, co-innovation in extensive development projects expanded as the product manufacturers involved the converters that produced their packaging, and other partners such as third parties' testing labs for material validation, machine producers, and engineers. Hence more complementary skills and abilities were pooled to support and speed up the development project, as in the SoluCo, ChemiCo, DrinkCo, NutriCo, ConveCo and PharmaCo cases. However, in the simple and narrow development project, co-innovation might not involve biopolymer producers because the converter has managed to serve small product manufacturers' needs; hence co-innovation is less likely to stretch.

In the case study, the product manufacturers, either industry leaders or small businesses, looked for sustainable packaging solutions, set the standards and specifications, but were not directly involved in developing materials and production processes. At the prototype development and validation stages, the packaging was produced on a small scale by the converter, and the product manufacturer evaluated the quality and performance of the packaging. As in DrinkCo, NutriCo, and PharmaCo, the biopolymer producers must produce material on a small scale to be tested and processed into packaging by the converter. The product manufacturer validates the packaging from the converter, particularly emphasising the function of the packaging to protect their products; it should not affect the product quality when used by the end consumers. This process can be lengthy as it involves many iterations to improve the prototype according to the product manufacturer's expectations, or a compromise due to limited material that performs exactly like conventional plastic packaging, or the standard set by the product manufacturer. Once the product manufacturer approves the packaging prototype, the process that follows involves the implementation of actual production.

5.1.3. Summary of the co-innovation process (fulfilling RO2)

The bioplastic packaging product development works in the same way as the product development in other industries, generally consisting of partnership development, concept development, product development, and implementation. Partnership development is essential as the customer thoroughly reviews the supplier's capability. Concept development occurs during the partnership development, in which the biopolymer producer presents the project feasibility, carefully learns details of the product manufacturer's requirements, and the product manufacturer learns reciprocally about the new technology, and the opportunity to gain advantages through sustainability.

Co-innovation occurs in two stages (see Figure 20). The first stage is the co-innovation to develop a viable packaging prototype using the new material. At this stage, the new bioplastic material did not work straightforwardly in the packaging manufacturing process. Typically, the biopolymer producer works with the converter to improve the material, on the packaging design, adjusting the tools, and on the conversion process. At this stage, the material works for small-scale production but is not completely ready for industrial-scale application and did not necessarily fit the product manufacturer's standard. Therefore, co-innovation proceeded to the next stage, which aimed at further developing the packaging for the product manufacturer's specific use. In the further development stage, co-innovation in developing complex packaging with extensive application involves biopolymer producer, converter and product manufacturer, and the outcome covers material, packaging improvement, process adjustment and usually takes a long development period. On the other hand, co-innovation in simple packaging applications occurs between the small/medium product manufacturer and the converter, who are generally able to manage the project themselves and might involve the biopolymer producer when needed to assist in trials.

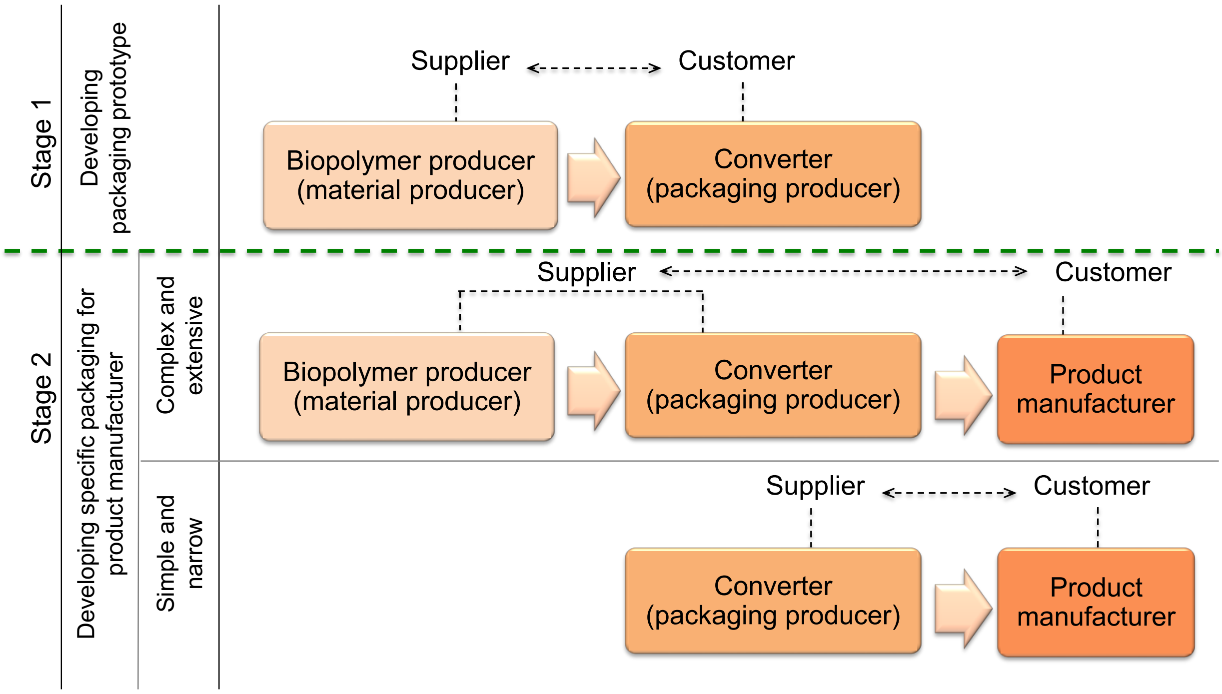


Figure 20 Stages in co-innovation for developing bioplastic packaging

In the co-innovation, the customer was involved in late product development or even implementation. This activity delivered product and process improvement, and also increased the customer's acceptance of the final product. Nevertheless, problems regarding the extensive scale and scope of the product's implementation and commercialisation could occur due to the difficulty of the material to be scaled up, and problems at the end-of-life create negative responses that inhibit its commercialisation. The supplier was also very protective at the initial material development stage and did it internally. Furthermore, a strong business motive impeded the customers' interest, similarly to that of the product manufacturer or converter, in becoming involved in product development until they were able to see the clear potential of the market demand and its feasibility. These conditions limited suppliers in understanding the customer's exact needs during the internal material development, leading to lab-scale prototype failures when applied to the actual production. At the partnership development stage, the biopolymer producer obtained detailed requirements from the product manufacturer and needed to improve the material to deliver a specific packaging performance that fitted the product manufacturer's different products, logistics and supply chain, add material certifications, and comply with regulations worldwide. These iterations led to a long period of development and consumed many resources, whilst the technology, market, and regulations were rapidly changing.

5.2. The key mechanisms in co-innovation for bioplastic packaging

This section presents how joint activities, joint resources and relationship management work together as the key elements of co-innovation. Furthermore, the cross-case analysis points out how the absorptive capacity strengthens the co-innovation mechanisms and reveals possible co-innovation approaches. Eventually, this section, in conjunction with the previous section, fulfils RO2, which aims to reconstruct the process and unveil the key mechanisms of co-innovation in developing bioplastics packaging.

5.2.1. Joint activities as the fundamental development mechanism

Suppliers and customers interact through joint activities, which are a series of reciprocal actions taken proactively to achieve the collaboration objectives. Joint activities in the supplier cases emphasise efforts in further developing the material and packaging with the customer. In the smaller scope of co-innovation, product development with the customer focused on creating or improving the packaging to meet the product manufacturer's requirements without modifying the material. In this case, the converter and product manufacturer worked on the packaging design, managed the trial at the customer's production site, and collected customer feedback. The informants from FilmpackCo, BarrierCo, and BiopackCo stated that feedback was crucial. Trials with the customers and a feedback loop allowed all partners to understand the problems, and improve or tolerate limitations so that the co-innovation project would thrive.

In the extensive co-innovation, the biopolymer producer involved the product manufacturer in the concept exploration for a specific packaging application, trial and iterations, improvement of the material and packaging design, and validation of the packaging. In all cases, developing bioplastic packaging with the customer involved many adjustments and improvements to reach the point where the material successfully converted into bioplastic packaging and met the customer's requirements. SoluCo took up to 24 months to develop materials and had many iterations with the converter to develop the features expected by a product manufacturer and present the packaging prototype to the product manufacturer.

ChemiCo conducted concept exploration with product manufacturers, then developed the materials further to meet the product manufacturer's requirements. This situation differs from CbagCo who determined the bioplastic packaging features, directing trials and iterations with the converter and did not accept customer requests for customisation on the packaging functionality.

Product manufacturers such as PharmaCo, ConveCo, DrinkCo and NutriCo explored new materials because they looked for a specific comprehensive performance, which was unavailable with most of the materials in the market. In the concept development, ChemiCo and SoluCo adapted to the product manufacturer's requirements and learned from their expertise about industrial aspects, commercialisation, logistics and the supply chain. The product manufacturers, especially industry leaders, were highly knowledgeable on industrial aspects and have established operations and supply chains. Accordingly, bioplastic packaging for industry leaders must accommodate their needs, including every detailed technical requirement, and work on an industrial scale. Ultimately, it was unlikely to produce superior bioplastic packaging without improving the material, and the product manufacturer involvement in the development was crucial.

Knowledge sharing was found in the partner's interactions during concept exploration, regular meetings or discussions, and trials at the customer's site. In the SoluCo and ChemiCo cases, product manufacturers opened up network access and information for the biopolymer producer under an NDA. In addition, product manufacturers shared technical and operational information in many countries, including logistics, commercial and supply chain, to allow the biopolymer producer to understand how the industry uses the packaging. The product manufacturer shared their exact packaging requirements, which the biopolymer producer needed to accommodate through material improvement. Knowledge sharing became a valuable opportunity to learn the product manufacturer's needs, improve the process and material, and generate new knowledge. Partner's feedback created specialised knowledge regarding better ways to make bioplastic packaging work for the customer. The biopolymer producer and converter took advantage of gathering and processing feedback and complementary information from each partner, creating a new combined knowledge that would in turn contribute to the supplier's problem-solving capability and successful product development.

In the BarrierCo and BiopackCo cases, the questionnaire appeared to be a useful tool for acquiring comprehensive information and feedback, but in return, the customer was required to cooperate and share the requested information. BarrierCo distributed the questionnaires through marketing teams to capture the needs of prospective customers and the assumed product specifications. BiopackCo systematically enquired about the customer's manufacturing process and equipment to assess their suitability for converting to the bioplastics material. BarrierCo and BiopackCo asked their respective customers to fill in the questionnaire, which was then used in the product design.

The cases conclude that it is challenging to create bioplastic packaging that works and performs just like conventional plastics; consequently, extensive mutual adaptation is crucial. Joint activities representing mutual adaptation were seen from the biopolymer producer adjusting the raw material formulation or grade, to the converter adjusting the process and packaging design. Furthermore, the product manufacturer accommodated the new packaging characteristics by modifying the packaging design, adjusting the production process, spare parts, and settings. In the ServpakCo, ConveCo and ChocolateCo cases, the converter also made adjustments to the packaging design, manufacturing tools and setting to process the new bioplastic materials. Overall, the product manufacturers adjusted their required specification, accepted the bioplastic packaging limitations and were willing to pay a reasonably higher price than that of conventional plastic. The product manufacturers were tolerant, as long as changing to bioplastic packaging brought other benefits such as enhancing their brand or being highly relevant to their sustainability agenda, and the new packaging did not affect the primary product quality.

Besides the customer tolerating the limitations of the bioplastic packaging, the supplier must also provide substantial support for the customer. These supports are related to technology, technical solutions, and advice related to implementing the bioplastic packaging, but not highly interconnected to the customer's business, such as co-locating the packaging production with the customer or integrating the information system into a supplier-customer enterprise resource planning (ERP). ChemiCo and SoluCo offered sustainable packaging solutions to product manufacturers, communicating how product manufacturers could improve their sustainability practice by using bioplastic packaging, and explaining the potential commercial benefits with a data-driven approach. ChemiCo assisted product manufacturers by supplying data and marketing communication materials, enabling the product manufacturer to adjust the brand image and consumer base and communicate the new packaging as a positive move towards sustainability. Converters usually provide a consultancy related to material selection and packaging design, as shown in the BiopackCo, ServpakCo, TeaCo and ChocolateCo cases.

Unlike in other cases, CbagCo did not provide packaging customisation, and the customer bought the licence and accepted the bioplastic packaging as it is. In return, CbagCo supported the customer by providing training to operate the equipment, and gave advice and technical solutions to ensure the customers could produce the CbagCo bioplastic carrier bag using materials from CbagCo. This training is considered to be one form of knowledge-sharing activities, in which CbagCo transferred know-how to the customer. Moreover, CbagCo also transferred some carrier bag buyers to the licensing customers and allowed them to copy, modify and multiply the conversion machine free of charge. This support allowed CbagCo's customer to generate sales and grow their business from bioplastic packaging.

In simple and narrow co-innovation, the converters have more opportunities to support and build inter-connected activities with the product manufacturer, usually the small and medium-sized companies. The product manufacturers, such as TeaCo and ServpakCo, relied on their converters as manufacturing partners and co-innovated with converters instead of biopolymer producers. Product manufacturers such as TeaCo and ChocolateCo were small companies and did not interact with the biopolymer producers. These companies considered that converters were very supportive and always provided solutions to packaging applications; therefore, interdependence was built up over time. Further inter-connected activities can be seen in ServpakCo that supported its business customers in marketing communication and waste management.

Based on the descriptions above, joint activities become a fundamental element that builds co-innovation. Joint activities are carried out at the later stage of product development, in which the prototype and small-scale operation are ready. Customer involvement in the product development appears in the concept exploration, iterations and user validation regarding the packaging application. Knowledge sharing and extensive mutual adaptation occurs reciprocally, which is valuable for improving the material, packaging, and process, and facilitates higher tolerance to accommodate different bioplastic packaging characteristics or the limitations of conventional plastics. The supplier must provide support for the customer to implement bioplastic packaging in the production and its wider operations successfully; respectively, these supports seem to correlate to customer tolerance to the limitation of bioplastic packaging compared to the conventional plastics while having to pay a higher price. Figure 21 illustrates and summarises supplier-customer joint activities in a dyadic relationship.

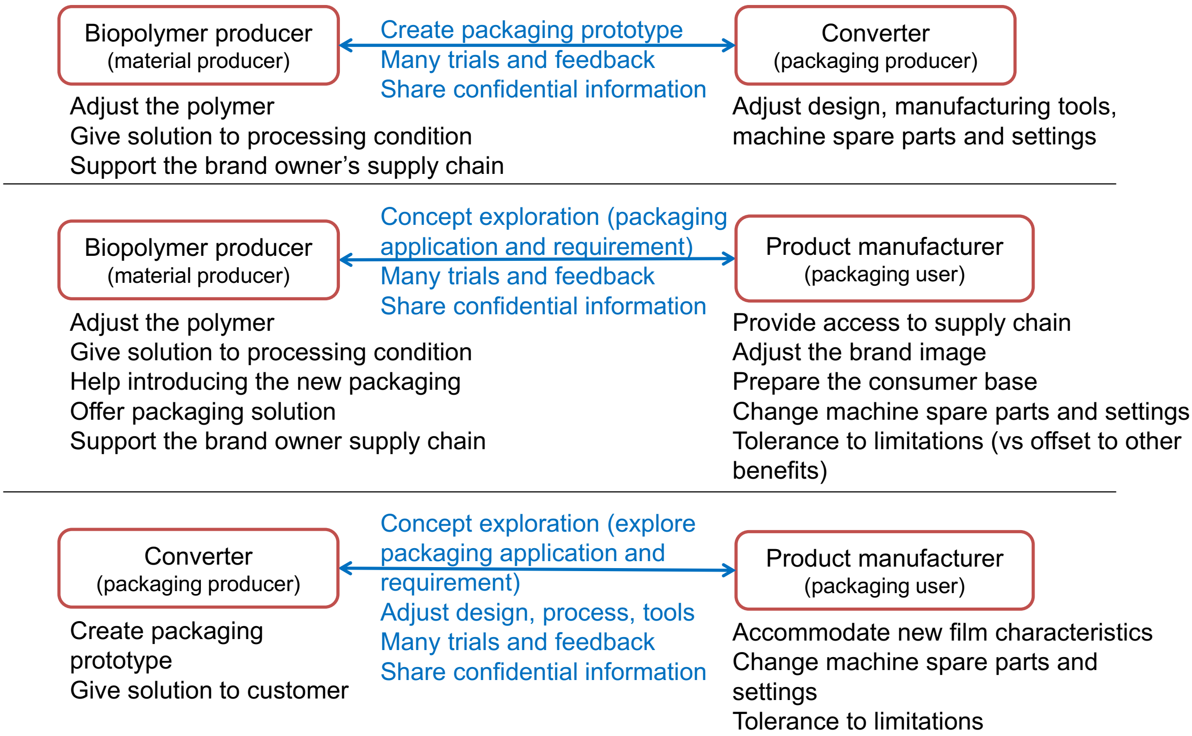


Figure 21 Supplier-customer joint activities seen in a dyadic relationship

5.2.2. Joint resources based on sharing the existing assets

All co-innovation partners dedicated tangible and intangible resources as their contribution to the development project. The evidence from almost all cases indicates that knowledge, technology and expertise are the essential resources jointly shared among partners. The biopolymer producers shared their technology, expertise and invested more resources for further material development, such as a dedicated team to handle the project with the product manufacturer. CoffeeCo, DrinkCo and NutriCo, who co-innovate for material development, stated that biopolymer producers shared their expertise and novel technology in material development. Large product manufacturers such as DrinkCo and PharmaCo also shared their expertise in product commercialisation and knowledge of the industry in which the packaging is used. Meanwhile, the converter's expertise in packaging manufacturing was also critical in the co-innovation to improve the manufacturing process and highly valuable for the biopolymer producer to improve the material. Ultimately, adding partners with complementary expertise, such as converters, machine suppliers, and testing laboratories, would speed up the development process.

Co-innovation in the extensive and complex project requires substantial financial capital but joint resources depend on the product manufacturer's ability to invest a certain amount of financial capital into the development project with the biopolymer producer. The biopolymer producers had invested enormous resources for the initial material development before co-innovation and expected a financial contribution to the initial cost from the co-innovation partner. The DrinkCo and ChemiCo cases showed that the biopolymer producers received financial support from product manufacturers to build R&D facilities and pilot plants. In the SoluCo case, the product manufacturer paid a part of the development cost to obtain exclusive use of the material. In the ConveCo, DrinkCo, NutriCo and PharmaCo cases, the product manufacturers, who were industry leaders, invested significant financial capital in the material development project to gain access to the material and obtain exclusive rights to use the new packaging material and receive joint IPs.

A unique co-innovation mechanism was found in the CbagCo case. The biopolymer producer covered all the initial development costs and built specific converting machinery for its material. Accordingly, the converter was required to buy a licence from CbagCo to produce CbagCo's bioplastic packaging. CbagCo realised that the biopolymer could not work straight away in the existing machine and built a specific machine to support the customer in manufacturing CbagCo's bioplastic material. This machinery was free to copy, multiply or modify by the customer, hence promoting more production and use of bioplastic carrier bags. This strategy was intended to eventually penetrate the market in Indonesia.

All partners contributed resources for the trials, such as allocating personnel, machine time, and materials for the actual production trials. Before implementation of the packaging, all partners provided resources for the trials. The biopolymer producer provided material samples and their engineers or technical experts; the converter contributed hours of machine time, including operators and additive materials; the product manufacturer provided the product to be packaged using bioplastic packaging and covered the machine time as the converter; all partners allocated a dedicated team to handle the project. Trials were carried out on the converter and product manufacturer facilities; thus, machine time and personnel were allocated to run the trial at each site. There was also limited evidence of sharing the cost of product development and trial costs, each partner being responsible for the development or the trial costs at their facility. Nonetheless, resources for the trials were considered a big capital spend, and FoodpackCo confirmed that testing at the conversion machine cost significantly more than the raw material. On top of that, trials at the customer's actual production facility were important to test the compatibility of the material in the customer's machine; however, FoodpackCo conducted the testing at the machine supplier instead of involving the customer for this trial.

Joint resources combined and shared access to the resources already owned by each partner, and there was little evidence of a shared investment to build specific assets for the project. For example, BarrierCo relied on their expertise and R&D to develop products from the technological aspect, while the customers provided access for trials at their existing production facility, such as using real production facilities, and covered the machine time. FilmpackCo did not contribute to the technical aspects of material development but contributed resources for trials at its production facility. While SoluCo and ChemiCo worked at each partner's existing production facilities, the partners modified tools to work with the new material with different technical properties rather than changing the prime machinery.

However, there is also limited evidence of idiosyncratic assets built from resource combination, exchange or co-investment from co-innovation partners; for example, co-location, building a specific physical asset such as customisation of machines and equipment among partners. Instead, the bioplastic packaging must be able to work on the existing machines and production systems, and as indicated in a number of cases, many converters and product manufacturers are reluctant to change their existing production system. The TeaCo, ChocolateCo, CoffeeCo, PharmaCo, and ConveCo cases indicated limited joint investment to build facilities or buy special equipment that requires a significant amount of financial capital. When necessary, product manufacturers would buy the new tooling or parts needed to fit with the bioplastic packaging, due to its different technical properties compared to those of conventional plastics.

An anomaly in joint resources was found in several cases; first, the ConveCo case, in which the product manufacturer implemented a significant change to the process and machine when applying biodegradable teabags, due to the change from heat sealing to adhesive. ConveCo was confident that changing to the biodegradable teabag was far more suitable for their instant tea product line than the re-use and recycling option. The decision to implement significant change was taken after carefully considering the overall environmental impact, suitability to ConveCo's sustainability agenda and the commercial benefits. Another case is ServpakCo, which co-invested with the converters to purchase tooling, machine parts, and machinery. In this case, the product manufacturer and converter had built a strong partnership over time and were confident of the potential of this investment.

Figure 22 depicts the supplier-customer joint resources in a dyadic relationship. In short, the case study signifies the importance of the intangible joint resources, which include a team of experts, engineers and operational officers, production unit, R&D investment, and most importantly, complementary expertise, network and capabilities. Joint resources in the tangible assets are limited to sharing and using the customer's existing real production facilities for trials. In the complex or extensive packaging development project, the product manufacturer invested a significant amount of financial capital in contributing to part of the initial development cost, building an R&D facility and pilot plant. However, in a smaller scale project, the customers did not contribute to these R&D investments, and their contributions were mainly related to machine time, using their production facilities for trials and sharing information for designing the packaging. Lastly, investment in building dedicated tangible assets for bioplastic packaging was made possible based on the project's feasibility, commercial advantages, and the packaging potential for long-term application. Further understanding of factors in the industry behind the limited creation of the idiosyncratic assets is presented in Section 5.4.

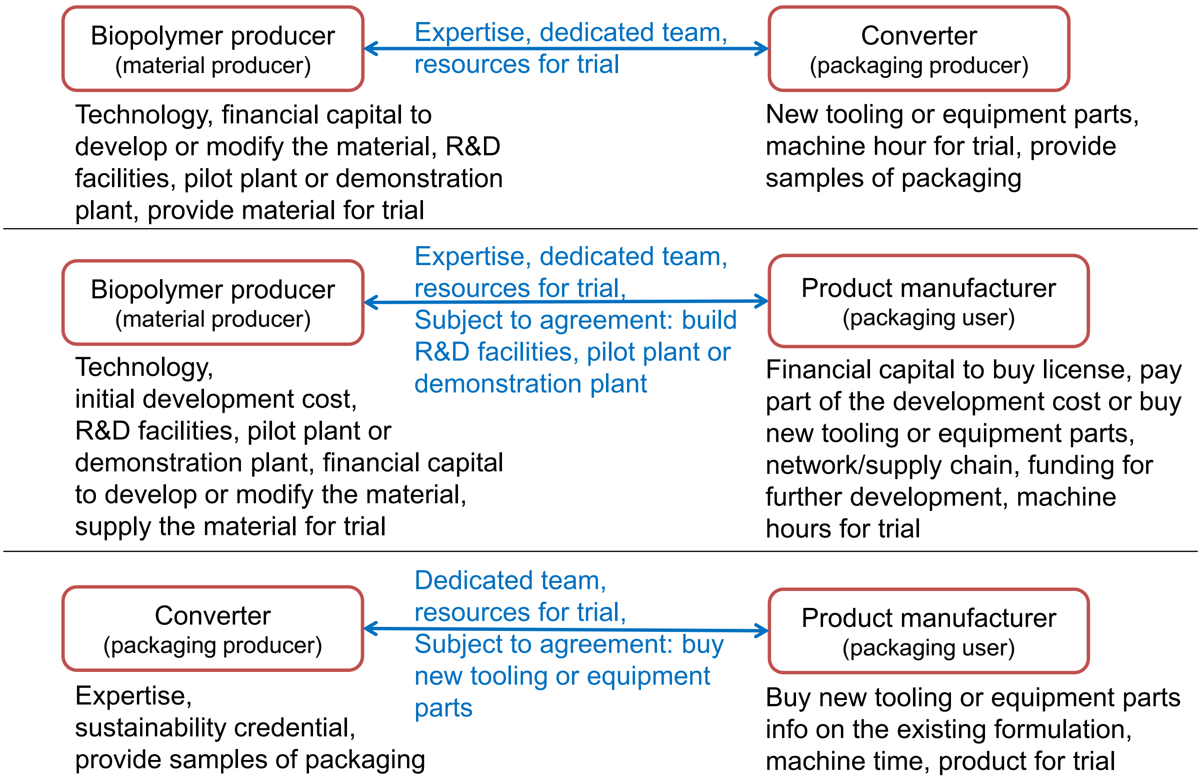


Figure 22 Supplier-customer joint resources seen from a dyadic relationship

5.2.3. Relationship management: approaching and working with new partners

The findings related to the relationship management theme showed the importance of partnership development. Approaching potential product manufacturers, especially industry leaders, opens the opportunity for extensive co-innovation that will generate material, packaging and process improvement, and proceed to scale-up and commercialisation in an industry. SoluCo and ChemiCo approached the customer by demonstrating packaging solutions using their materials, and at the same time, the product manufacturers were looking for packaging solutions and new technology. Co-innovation occurred when the solutions offered by biopolymer producers fitted the product manufacturers' needs. Therefore, the biopolymer producers needed to precisely target their potential partners since the material is limited to certain packaging applications and, as shown in the SoluCo and ChemiCo cases, the biopolymer producer presented a business case tailored specifically to each potential partner. In selecting partners, biopolymer producers prioritised partnering with product manufacturers that showed commitment and the capability to support the project. ChemiCo noticed that not all product manufacturers had the capability to collaborate with them, hence prioritised partners with similar vision and innovative focus, and having the ambition to be the first to use innovative bioplastic packaging.

Similarly, product manufacturers were very selective in choosing partners. Summarised from industry leaders such as ConveCo, DrinkCo, NutriCo and PharmaCo, partners have successfully developed materials on a small scale and have the capability to further develop the material to meet industrial-scale needs. The product manufacturer assesses the project's feasibility presented through a comprehensive business case by the material producer. Biopolymer producers who co-innovate with industry leaders were capable of accommodating the complexity of the product manufacturer's operations, including meeting the logistical needs and quality standards, compliance with regulations, supporting the product manufacturer's sustainability agenda, for example by reducing carbon emissions through using plant-based material, and optimising the recycling scheme.

Product manufacturers engaged in co-innovation for material development and will also engage with other partners, such as converters, independent labs and partners along the supply chain into the partnership. The goal is to build complementary capabilities and synergised projects among partners. In the SoluCo and ChemiCo cases, the product manufacturer invited the converter that supplies their packaging in the co-innovation to complement expertise in packaging manufacturing; thus, the material being developed can be compatible with the converter's process. PharmaCo also invited third party labs to test compostability, and the food safety of packaging. In the SoluCo case, the converter was initially not interested in working with SoluCo; however, the product manufacturer had the power to influence the converter to become involved in the project and change the converter's perspective on the potential of developing bioplastic packaging.

In all cases, biopolymer producers managed the collaboration and relationships with partners following an agreement. The co-development agreements with SoluCo and ChemiCo governed equal contributions from each partner, the project timeline and deliverables. Because the development project involves specific information from each partner and will result in breakthroughs in bioplastic packaging, all partners also signed an NDA. According to SoluCo, working together following the agreement provided clear directions and pushed the development forward to produce agreed deliverables. CbagCo arranged cooperation with an external converter through a licensing agreement to produce plastic bags using CbagCo material. In the agreement, the converter could purchase a set of production equipment specially designed by CbagCo to process the materials, and the converter was free to reproduce, modify, or improve the machinery.

Relationship management in routine communication, coordination of development or trial plans, educating users and managing their expectations are all essential for maintaining and developing a fruitful co-innovation. All cases showed routine communication through meetings to coordinate expectations, follow up on problems and discuss solutions. The application of bioplastic packaging is new and not easy, so communicating this to customers at the beginning of the project is vital to gain the agreement and commitment of all parties, as in the example of the BiopackCo case. TeaCo and ServpakCo communicate daily with the converter because the converter is a manufacturing partner, so there is no difficulty building intensive communication for packaging development purposes. Nevertheless, regular meetings and communication to track product development progress occurred in every case.

There is a missing link, however, because customers do not fully understand how bioplastic is applied or the limitations of this material, while biopolymer producers do not fully understand the details of the production process and large-scale machinery. Therefore, managing the consumer’s expectation and educating users is crucial. The converters found that many customers tend to ask for products, the performance and price of which are similar to those of conventional plastic. Accordingly, in the BiopackCo case, managing customer expectation at the beginning of the project was essential as the customer expected the bioplastic packaging to work well as the conventional packaging. In line with that, the small/medium product manufacturer cases showed that the converter plays a vital role in promoting bioplastic packaging, explaining the extent to which customer expectations can be met from the bioplastic materials available in the market.

Dealing with the customer is not as easy because the bioplastic packaging and its material are new and unique. Almost all cases exhibit how the suppliers manage knowledge flow and educate the customers regarding environmental knowledge, how to work with the unique properties of bioplastic packaging and what they are. CbagCo provided training in operating the machinery to the converter, and BarrierCo provided a systematic guide during the project handover; this process helps users understand and continue using bioplastic packaging. CbagCo educated the customer to produce plastic bags themselves, convinced the customer of the sustainable packaging potentials in Indonesia and supported the customer's sales by transferring buyers who used to buy packaging from CbagCo to the converters. CbagCo managed to maintain the customer dependence, by continuing to use CbagCo's material, and strengthened its own position as a leading biopolymer supplier in Indonesia.

Product manufacturers deemed agreement and commitment to be very important in co-innovation. For example, DrinkCo, NutriCo, ConveCo and PharmaCo arranged a formal agreement that included development stages, timelines and deliverables. Commitment in co-innovation was apparent, especially in problem-solving; for example, when there were problems or delays in achieving deliverable targets agreed upon in a formal agreement, the product manufacturer understood the challenges of developing novel materials and was committed to working together for a resolution.

Other examples of strong commitment are found in TeaCo, ChocolateCo, CoffeeCo and ServpakCo, as they work together with the converter to supply packaging or as manufacturing partners. The converters showed their commitment to support small product manufacturers by providing the best possible support to help the product manufacturer use bioplastic packaging. For example, the converter allowed minimum orders that suited ChocolateCo's turnover as a small business. In the ChocolateCo and ServpakCo cases, the converter adjusted the size, colour and standard to meet the requested design. Another example of supplier commitment is when CbagCo in collaboration with retail shops and hotels launched environmentally friendly single-use packaging. CbagCo, as a biopolymer producer, also produced small-scale packaging for retail and hotels to educate, penetrate the market and build the consumer base, then approached the converter to buy the licence and transferred the consumer base to the converter.

Despite communication, openness and honesty being essential for co-innovation, not all customers are highly cooperative. The converters, such as FilmpackCo, BarrierCo and BiopackCo faced challenges when interacting with customers, for example, to meet the deliverable timeline agreed with the customer, while FilmpackCo faced a demanding customer that eventually did not continue the collaboration. In all cases, business motives were underlying the company initiative to adopt bioplastic packaging, which influenced customers' attitude to the co-innovation. BiopackCo was involved in close collaboration, considering the exchange of confidential information throughout the collaboration and efforts to work through the problem together. However, some customers in the BarrierCo, CbagCo and FilmpackCo cases retained confidential information, such as their existing material and equipment details, which are essential to develop the right product; hence suppliers must put greater effort into finding a way to develop the product.

In general, co-innovation for bioplastic packaging between product manufacturers and material producers or converters will be developed for long-term relationships. Co-innovation between the product manufacturer and material producer occurs because product manufacturers see the long-term material potential. However, DrinkCo, ConveCo and PharmaCo also continue to explore new, alternative, sustainable packaging, and this can affect the continuity of co-innovation that is already running. Consequently, the ongoing co-innovation could be stopped because the material being developed was no longer interesting for the product manufacturer, as seen in the ConveCo case.

On the other hand, simple and narrow co-innovation indicates a stronger interdependence and long-term relationship between the product manufacturers and converters. The collaboration between ChocolateCo and the converter was likely to be developed in the long-term because ChocolateCo was very impressed with the support provided by the converter, even though ChocolateCo was currently classified as a small business. High interdependence of product manufacturer and converter was seen in TeaCo and ServpakCo, which rely on converters as their manufacturing partners. TeaCo and its converter planned to explore new materials together, and if there were new, more efficient materials, TeaCo would attempt to maintain the relationship with the converter rather than change to a new converter. Meanwhile, ServpakCo managed relationships with material producers without converters and focused on cooperation with converters in packaging development.

In summary, co-innovation for developing bioplastic partners is highly dependent on relationship management. Partnership development is essential, and it includes the approach to a potential partner, partner selection and establishing a co-innovation agreement. Partner selection is based on a business approach, as the suppliers want to market their products, and the customers are looking for a solution for sustainable packaging available in the market. Biopolymer producers choose key customers, such as product manufacturers that are industry leaders whose packaging fits the biopolymer producer's material. Large product manufacturers implement a stringent filtering mechanism and have more power to determine the co-innovation direction and continuation, which is inferred as an unequal partner position. Regular communication, educating the customer, and managing expectations are essential for building fruitful relationships in co-innovation in bioplastic packaging. Commitment to the project facilitates problem-solving and successful implementation for the customer.

5.2.4. The absorptive capacity: a mediator to seize more benefit

The absorptive capacity from the biopolymer producer cases indicated what and how information is acquired from partners, new knowledge built during the interaction and its implementation for improvement. The biopolymer producer looked to find useful information for material development. SoluCo and ChemiCo, which were engaged with product manufacturers, looked for information on critical features of the customer's process and needs, regulation and law, and price expectation. SoluCo received complete access to the product manufacturers' technical and commercial teams, and a broader supply chain through co-innovation, then acquired information on the ongoing development project, recent findings, and technology. This information built a new understanding for SoluCo and opened possibilities of synergising the project and other partners' technology. For ChemiCo, information on the timeline of the development was essential to produce deliverables. ChemiCo and SoluCo obtained information from the product manufacturer on countries where the packaging would be applied, the regulations therein, such as recycling and food contact approval. Accordingly, these requirements were considered during the development to ensure compliance when the packaging was implemented in different regions or countries. Interestingly, CbagCo, which conducted material development internally, had obtained information for product development that was from external references in chemistry and mechanics. CbagCo also learned about additive technology from suppliers and followed updates on technology developments and similar products from exhibitions and literature research.

Compared to ChemiCo and SoluCo, there appears to be a difference in the accumulation of new understanding and its exploitation into advantages. ChemiCo and SoluCo learned the product manufacturer's exact need, understood more about the industry, the industry leaders' operations, and communicating the new bioplastic packaging to the end-users. All this new knowledge was used to improve the material, speed up the project, increase adaptability to meet various requirements and work with a wider supply chain, as well as different customers. In the CbagCo case, the new understanding was accumulated to improve the material and conversion process of a smaller scope than SoluCo and ChemiCo. CbagCo customers looked for environmentally friendly packaging driven by the Indonesian government regulations on restrictions on single-use packaging. The converter, that also became CbagCo's licensing customer, learned about the bioplastic conversion process from the training, then combined it with their expertise in conventional plastic manufacturing to improve the machinery and bioplastic packaging production process. However, this new knowledge was not shared back with CbagCo because they wanted to maintain this advantage themselves exclusively.

The absorptive capacity in the converter cases indicates similarities regarding the detailed information needed for product development, such as the technical specifications of existing packaging, machine, process and requested specifications, as in FilmpackCo, BarrierCo and BiopackCo. Feedback, especially during the trial with customers, is also essential to improve products and provide appropriate solutions. Information from other external parties also contributes to product development and encourages co-innovation. From the position of the customer, BiopackCo showed information regarding a similar product, and existing product development from various external sources, such as literature, patents, media and exhibitions, were also important for product development. Meanwhile, from the customer side, external information such as pollution, market pressure and bad press encouraged FilmpackCo's customers to seek packaging solutions actively.

The most crucial assimilation process in FilmpackCo, BarrierCo and BiopackCo occurred during visits and the trial at the customer's production site because on this occasion the supplier learned to develop and improve the product so that it could be applied and the customer learned to apply the new packaging to the existing system. In contrast, FoodpackCo conducted trials at machine suppliers that sell conversion machines like those of the customer, so there was no need to involve the customer for trials. During the trial, FilmpackCo, BarrierCo and BiopackCo showed that feedback from customers was critical to improve and provide solutions. Conversely, as seen in all cases, customers learned material characteristics and how to apply them in their production process. Constraints in the supplier-customer assimilation, as shown in FilmpackCo, BarrierCo and BiopackCo, occurred when the customers did not share the required details of information due to confidentiality issues. Consequently, this slowed the product development because the supplier needed to place more time and effort into finding alternative solutions. In addition, regular meetings also facilitated mutual learning, updating on progress, solving problems, and making decisions in those companies.

The information acquired from the customer and interaction between the converter and customer has generated a new understanding of bioplastic packaging. The understanding on the converter side is how new materials can be applied to existing processes for the customer, how to provide the right solution for various problems and to improve the product performance to meet the customer's expectations. The converter learned about working with various parameters, making adjustments and changes to the material, process or machine to make the product work. However, each company also established a specific new understanding; FilmpackCo became aware that the current situation for bioplastic packaging was a 'tangled web' but projected to become urgent in 10 years, while BarrierCo and BiopackCo understood more product parameters. Additionally, BarrierCo created detailed systematic recording and a database for future reference. On the other hand, the understanding on the customer side was about working with bioplastic material and/or packaging, its unique characteristics and limitations and, more importantly, how to manage through adjusting the conversion process or tools.

New understanding on the converter side is implemented into product improvement and providing better solutions for customers to serve the broader market. BiopackCo implemented the new knowledge to improve product performance and meet the customer's expectations, as well as apply good results to the next product development project. On the customer side, exemplified by FilmpackCo, BarrierCo and BiopackCo, some customers have shown more willingness to adapt and change after working together or having interaction with the supplier through trials.

The absorptive capacity also indicated how the product manufacturer acquires information from the partner and other external sources. In all cases, product manufacturers are always looking for information on available technology or solutions in the market, and they look for better and suitable alternatives. Product manufacturers that were also industry leaders such as PharmaCo, DrinkCo, NutriCo and ConveCo reviewed information comprehensively, starting from potential partners, commercial aspects and price expectations. Smaller companies such as ChocolateCo and CoffeeCo looked for bioplastic packaging suppliers that provided packaging made of a certain material, a suitable price and minimum order quantity, often far below the industrial level.

Next, the absorptive capacity is indicated by how the product manufacturers learn from biopolymer producers about new technologies and working with bioplastic materials, then exploit their new understanding for improvement. DrinkCo learned about developing new bioplastic materials and technologies without researching the early material development. Product manufacturers such as DrinkCo and PharmaCo shared much information with biopolymer producers regarding industrial aspects, product commercialisation, various regulations related to packaging in various countries, detailed product manufacturer needs from technical aspects, supply chain, logistics, and many others. From here, the biopolymer producers understood the critical aspects for the new materials to be applied to industry and to be scaled up. A comprehensive understanding of the industry enabled the biopolymer producers to improve materials to meet complex requirements. Even though all product manufacturers determined the requirements that must be met, it seems that the requirements will be increasingly complex for a product manufacturer who is also an industry leader. This situation was not found in co-innovation between product manufacturers and the converters because packaging applications and requirements were simpler, as in TeaCo. Alternatively, product manufacturers and converters finally accepted packaging limitations and found ways to overcome them by adjusting the packaging design, such as in ChocolateCo and ServpakCo.

The flow of knowledge and its exploitation among the biopolymer producer, converter and product manufacturer were concluded from comparing the absorptive capacity. As seen in Figure 23, the biopolymer producers are expert in bioplastic technology, the converters are expert in packaging manufacturing, and the product manufacturers are highly knowledgeable about the industry. When viewed from the development of bioplastic material, knowledge from the product manufacturer flowed to the biopolymer producer, as the product manufacturer shared their operations, supply chain and extensive requirements for the future material. Since the material must be compatible with the existing packaging manufacturing process, the converter shared their packaging expertise, helped with additives, designs and trials on the machinery. With all this knowledge, the biopolymer producer built a new understanding to improve the material, scale-up and commercialise the material. For the converter, knowledge from the biopolymer producer enabled them to work with bioplastic material in different parameters and offer a bioplastic product range to customers, thus increasing their manufacturing capability and expanding the market. Furthermore, the product manufacturer learned about new bioplastic technology, sustainability from the biopolymer producer or the converter and would use this knowledge to look for better technology and leverage the commercial benefits from using sustainable packaging.

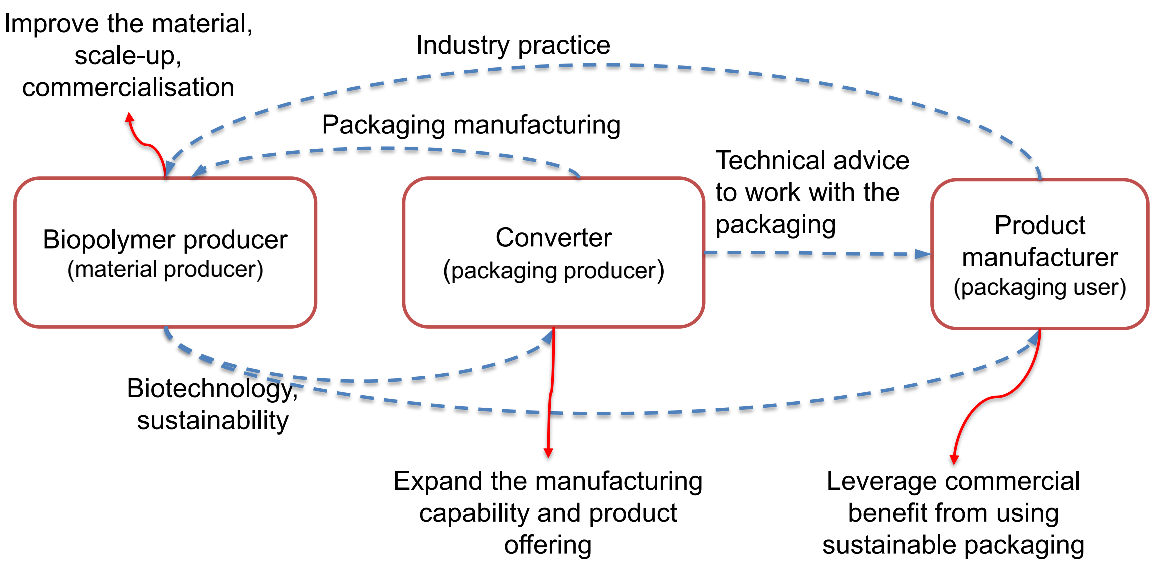
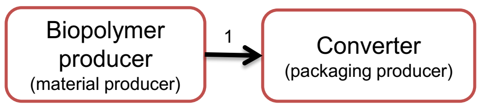
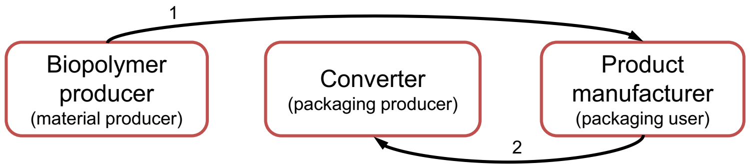
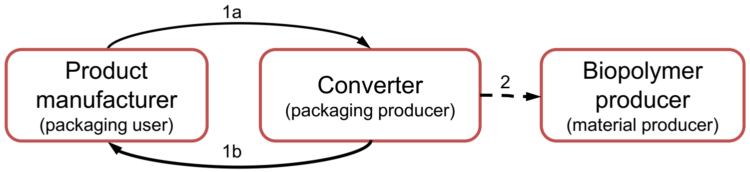
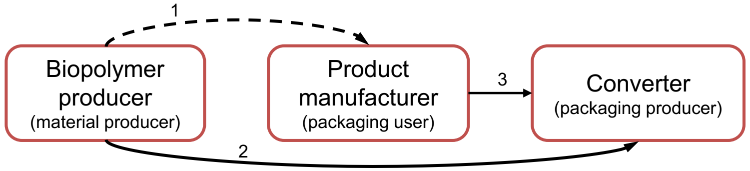


Figure 23 Flow of knowledge in co-innovation and its exploitation

5.2.5. Possible approaches to co-innovation

There are four approaches to co-innovation based on different purposes, as seen in Table 26; first, co-innovation to develop a bioplastic packaging prototype up to production level on a small scale. In this approach, the biopolymer producer collaborates with the converter to develop a bioplastic packaging prototype, as seen in BarrierCo and ChemiCo. BarrierCo is an expert in packaging barrier technology and was approached by a biopolymer producer to improve bioplastic packaging performance. In this project, BarrierCo added its technology to provide high barrier properties, in which bioplastic packaging typically does not perform as well as conventional plastics. ChemiCo co-innovation with the converter aimed to improve the material for implementation in a small-scale manufacture, as in a pilot plant. This collaboration improved the material mainly from the technical aspect during the processing and performance of the packaging. A converter such as BarrierCo owns specific technology, which would create a distinct advanced feature of bioplastic packaging when combined with bioplastic technology; however, most converters are expert in packaging manufacturing but do not add specific technology or involve material development.

Table 26 Different approaches to co-innovation

Approaches to co-innovation		Aim	Possible outcomes	Cases
I		To develop bioplastic packaging with new material	Improved material, improved packaging application, joint IPs, exclusive supply and right to sell the co-developed packaging	ChemiCo, BarrierCo, CbagCo
II		To develop complex and extensive bioplastic packaging application	Improved material, improved packaging application, scale-up, meets comprehensive requirement (industry leader and its supply chain), exclusive use of material, joint IPs	ChemiCo, SoluCo, DrinkCo, NutriCo, PharmaCo, ConveCo
III		To develop bespoke bioplastic packaging in a less complex and smaller project	Bespoke packaging application, buyer-supplier interdependency	FilmpackCo, BarrierCo, BiopackCo, FoodpackCo, CoffeeCo, TeaCo, ChocolateCo, ServpakCo
IV		To penetrate plastic packaging market	Market penetration, buyer-supplier interdependency	CbagCo

→ Main engagement
--→ Temporary

Second, the key approach to further developing complex packaging and extensive co-innovation usually involves industry leaders. In this approach, the material producer viewed the best approach as being to the product manufacturer, and reciprocally, the product manufacturer, who is also an industry leader, looked for new technology and approached the biopolymer producer. When co-innovation was agreed, the product manufacturer would bring in more partners, such as the converter, machine supplier, testing laboratories, or other partners along the supply chain. As confirmed by ChemiCo, SoluCo and large product manufacturers, who are also industry leaders, more partners allowed a higher synergy of complementary expertise from each partner. This co-innovation aims to implement bioplastic packaging for one of the industry leader's products and accommodate the industry leader's detailed and broad requirements. Co-innovation is likely to bring material improvement, adaptation along the supply chain, innovative packaging application, scale-up to industrial scale, and wide adoption of bioplastic packaging. However, these outcomes need further review in the future because the co-innovations were ongoing at the time of data collection in this study.

The third approach appears in co-innovation for developing bespoke packaging, which occurs in small or medium-sized product manufacturers' cases. In this approach, the product manufacturer looked for a sustainable packaging solution and contacted the converter or vice versa; the converter approached product manufacturers to sell bioplastic packaging. The product manufacturer requested bioplastic packaging with specific performance and design requirements, such as size, shape, barrier properties, and thickness, which are usually manageable by the converter. This approach is confirmed from the converter cases, in which the converter made every effort to accommodate their requirements, helped in the application, solved problems during application and contacted the biopolymer producer when necessary to obtain more technical advice. In the BiopackCo case, the converter involved the biopolymer producer in improving specific clarity and strength of the bioplastic material to meet the customer's expectation. This approach also illuminates the fact that the biopolymer producer's approach to the converter was not well responded to until the converter clearly saw the business potential, such as customers' enquiries for sustainable packaging or future demand, as seen in the SoluCo case and some of the converter's cases; afterwards, the converter looked for a material supplier and produced the bioplastic packaging.

The fourth approach is a unique finding showing a biopolymer producer approach to market penetration, especially for pioneers in the undeveloped bioplastic market. In this approach, the biopolymer producer produces packaging through an internal converter that functions as a pilot plant or demonstration showroom, then sells the product to product manufacturers and other packaging users. After that, the biopolymer producer approaches the external converter to buy the licensing programme to produce packaging and use the material exclusively. The biopolymer producer would also divert some of its packaging users to converters to help establish sales. If the bioplastic packaging market develops, the biopolymer producer will switch its focus from producing bioplastic packaging to producing bioplastic material and supplying the converter.

5.2.6. Summary of the co-innovation mechanisms (fulfilling RO2)

Co-innovation for bioplastic packaging involves the biopolymer producer, converter and product manufacturer through joint activities, joint resources and relationship management as an integrated mechanism. Joint activities occur at the later stage of packaging development. Extensive mutual adaptation among partners and providing support are essential to implement the bioplastic packaging at the customers. The joint resources mechanism emphasises sharing the existing tangible resources, while co-investments to build dedicated assets for bioplastic packaging are limited unless the bioplastic packaging development shows a high feasibility to scale-up and commercial benefits in the future. Relationship management is essential to start the collaboration and determine a long-term collaboration in simple and narrow co-innovation. However, unequal partner positions appear in the extensive and complex co-innovation, in which the industry leader implements a stringent partner selection mechanism, standards and comprehensive requirements, and has the power to bring in more partners to expand the project's capabilities. Accordingly, although owning the technology, the biopolymer producer would have to accommodate the industry leader's complex needs as much as possible and share partial ownership of the technology with the co-innovation partners.

From the joint activities and joint resources mechanism, sharing intangible assets in the form of information, knowledge and complementary capability is highly essential to advance bioplastic packaging. Complementary knowledge, as intangible joint resources assimilated in joint activities and transformed into combined knowledge, improves the product and process, and continues into a successful implementation. This mechanism indicates a successful co-innovation in developing bioplastic packaging. The findings indicate different levels of absorptive capacity at the supplier and customer. Moreover, stronger supplier absorptive capacity enables improvement in the material, packaging, process and support that better accommodates the customer's need for the packaging to work in the industry. Thus, a stronger supplier absorptive capacity promotes more successful co-innovation.

The biopolymer producer, converter and product manufacturer interact differently for different situations, indicating different co-innovation mechanisms are applied for different purposes. Four approaches are summarised in Table 26, which also details the process of co-innovation in a certain sequence to achieve successful engagement and product development. The key approach to extensive and complex co-innovation requires collaboration among the biopolymer producer, converter, product manufacturer, and partners from the product manufacturer's network. This approach allows co-innovation of advanced bioplastic material and packaging, which also applies to an industrial scale. As the product manufacturers in this co-innovation are mostly industry leaders with significant influence on consumers, market and supply chain, this approach is likely to promote the wider adoption of bioplastic packaging. However, approaching an industry leader takes enormous effort to prepare the bioplastic material to a certain level, demonstrate the project's feasibility based on massive data, show a fully running pilot plant, and meet the product manufacturer’s detailed comprehensive requirements. Therefore, only a few biopolymer producers that have very high capability would cope with working with the industry leaders.

5.3. The outcome and potential relational rent from co-innovation

This section addresses RO3, explaining the biopolymer producer, converter and product manufacturer’s view regarding the successful bioplastic packaging developed through co-innovation. The cross-case analysis reviews the co-innovation outcomes through the measures defined in the initial framework and presents the outcomes that indicate relational rent and supplier-customer interdependence.

5.3.1. Advanced bioplastic packaging for wider adoption in industries

Co-innovation aims to apply the bioplastic material for a certain type of packaging and improve the material or packaging performance. In almost all cases, the performance expected by the product manufacturers is related to the packaging functionality, emphasising protection without affecting the main product quality. As the bioplastic packaging in the case study is mainly used for food and beverage products, it must maintain product freshness throughout its shelf-life. ChocolateCo explained that the barrier properties were crucial because a chocolate bar product is sensitive to external environments, such as moisture, and easily absorbs odours. In the CoffeeCo case, the packaging must keep the coffee fresh and work well in a coffee machine to provide consistently delicious coffee to consume, as their consumers prioritise product quality. ServpakCo explained that packaging must be durable to hold hot drinks or food, secure and not flimsy when held in the hand. A bioplastic packaging that has successfully worked for a certain product, such as beverages, might not automatically work for a different product, such as medicine, with a longer shelf-life; therefore, product manufacturers such as PharmaCo carefully re-tested the packaging to ensure the safety of the new packaging. Similarly, TeaCo required the packaging to meet food safety requirements, and NutriCo, which has superior products in the market, did not tolerate packaging that compromised product quality in order to protect its reputation.

Co-innovation has been proven to produce better product performance for bioplastic packaging. The barrier layer innovation shown in the BarrierCo case or glossy transparent flexible wraps, such as in the case of BiopackCo, illustrates that co-innovation has improved the product's aesthetics and delivered improved bioplastic packaging performance. Through co-innovation, suppliers are trying to meet customer expectations to produce bioplastic packaging that matches the performance of conventional plastic packaging. It ultimately succeeds in increasing the use and functionality, for example film sealed food trays for fruit have been developed with good barrier properties that keep the product shelf life similar to that of conventional plastic packaging. Also, a similar tray has been developed for fresh fish, which shows the increased variety of applications.

All biopolymer producers developed the bioplastic material from a renewable source, and at the end-of-life, ChemiCo’s material was recyclable, SoluCo’s material had two options, water-soluble and compostable, and CbagCo’s material was compostable. All cases showed that co-innovation did not create a novel material or change the material's source and end-of-life developed by the biopolymer producer. The important indicator related to sustainability performance is the extent to which the bioplastic packaging supports the product manufacturers’ sustainability agenda. All product manufacturers have a sustainability agenda aligned with the global agenda, such as targeting net-zero carbon, optimising recycling, waste reduction and a circular economy.

Subsequently, packaging from plant-based or renewable resources is developed or used by all product manufacturers in the case study as it is considered to have a positive impact on the carbon footprint. LCA was used in selecting material, and product manufacturers that are also industry leaders, conducted very detailed reviews of new material LCAs. Smaller companies such as TeaCo, CoffeeCo and ServpakCo conducted LCAs internally and ChocolateCo referred to the LCA released by the suppliers.

All converters and product manufacturers were concerned with the bioplastic packaging end-of-life. All product manufacturers considered how their consumers would use the packaging and avoided creating problems with the existing end-of-life infrastructure. Therefore, some product manufacturers, such as DrinkCo, NutriCo and ConveCo, optimised recycling; in contrast, ServpakCo, CoffeeCo, TeaCo and ChocolateCo chose compostable packaging. ConveCo explained that sustainable packaging must be fit for purpose, and prioritised reducing or eliminating unnecessary packaging or optimising recycling before going for a compostable option. CoffeeCo, TeaCo and ConveCo considered compostable packaging as suitable for their product because coffee pods and teabags would be mixed with coffee grounds or tea and not be possible to recycle. The same applied to foodservice packaging, such as cups and meal boxes that are difficult to recycle because they are contaminated with food scraps; thus, a compostable solution is appropriate. However, DrinkCo accessed new materials for water bottles that would be recyclable as this was considered more appropriate than compostable packaging.

Table 27 summarises the bioplastic materials commonly used by the product manufacturers in the case studies. Inferred from the cases, a product manufacturer could use more than one bioplastic material, depending on the product, and bioplastic packaging has been used for a product line and sold in a specific market. The large product manufacturer has not used bioplastic packaging for its entire range of products. The product manufacturer carefully selects packaging material that fits the purpose; for example, compostable tea bags and food tray would be mixed with food waste, therefore are best composted as recycling is unlikely to be possible. Large product manufacturers currently choose a limited market to launch the product using a certain type of bioplastic packaging; however, the participants did not share information on their plan to use the packaging for other products or expand the market. Despite that, compostable packaging has been critiqued due to problems at the end-of-life, such as limited industrial composting infrastructure and contamination of the current recycling, and therefore using compostable packaging could not properly solve the plastic pollution problem. ServpakCo and PharmaCo added concerns over the availability of the supply of PLA, as according to the participants, there are fluctuations and scarcity in its supply.

Table 27 The bioplastic materials mostly used by the product manufacturer

Material	**Format**	**Disposal**	**Case example and availability in the market**
PLA	Rigid and flexible packaging	Industrial composting	Used in some of ServpakCo, CoffeeCo, DrinkCo and ConveCo products. Available in the market
Cellulose	Flexible packaging	Industrial and home composting	Used in TeaCo, ChocolateCo, and some of ServpakCo products. Available in the market
PEF	Equal to PET	Recycling with other plastics	Will be used in some of DrinkCo, NutriCo and PharmaCo products. Not yet available in the market
PVOH	Flexible packaging	Compostable, water-soluble, works with recycling when used with other recycled material	Used in many products Available in the market
Paperboard layered with bioplastics	Rigid packaging	Compostable, recyclable	Used in ConveCo products, available in the market

Although co-innovation successfully improved product performance, there is limited evidence on how co-innovation reduces costs. Bioplastic packaging is about three to four times more expensive than conventional plastic packaging due to the cost of the raw material. All cases demonstrated that bioplastic must work with the existing manufacturing process and follow the plastic packaging supply chain, which means running the same process is unlikely to reduce cost significantly; adjustments are often required, such as changing tools and dies, creating additional cost. Product manufacturers could accept more expensive packaging than conventional plastic as long as it is offset by other benefits and they would have agreed on the feasible costs with the biopolymer producer or converter before collaborating. Product manufacturers expected several benefits from using bioplastic packaging, including commercial benefits, brand enhancement, achievement of their sustainability agenda, and the exclusivity of using materials or joint IPs for product manufacturers involved in material development, such as DrinkCo, NutriCo, PharmaCo and ConveCo. Besides offsetting the cost to other benefits, the product manufacturer would manage more efficient processes, logistics, or scale-ups to achieve economies of scale.

The innovation in bioplastic packaging co-innovation is considered to be incremental, which is indicated by creating a new or improved product or process. Co-innovation with product manufacturers enables the biopolymer producer to improve the bioplastic packaging performance by improving the material. Biopolymer producers involve the product manufacturer in the packaging concept development, which promotes their understanding of the product manufacturer's precise needs, and how the material and packaging should be fit for different products and work for the product manufacturer's, and its supply chain, operations. Furthermore, co-innovation with the converter helps to improve the technical performance of the bioplastic material and/or packaging, and compatibility with the existing manufacturing process through minimum adjustments. For example, converters such as BiopackCo would include additional materials during processing to improve the functionality while preserving biodegradability and compostability according to a certain standard, while co-innovation with a converter who owns a unique technology, such as BarrierCo, would also create an innovative solution for the bioplastic packaging functionality. Biopolymer producers such as SoluCo and ChemiCo shared IPs with the product manufacturer or converter who contributed to an innovative solution. The joint IPs were carefully managed in different areas of packaging design and application to protect the biopolymer producer's invention and avoid conflicting rights.

The case study shows that the converters and product manufacturers are reluctant to have significant changes to their operations and they expect results similar to conventional plastic packaging. The converters consider that changing the current system requires changes to the current infrastructure, which in turn requires substantial capital, a longer period to change, and other complexities due to how the packaging is used in broader aspects of life. Therefore, incremental innovation is more appropriate for the bioplastic packaging product development, considering its feasibility and higher acceptance by customers. Disruption to the existing system could be difficult to apply or be adopted because the current packaging supply chain is massive and well established.

From the case of the product manufacturer, converter and biopolymer producer, it can be concluded that the product manufacturer determines the output produced from co-innovation. Although biopolymer producers and converters try to ensure product excellence, the decision to accept bioplastic packaging that does not fully meet the requirements is back in the hands of the product manufacturer. Besides, different expectations are found regarding the bioplastic packaging that can be accepted by the converter and product manufacturer. The converter prioritises cost efficiency and expects the ability of bioplastic packaging to be like conventional plastic because the material will be processed in the same machine then launched to the market and have to compete with conventional plastics. Meanwhile, product manufacturers emphasise packaging to protect product quality when received, consumed or used by consumers. The product manufacturer does not tolerate the disadvantages of bioplastic packaging in this regard. Furthermore, product manufacturers are more tolerant of paying higher bioplastic packaging prices than those of conventional plastics because they consider other benefits generated from using bioplastic packaging, such as fulfilling the sustainability agenda in line with the UN SDGs (United Nations Sustainable Development Goals), commercial benefits such as fulfilling customer's sustainability expectations, increased brand, and exclusivity in using a specific material. Therefore, when a product manufacturer wants to use bioplastic packaging, the converter will try to meet the needs of the product manufacturer and work with the biopolymer producer to produce bioplastic packaging.

5.3.2. Relational rent and long-term interdependency from co-innovation

The product manufacturers decided the ideal bioplastic packaging would be suitable for the purpose, comprising functionality and convenience when used and disposed of by the consumers, maximising compatibility with and minimising problems to the existing waste stream. The product manufacturers also expect a continuous availability of the biopolymer supply. These expectations are currently challenging and inhibit many start-ups that are developing novel material because of at least one of the following problems: their material source is limited or difficult to extract; there is an inability to demonstrate the packaging prototype; suitability for purpose and application in many countries; and the inability to show a clear scale-up plan. Addressing these challenges would provide an opportunity to create a sustainable packaging solution difficult to imitate and should be preserved within a long-term interdependence through relationship management.

ChemiCo considered that co-innovation with industry leaders encouraged scale-up of the project to industrial size. ChemiCo and SoluCo were able to accelerate the material development because product manufacturers opened their supply chain networks to supply or be involved in projects. Product manufacturers that are industry leaders such as DrinkCo and NutriCo, could finally access the material to be developed according to their complex needs, then invited their converters and other partners in their supply chain to support the development project. Unlike those who did not co-innovate with biopolymer producers, the product manufacturers worked with and became more dependent on the converter; they have to accommodate the capabilities and limitations of the materials to use the bioplastic packaging either through improving the material or the existing bioplastic packaging range at the converter.

Supplier and customer engaged in two types of co-innovation: customised packaging or further development. Based on the case study, each of these types is described below:

Table 28 Types of co-innovation based on the case study

Customised packaging	Further development
Short term	Longer term
Limited customisation from the supplier's existing product lines. The trial aims to make the product work on customer's manufacturing system.	Develop, improve, add specific features, bioplastic properties, and performance (add barrier, layers, improve gloss and transparency, etc.)
Converter wants to use the biopolymer or product manufacturer wants to use the bioplastic packaging. Supplier drives the innovation and customer does not add technology. Buyer-supplier relationship or arms-length market transaction.	Converter adds technology while working with biopolymer producer.
The supplier may create supply dependence: difficulties for the customer to change to another bioplastic product because of difficulties in application and limited suppliers who can meet industrial quantity	Relational rent may develop. There are internal rents for supplier or customer, for example: converters expand product lines, market/customers

The further development purpose creates internal benefits and potentially relational advantages that bind supplier and customer, while the customisation purpose creates internal rent for either the supplier or customer but is unlikely to deliver relational rent. When there is little internal rent back to an individual company and no obvious relational rent, then reluctance happens. The customer or supplier will choose to move or stay in the buyer-supplier relationship. When there is no substantial benefit, then the customer will not using bioplastic packaging, for example, in a scenario where there is no government enforcing regulation, the profit margin is tight, and the market segment is sensitive to price and does not have strong concerns regarding plastic pollution. The conditions that promote or inhibit relational rent from co-innovation in bioplastic packaging are shown in Table 29.

Table 29 Conditions that create supplier-customer relational rent and interdependency

Conditions	Influence	Category
Enabler		
An existing close relationship between converter and product manufacturer since before co-innovation	Product manufacturer's confidence in and loyalty to the converter	Pre-condition
Performance of supplier: meeting deliverables, good progress, support customer's need during co-innovation, support customer's sales, support customer's marketing communication, waste management	Continuation of the co-innovation project, product manufacturer's confidence in and loyalty to the converter	Mechanism
Investment of a significant financial capital to biopolymer producer's project, co-invest in special machinery or tooling with the converter	Increase commitment to succeed in the co-innovation project, avoid loss	Mechanism
Contract agreement: long-term project, licensing	Bind partner to commit, support and deliver result	Mechanism
Co-development of a novelty, such as design, processing for specific packaging using novel material, application of a novel material in certain products	All partners want the benefit, such as joint IPs, increasing commercial benefits	Output
Exclusivity of selling/using innovative material	Bind supplier-customer relationship to a certain period, increasing commercial benefit	Output
Material potential in the future: use as the packaging, scale-up, commercialise, fit for sustainability agenda	All partners want the benefit in the future, such as enhancing the brand, selling the product	Output
Better material that comprehends broad complex requirement (technical performance, good functionality, reasonable cost, fit for supply chain, regulations, end-of-life)	Difficult to achieve and become the industry leader's interest, would be highly competitive in the market	Output
Availability of supply	Scarcity, disruption to packaging supply, risks running out of supply	Output
Inhibitors		

New and better technology or material	Continuation of the existing co-innovation project	External environment
New regulations	Existing material might be banned	External environment
Bioplastic has a very small fraction of the packaging market	Converter has less interest in or gives priority to bioplastic packaging	External environment

5.3.3. Summary of the outcomes from co-innovation (fulfilling RO3)

Co-innovation aims to implement bioplastic packaging for customers by improving the material, packaging and processes that address the consumer's needs. Co-innovation does not seem to significantly reduce the cost of bioplastic packaging; however, product manufacturers would accept the higher price in exchange for other benefits such as commercial benefits or improved sustainability credentials. In the extensive co-innovation projects, cost efficiency could also be managed through scale-up or by managing its operational processes more efficiently. Co-innovation does not create new materials, nor change the source of biopolymers, or the packaging end-of-life. However, co-innovation helps customers, especially product manufacturers, achieve sustainability agendas such as reducing carbon emissions, running a circular economy, addressing consumer's expectations regarding sustainability, and reducing plastic pollution. Co-innovation delivers novel product concepts related to the material application, such as a packaging design for new material, or an innovative application for a certain product, which occurs in the development of complex packaging in an extensive project scope. This achievement promotes each partner’s credentials in sustainability and innovation. The bioplastic packaging created from co-innovation potentially becomes innovation sustainability, which should be widely applied for the greater good; hence, joint IP must be managed to allow the sustainability impact to be spread.

The initial framework proposed that co-innovation would create superior bioplastic packaging measured by the product, cost, sustainability and innovation performance. Based on these indicators, the outcome from co-innovation in the case study is summarised in Table 30. A successful co-innovation will bring improved bioplastic packaging implemented for the customer and produce commercial benefits, especially for the customer. The commercial benefits that matter for the biopolymer producer are scale-up and commercialisation, for the converter it is having a new product offering, expanding the market, and for the product manufacturer it is brand enhancement, addressing consumer's expectations on sustainability and the global sustainability agenda.

Table 30 The outcome from co-innovation viewed from the initial framework

Indicators	Themes	Descriptions
Product performance	Improved functionality	Improved protection to the main product (barrier properties, heat resistance) easy to process, strength, time to heat-seal
	Improved processing	Improved machinery, machine settings, technical parameters, additional tools compatible with processing bioplastic material/packaging
	Improved aesthetics	Improved design, clarity, transparency, printing result
Cost performance	Ways to compensate for the higher cost of bioplastic material or packaging	Compensating the cost of the material with commercial benefits or managing efficient operations
Environmental performance	Improve customer's environmental/sustainability credentials	Lower carbon emissions, no harmful residue, better LCA, reduced waste or plastic pollutions, circular economy practice
Innovation performance	Joint IPs	Share IPs in different areas: design, material application for certain products
	Incremental innovation	Improved compatibility of the bioplastic packaging with the existing value chain, minimise disruption to an established value chain

Enablers for successful co-innovation are showing the feasibility of the project, incremental innovation and extensive mutual adaptation. To engage the customer in co-innovation, the supplier must show the project's feasibility, comprising how the material and packaging would be fit for purpose, provide commercial benefits, and show the scale-up potential when engaging the industry leader. As the bioplastic packaging comprises a tiny percentage of the packaging industry, which is dominated by an established value chain, including at the end-of-life, and a mature product that has been used very efficiently in the broader aspect of the industry and daily life, it will be extremely challenging to penetrate the packaging industry. The industry players are reluctant to commit to a significant change in the existing value chain built for an industrial scale; therefore, maximising compatibility, while keeping disruption to a minimum in the existing value chain is crucial for bioplastic packaging to penetrate the packaging industry. Subsequently, implementing bioplastic packaging still requires extensive mutual adaptation from all co-innovation partners, especially to adapt the bioplastic packaging performance, which is unlikely to be the same as that of conventional plastic, and accept a higher cost in compensation for the commercial benefits or efficiency of operations when possible.

Before co-innovation, there were gaps between the biopolymer producer's offering and the converter's and product manufacturer's expectations. The converter's expectations are mainly around cost and efficient manufacturing to be able to sell the bioplastic packaging. The product manufacturer's expectations focus on commercial advantage, contribution to the global sustainability agenda and a non-negotiable requirement where the packaging must not compromise the product quality. Moreover, it seems that the biopolymer producer offering before co-innovation cannot address some of these expectations, as seen in the red arrows in Figure 24. However, co-innovation brings with it improvement of material, packaging and process, and provides exclusivity and joint IPs, all of which accommodate more of the converter's and product manufacturer's expectations. Figure 24 illustrates how co-innovation outcomes address the gaps between the supplier's offering and customer's expectations before co-innovation.

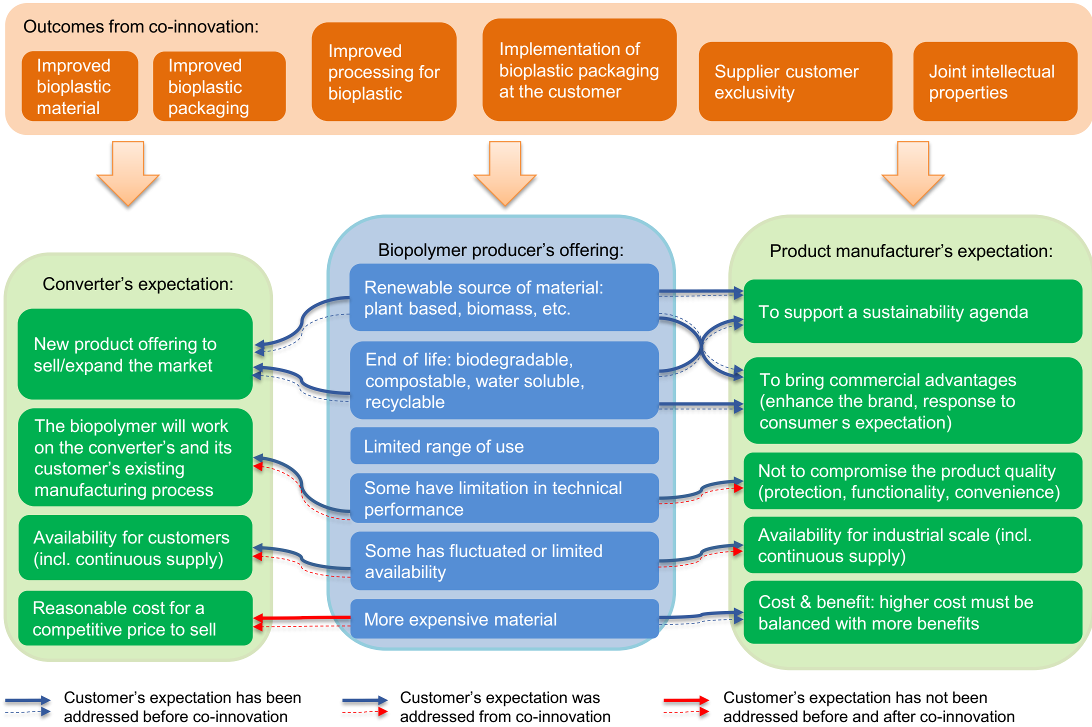


Figure 24 The outcomes of co-innovation addressing the supplier-customer gaps

The extent to which these outcomes would become a relational rent for all partners is determined by the long-term non-financial benefits, such as achieving a sustainability agenda, brand enhancement created from using the bioplastic packaging, or joint ownership of the technology. Ideally, the outcomes from co-innovation benefit all partners, indicating a relational rent; however, the outcomes possibly benefit one partner and are not shared with the other co-innovation partners, indicating an internal rent. Both narrow and extensive co-innovation would generate internal rent, but greater relational rent is more likely to be generated in the extensive and complex co-innovation, indicating a disproportionate distribution of rent, depending on the different co-innovation mechanisms.

5.4. The key factors and supplier-customer roles in facilitating a successful co-innovation

This section elucidates the key factors influencing co-innovation in developing bioplastic packaging and how the supplier and customer play their roles in co-innovation. Therefore, this section also fulfils RO4 in this study, which aims to illustrate how the key factors and the roles of supplier and customer influence a successful co-innovation in developing bioplastic packaging.

5.4.1. Key factors influencing co-innovation in bioplastic packaging

Understanding the background conditions in the plastic packaging industry is necessary to discover the reason behind the limited creation of the idiosyncratic asset. This industry works on a massive scale to produce packaging, and a supporting product usually fixed at low prices, such as plastic bottles, shrink sleeves and shrink wrap for soft drinks. To create asset specificity, first, replacing machinery or the production process requires a substantial long-term investment. High fixed upfront costs and their long-term nature must be assessed to safeguard the investment. On the other hand, the bioplastic market is still in its infancy, and adverse reactions emerged regarding the compatibility of bioplastic packaging waste with the end-of-life waste streams. Furthermore, at the time of this study, the bioplastic material supply was quite limited for extensive industrial-scale application; therefore, the industry leaders were extremely cautious in selecting a co-innovation partner or investing in a bioplastic development project.

Another condition is the mature supply chain, in which bioplastic packaging is applied. Building tangible assets specificities, such as specific machinery or waste facilities, is difficult for bioplastic packaging, which is still a tiny part of the packaging industry, in which the technology, process and supply chain are already mature. Penetrating the industry best follows what already exists and it would be very difficult to require the existing industry players to change significantly. ChemiCo, SoluCo, DrinkCo, NutriCo, ConveCo and PharmaCo showed that co-innovation was carried out for material improvement to work in the existing process and supply chain, adjustments were kept at a minimum level, and all investment and costs must be calculated against commercial benefits and any other advantages at the end of the project. These situations seem to suppress the investment feasibility for building specific tangible assets. Most industry players tend to wait and see, are reluctant to change, and joint resources become limited to using each partner's existing facilities.

The development of bioplastic packaging is highly dependent on factors outside the co-innovation: the market, regulations and technology, each of which provides opportunities and threats. Speedy changes in technology, market and regulation also impact co-innovation for bioplastic packaging that predominantly takes a lengthy time in its development. The market is the most critical factor that influences the development of bioplastic packaging. When bioplastic packaging is increasingly used, and the market has the potential to grow, developments in this field will increase, one of which is through co-innovation. From the biopolymer producers' perspectives, the packaging market is quite challenging to penetrate and there are barriers to co-innovation with the converter. The SoluCo case exemplified a situation where the converters always compared bioplastics with conventional plastics and failed to consider the potential of bioplastic packaging beyond price and efficiency; therefore, before showing collaboration with product manufacturers, SoluCo's approaches to the converters were not well responded to. Working in a bioplastic packaging development project with ChemiCo was a small part of the converter's operations, placing innovation and development in bioplastic packaging as a lower priority.

In addition, the CbagCo case illustrated an early market penetration in an emerging market such as Indonesia, where bioplastic packaging is sold to small retail businesses, hotels and distributors. In the CbagCo case, government regulation was considered a positive driver that cultivated the bioplastic packaging market, as the converters noticed the changing market, saw a new opportunity to produce environmentally friendly packaging solutions and anticipated the risk of losing business when plastic packaging is banned. In Indonesia, plastic packaging is used for many low priced products, started from around IDR 2,000 (approx. GBP 10p); therefore, CbagCo found it challenging to penetrate the plastic packaging scenario and convince the converters who are generally sensitive to price. CbagCo must convince the converter that an environmentally friendly packaging market will develop in Indonesia and have good business potential. Furthermore, a good example of engaging with the converter is also shown in the CbagCo case, in which CbagCo transferred several customers to the converter to show demand, enabling the converter to sell its products.

In all converter cases, the business motive was an essential factor, and the market appeared to be the driver of the adoption of bioplastic packaging and co-innovation. Market pressure on plastic packaging made companies such as FilmpackCo and BiopackCo's customers search for bioplastic alternatives to protect their brands from the negative press. However, many bioplastics in the market were unable to be immediately applied to the existing system; hence became a weakness. FilmpackCo, BarrierCo and BiopackCo undertook many costly trials with customers where needed, and a successful application at one customer could be broadened to other similar customers, or even for similar applications in different industries whose systems are similar. The converter needed to understand the unique characteristics, including the limitations of bioplastic material and make it work within various parameters, whilst customer willingness to adapt reciprocally is also crucial. FilmpackCo, BarrierCo and BiopackCo explained the adjustments made by customers such as replacing several tools, and adjusting the production process to work better for bioplastic packaging. FoodpackCo tried to adjust its manufacturing to bioplastic packaging, but the results did not meet the required standards, and the process took too long.

Next, the product manufacturer's views on both the market and demand highlighted the customer expectations of sustainability in line with commercial advantages, such as enhancing the brand and creating higher sustainability credentials by using sustainable packaging. However, its implementation in many countries or the global market was challenging as product manufacturers must comply with regulations in different regions or countries. PharmaCo explained that there was a hierarchy of customer expectations on sustainability for different product categories. The sustainability expectations for convenience goods were higher than medical and pharmacy products, in which health and safety were the priorities. In line with that, CoffeeCo consumers prioritised quality, taste and the price of coffee capsules. TeaCo highlighted that consumers complained when they discovered that tea bags contained plastic and expected to consume plastic-free tea. ChocolateCo, which sells organic, vegan chocolate bars, said that consumers were very aware of waste from the packaging and had high expectations for sustainable packaging.

Today, along with the higher market expectations for less polluting packaging, product manufacturers see a commercial benefit when replacing packaging with a more sustainable one. Therefore, PharmaCo and ConveCo prepared their consumer base and marketing communication accordingly; hence the newly launched bioplastic packaging would leverage the brand through sustainability. Product manufacturers that operate in many countries need to understand the market differences in each country or region before implementing the new packaging for a product marketed in a particular country. PharmaCo stated that the company must strictly comply with regulations regarding pharmaceutical and healthcare products, including the regulations on packaging materials. Each country has different rules; for example, the EU allows recycled materials for drug packaging, while this is not the case in China.

While the market is the most important driver of bioplastic packaging development, most of the participants in this case study indicated that governments and regulations have not yet sufficiently supported or driven the bioplastic packaging development and co-innovation in this field. For example, the participant from SoluCo considered that the additional tax imposed on plastic packaging by the UK Government is not sufficient to encourage innovation because product manufacturers might impose this tax burden on the product price, which the consumers in turn have to pay. Meanwhile, FoodpackCo saw that tax for plastic packaging and the requirement to use a certain percentage of recycled material in plastic packaging would increase the total cost of producing conventional plastic packaging, possibly encouraging customers to consider bioplastics and drive the demand for bioplastic packaging. In addition, the CbagCo case showed that the Indonesian government was starting to regulate single-use packaging and waste management. Accordingly, central government regulations were further detailed in the local government regulations; however, the implementation varied in different regions. For example, some regions allow compostable materials for single-use plastics, but others prohibit all single-use plastics, including those made from bioplastic. Regulations also vary in different countries, and product manufacturers must comply with different regulations regarding using plastic and bioplastic packaging to market the product in many countries. Therefore, it is crucial to comprehend this need when developing the material, for it to be applied globally.

Next, the ongoing development of bioplastic technology is another factor that influences co-innovation in bioplastic packaging. Having a breakthrough in bioplastic technology would attract partners for co-innovation. The DrinkCo, PharmaCo and ConveCo cases showed that product manufacturers were always looking for new, better technologies and better ways to achieve their sustainability agenda, and thus respond to current environmental issues. The participant from DrinkCo shared that new technology could disrupt the ongoing bioplastic packaging development, which is in line with ConveCo, where a co-innovation project was stopped because the material being developed was no longer attractive to product manufacturers. In addition, changes in regulations and environmental issues might distract the product manufacturers' interest from ongoing packaging projects; for example, the waste issue currently developing in Indonesia could distract DrinkCo's focus on the ongoing recycling programme. Similarly, ServpakCo was aware of changing regulations on single-use cutlery in the EU, including cutlery made of PLA, and anticipated this by preparing the withdrawal of its PLA product range and replacing it with a new range suitable for the European market.

In addition to the above factors, the following are other factors influencing product manufacturers using bioplastic packaging, which need to be accommodated in its development. First, the end-of-life is of significant consideration, especially compatibility with the main product's end-of-life and the waste infrastructure. Informants from DrinkCo and NutriCo shared that recyclable packaging is a higher priority because recycling applies well to water bottles, and the recycling infrastructure has been widely available compared to compostable packaging that require industrial composting. This option is suitable to be implemented for DrinkCo's packaged beverage products in many countries, including Indonesia, because the recycling waste stream exists in Indonesia, while industrial composting is very limited. ChocolateCo, ServpakCo and TeaCo, which used compostable packaging, also explained the challenges of today, where customers have found difficulty disposing of compostable packaging because some councils in the UK do not collect food waste or do not accept compostable packaging.

Understanding the business customer's views on bioplastic packaging and their specific needs would facilitate approaches to potential co-innovation partners. The following are some examples of successful engagement, highlighting the key factors leading to co-innovation. In the SoluCo and ChemiCo cases, the key factors to successfully engage product manufacturers, that were also industry leaders, are their ability to present the project's potential in a business case and meet comprehensive requirements in the product manufacturer's filtering mechanism. The product manufacturer showed the potential for long-term packaging materials and applications. The key points shown were the suitability of the development project for the product manufacturer's sustainability agenda and innovative direction, the ability of material production to scale-up, commercial benefits for the product manufacturer, and business feasibility, including cost. Even though biopolymer producers offered more expensive material prices, they could offset the cost against greater commercial benefits for product manufacturers in the long run. ChemiCo and SoluCo could ensure availability and supply, meeting the needs of packaging industry leaders on an industrial scale that reaches millions of tonnes. SoluCo has an advantage regarding this availability because it developed material derived from raw materials that abundantly available; however, ChemiCo needed to manage allocations for customers in advance and reserved their needs from 2-3 years before.

5.4.2. Dynamics of supplier and customers

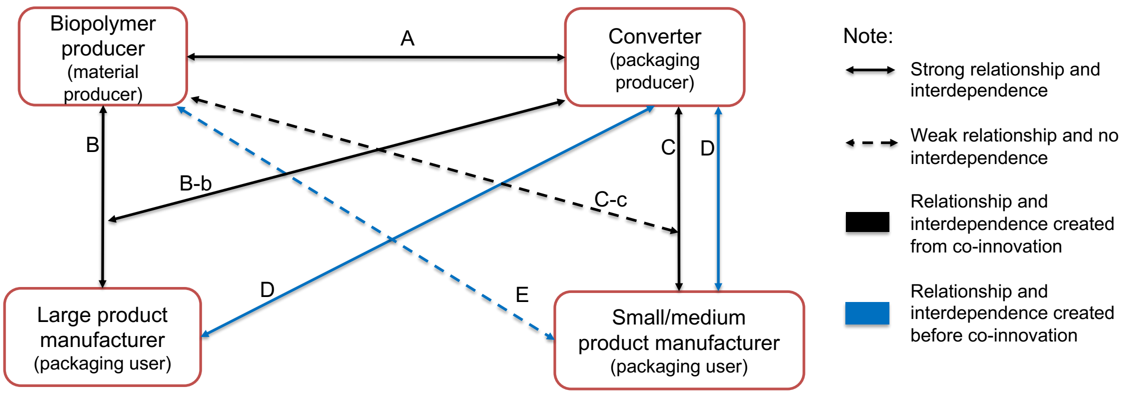
The dynamics of supplier and customer interaction throughout the co-innovation project shape the co-innovation partners' relationship and indicate how supplier-customer interdependence from co-innovation was formed. Several key interactions that shape the co-innovation dynamics were seen in joint activities such as trials, solving the customer's problem, providing training for the customer's employees, and providing technical support. Almost all cases showed challenges in the implementation of bioplastic packaging for the business customers that required many iterations. The key to managing the co-innovation dynamics is through open communications; however, building open communication can sometimes be challenging. For example, the biopolymer producer, such as SoluCo and CbagCo, found that the converter often withheld some details of formulation that could improve the packaging properties or create a more efficient production process. Similarly, in the BarrierCo and BiopackCo cases, the consumers did not allow the converter's presence in the production site, creating difficulties in solving problems and in trust issues when the consumer claimed it cannot use the packaging; however, CoffeeCo found it takes time to build open communication, and the ServpakCo case implied that the converter sometimes inhibited direct communication and relationship with the biopolymer producer that supplies the converter.

All biopolymer producer cases showed challenges in engaging co-innovation partners, especially with the converter, who according to SoluCo and CbagCo often focuses on cost and efficiency, hence is difficult to be convinced of the potential of bioplastic packaging in emphasising sustainability value even though it is more expensive. The ChemiCo case indicates that converters that already engage in co-innovation sometimes give the bioplastic development a lower priority. However, converters are important partners and can connect to business customers, also known as the product manufacturer, which pushes the co-innovation forward to commercialisation. Converters in many of the cases, such as in FilmpackCo, BiopackCo, ChocolateCo and TeaCo could influence the product manufacturer's packaging selection, hence promote bioplastic packaging. All cases show that converters were highly supportive to ensure implementation at the business customer's business location. Even industry leaders such as PharmaCo, DrinkCo and NutriCo have to involve their converters in co-innovation projects with the biopolymer producer.

The dynamics showed gaps in the expectations between the supplier and consumer. The suppliers considered the product manufacturer to be demanding, directing the development, which is partially true as shown by DrinkCo and PharmaCo. For example, a comprehensive partner selection procedure, capability consideration, scale-up, regulations, certifications, implementation in different regions, health and safety, supply, cost; all these were discussed during partnership building, before a formal agreement was reached. The biopolymer producer and converters are expecting the product manufacturer to be more understanding of the limitations of bioplastic packaging and tolerate some aspects; however, the product manufacturer insists some aspects could not be tolerated regarding protection of the main product and carefully considered sacrificing the aesthetics and function of the packaging when used by the consumers. The product manufacturer keeps searching for better technology and solutions, such as DrinkCo and PharmaCo, and could end the co-innovation, such as in the ConveCo case. Nevertheless, the product manufacturer contributes to the co-innovation by expanding it to a broader network of stakeholders. PharmaCo, ConveCo, DrinkCo and NutriCo, include more partners to fill the gap in the bioplastic packaging development, such as experts, a standardisation body, and their converters. SoluCo realises that working with a big product manufacturer would speed up the project as a product manufacturer brings more partners with complementary capabilities and the ability to synergise projects. ServpakCo could expand the co-innovation both to downstream business customers and waste service providers.

Interdependence occurs because of the position of suppliers and customers in the supply chain. Biopolymer, or the biopolymer producer, provides products to be processed into packaging by the converter. Furthermore, the converter supplies packaging to product manufacturers and retailers. In this position, retailers cannot directly use raw material from the biopolymer producer without going through a converter. Dependency between partners currently only occurs because of the demand for supply according to their respective positions in the supply chain. Strong relationships and high interdependence occur among partners as organisation boundaries are blurred; the suppliers are fully supportive, but they did not immerse themselves in the customer business process and, accordingly, the interdependence of co-innovation is limited to the relationship of supply and demand and the position of partners in the supply chain. Likewise, only the sharing of existing facilities, infrastructure, dedicated teams and other resources occurs, but all of these are less likely to be accumulated or become interconnected, specialised assets for bioplastic packaging production.

The relationship between the biopolymer producer, converter and product manufacturer can be seen in Figure 25. The close relationships among A, B and C are built from co-innovation in developing bioplastic packaging. Meanwhile, the B-b and C-c relationships occur because additional partners are required in the ongoing co-innovation. The converter has close interdependency with biopolymer producers and all material producers because of its role as a connector. However, the ChemiCo and ServpakCo cases indicate that the converters can become inhibitors because they have not seen the potential of producing bioplastic packaging nor prioritise the co-innovation project with the biopolymer producer. Therefore, the CbagCo case could illustrate an interesting example of how material producers penetrate the market and attract converters through licensing programmes. Inferred from the ChemiCo and SoluCo cases, biopolymer producers and large product manufacturers have created interdependency from co-innovation. All small and medium-sized product manufacturers have a high interdependency with the converter, either from a long-tracked supplier-customer relationship or co-innovation, which does not happen with the biopolymer producer. Hence, there is no interdependency without going through the converter. An exception is seen in the CoffeeCo case, in which a small product manufacturer expands its operation into developing materials and collaborates with a biopolymer producer, although the interdependency is not yet visible because the collaboration was just starting.



A : Supplier-customer relationship, biopolymer producer's recommended converter, co-innovation
B : Involved in a long-term co-innovation project
B-b : Converter supports product manufacturer's co-innovation with the biopolymer producer (relationship B)
C : Supplier-customer relationship, converter fully supports product manufacturer's new packaging implementation, long-term manufacturing partner before bioplastic packaging
C-c : Biopolymer producer helps the converter during trials in co-innovation with the small/medium product manufacturer (relationship C)
D : Supplier-customer relationship
E : Biopolymer producer shares information of the material or recommends a converter to the small/medium product manufacturer

Figure 25 The relationship and interdependency among partners in the co-innovation

5.4.3. Summary of the key factors and the roles of supplier and customer (fulfilling RO4)

There are three factors important to co-innovation in bioplastic packaging: first, the external factors comprising market, regulation and technology that influence the bioplastic packaging development and co-innovation in this area; second, it is necessary to know what kind of bioplastic packaging should be developed; and third, it is crucial to know the thoughts of industry leaders on using bioplastic packaging for their products as they can introduce bioplastic packaging, educate a broad range of consumers and the market, and also influence the supply chain. Ultimately, it is crucial to understand the key success factors for engaging co-innovation partners and working with the co-innovation mechanism following the framework proposed in this study.

Based on the case study, the market itself is the most important driver for co-innovation in bioplastic packaging; as this market grows, greater demand will push development, including co-innovation in bioplastic packaging. However, bioplastic packaging faces a substantial barrier to entry into an industry dominated by mature products and an established value chain. Furthermore, the industry players, especially the producers, were expecting more support from the government and regulations, but it seems that currently there is still insufficient support that encourages bioplastic packaging development and innovation for sustainable packaging. The feasibility for a broad implementation of bioplastic packaging is challenging due to the different regulations applied in different regions; changing the regulations adds to the risk of uncertainty, and a limited waste infrastructure, such as industrial composting, leading to problems at the end-of-life of bioplastic packaging. Due to these complexities, there are vast opportunities to create better technology through co-innovation and having a breakthrough bioplastic technology could drive co-innovation with business customers. However, this kind of development is usually a lengthy process, while the market is changing rapidly and the competition from newer technology is intensive; thus, the risk of obsolescence is also high.

Having a clear direction for co-innovation is crucial and it is vital to know as early as possible what bioplastic packaging is to be developed that would work in the long-term on an industrial scale. Inferred from the cases, there are many bioplastic materials that have been developed but these are insufficient for adoption by the industry due to lacking feasibility for further development and accommodating product manufacturer's needs, lacking feasibility to scale-up to at least a small industrial scale and offering a packaging solution that is not fully compatible with the existing waste stream or business customers' sustainability agenda. This study found several cases of successful co-innovation, all of which demonstrate a packaging solution that addresses the business customer's sustainability agenda, the capability to adapt or accommodate the product manufacturer's needs, feasibility to scale-up, guaranteed availability and works within the existing waste stream.

Therefore, the key factors of co-innovation in bioplastic packaging are summarised in the following:

1. Feasibility on an industrial scale, to present the project's potential, scalability and availability, suitability for the sustainability agenda and business customer's innovative direction, maximising long-term relational benefits such as exclusivity, commercial benefits, and benefits from joint IPs,
2. Maximising compatibility of the bioplastic packaging with the existing value chain,
3. Adaptability to a dynamic business environment, including the complexity of the packaging industry and competing with existing plastic packaging, which is a very mature product in the industry,
4. Behavioural changes, such as willingness to change at the business level and accepting sustainability value as an offset to direct financial benefits.

The interactions of the co-innovation partners show the dynamics of the biopolymer producer, converter and product manufacturer roles in developing bioplastic packaging (see Table 31). The dynamics are formed in a newly built partnership, and each partner contributes to the co-innovation, combining each of their capabilities and optimising sharing the existing tangible assets and facilities for product development, while the creation of specific assets for bioplastic packaging is limited in the majority of the cases. Inferred from the supplier-customer dynamics, challenges occurred in partnership building, especially in addressing the business customer's needs, building trust and open communication. Interdependence grows from an extensive and complex project but business customers seem to have the power to continue or stop the collaboration. Alternatively, converters have an important part in mediating interdependence with the product manufacturers through their expertise in packaging manufacturing and long-tracked relationship with the product manufacturers.

Table 31 The role of supplier and customer in the co-innovation

Biopolymer producer Supplier →	**Converter** Customer Supplier →	**Product manufacturer** Customer
Expert in bioplastic material/technology	Expert in packaging manufacturing	Expert in industrial practice
Initiates or creates the innovation	Influencer: promotes bioplastic packaging to customer	Defines the packaging specifications: the industry leaders set the direction for further development; smaller companies request less complex specification/bespoke packaging from the converter
Relies on the converter to produce the packaging	Connector between biopolymer producers and customers	Relies on the converter to produce the packaging; Connector to the wider supply chain, end users, wider number of consumers
	Inhibits co-innovation (in some cases)	Demanding (usually the industry leader)

5.5. The framework of co-innovation in developing bioplastic packaging

This section is the final part of the cross-case analysis, which also fulfils RO5, aiming to propose a theoretical framework portraying the underlying mechanisms of how co-innovation in developing bioplastic packaging occurs in the dyadic B2B supplier-customer relationship. In this section, the initial framework is reviewed and then refined, in which several initial propositions are retained or modified, and new propositions are presented.

5.5.1. Reviewing the initial propositions

This section explains the extent to which the evidence from the case study is relevant to the initial framework and the propositions developed from the SLR. First, joint activities generate new knowledge, improvements and solutions that enable the bioplastic packaging to be fabricated in the existing process at the converter and product manufacturer. This advancement is valuable for all co-innovation partners as not many biopolymers and bioplastic packaging in the market could successfully be implemented in real production settings. Higher joint activities that positively impact the bioplastic packaging innovation are not determined by the frequency of partners working together but more on the knowledge sharing or transfer of knowledge, co-development and extensive mutual adaptation. The implementation of bioplastic packaging is different from conventional plastics; therefore, besides providing the new technology, the supplier must fully support the customer's implementation.

These findings support the first proposition (P1) in the framework, which states: *In the bioplastic packaging co-innovation context, higher supplier-customer joint activities will increase the success of bioplastic packaging product innovation.*

Next, the proposition regarding joint resources (P2) assumes that the customer and supplier contribute both tangible and intangible resources and capabilities to co-innovation. When combined, the complementary resources and capabilities will become a source of increased productivity of individual resources, knowledge transfer and reduced cost, and facilitate product development success. The findings indicate that intangible joint resources are more likely to occur, such as sharing information, expertise and knowledge, leading to the creation of specific know-how related to bioplastic technology and its application, and the joint IPs of packaging design or processing. Furthermore, the creation of asset specificity is limited; partners very carefully invested in the tangible assets dedicated to bioplastic packaging and prefer working on the existing main infrastructure. Nevertheless, new knowledge or joint IPs will be applied to generate benefits for each partner, such as being licensed, and commercialised to a broader market and industry.

The evidence from this case study does not fully support the second proposition (P2): *In the bioplastics packaging co-innovation context, higher supplier-customer joint resources will increase the success of bioplastics packaging product innovation.*

Co-innovation for developing bioplastic partners depends on relationship management, and the key is how to approach potential partners to engage in co-innovation. The business motive significantly underlies the relationship among biopolymer or biopolymer producer, converter and packaging manufacturer. Therefore, agreement and commitment, educating the user and managing expectations are essential to build customer understanding and promote cooperative behaviour in developing advanced bioplastic packaging through co-innovation.

These findings support the third proposition (P3): *In the bioplastic packaging co-innovation context, higher supplier-customer relationship management will increase the success of bioplastics packaging product innovation*.

Accordingly, the higher efforts to build relationships through communication, build trust and honesty, educate users and facilitate knowledge transfer will encourage customers to be more open and honest. At the same time, agreement and commitment bind all partners to contribute to problem-solving. These efforts also affect customer willingness to adapt, including adjusting the process and accepting the limitations of the bioplastic packaging up to a certain point.

These facts also support the fourth proposition (P4): *In the bioplastic packaging co-innovation context, the higher the relationship management, the higher the joint activities dedicated to co-innovation*.

Partner selection prioritises complementary resources and expertise to support the co-innovation project. In the complex and extensive project, as in ChemiCo and DrinkCo cases, the biopolymer producer approached the product manufacturer to provide significant resources to develop the bioplastic packaging from its material. Product manufacturers who are also industry leaders carefully looked for biopolymer producers with complementary technology and expertise, which were not available internally. In addition, an increasing co-investment in assets may occur after the relationship has been developed over time, as in the ServpakCo case. Nonetheless, efforts to build relationships through communication, user education and commitment do not always have implications for joint resources. For example, in the CbagCo case, licensing customers bought machines from CbagCo, were trained by CbagCo and then succeeded in developing a new engine based on the CbagCo machinery principles. Unfortunately, the customer did not want to share. Relationship management does not always encourage relationship-specific assets, and does not always increase technological integration or complementary resources that are shared.

Thus, the fifth proposition (P5), *in the bioplastic packaging co-innovation context, the higher the relationship management, the higher the joint resources dedicated to co-innovation,* is not fully supported.

Interdependency among partners will develop after the co-innovation has successfully delivered the agreed outcomes. First, interdependency comes from an exclusivity agreement and joint IPs. Next, interdependency is likely to grow stronger when each partner obtains advantages from using the bioplastic packaging and/or the joint IPs. On the other hand, the co-innovation would end when deliverables are not achieved by the supplier or the customer finds a better alternative, even though all partners have then sacrificed a number of joint activities and joint resources. Therefore in bioplastic packaging co-innovation, interdependency is not determined by joint activities and joint resources.

Thus, these facts implied a lack of support to the propositions related to supplier-customer interdependence in the following:

- Proposition 6 (P6): *In the bioplastic packaging co-innovation context the higher the joint activities, the higher the supplier-customer interdependence, and therefore the bioplastic packaging product innovation.*
- Proposition 7 (P7): *In the bioplastic packaging co-innovation context, the higher the joint resources, the higher the supplier-customer interdependence, and therefore the bioplastic packaging product innovation.*
- Proposition 8 (P8): *In the bioplastic packaging co-innovation context, the higher perceived contribution of the supplier to the customer's innovation, the more the customer responds more actively to the ongoing co- innovation, the higher supplier-customer interdependence and, therefore, the bioplastic packaging product innovation.*

Co-innovation in bioplastic packaging showed the importance of an organisation recognising external new knowledge and acquiring and implementing it to achieve innovation. The findings also support the existence of the four capabilities: acquisition, assimilation, transformation and exploitation that result in value creation. In each case, the absorptive capacity mechanism is unique. Nevertheless, it can be concluded that co-innovation opens opportunities for learning from customers to produce solutions, opens a more comprehensive understanding of the existing system and produces solutions for a broad target market, or becomes a standard for the industry.

Thus, absorptive capacity mediates the co-innovation process with outcomes, which also supports the ninth proposition (P9): *In the bioplastics packaging co-innovation context, the absorptive capacity mediates the relationship between co-innovation and bioplastics packaging product innovation.*

Relationship management is shown in the partnership development, communication and commitment to the co-innovation project facilitating mutual understanding, higher tolerance to the limitations of the bioplastic packaging and maintaining the project governance. Furthermore, there is no direct evidence that links relationship management to increasing a partner's ability to acquire knowledge from the other co-innovation partners and utilise that knowledge to create value. In co-innovation, new knowledge is built mainly from joint activities, which include concept explorations, trials with the customers, using the customer's production facility and iterative work with the customer. Joint activities promote the supplier's understanding of the customer's manufacturing and value chains, and enables the supplier to improve the product and provide solutions.

Therefore, the evidence does not support proposition 10 (P10): *In the bioplastic packaging co-innovation context, the stronger the relationship management, the higher the absorptive capacity and therefore bioplastics packaging product innovation.*

Based on the analysis above, the propositions have been reviewed based on the evidence from seven cases. Figure 26 summarises the extent to which the findings supported the initial framework. The propositions supported by the case study are P1, P3, P4, and P9, all of which are illustrated by the green line. Next, P2 and P5 are partially supported; P6, P7, P8 and P10 are not supported; hence these propositions are illustrated by the red dotted line.

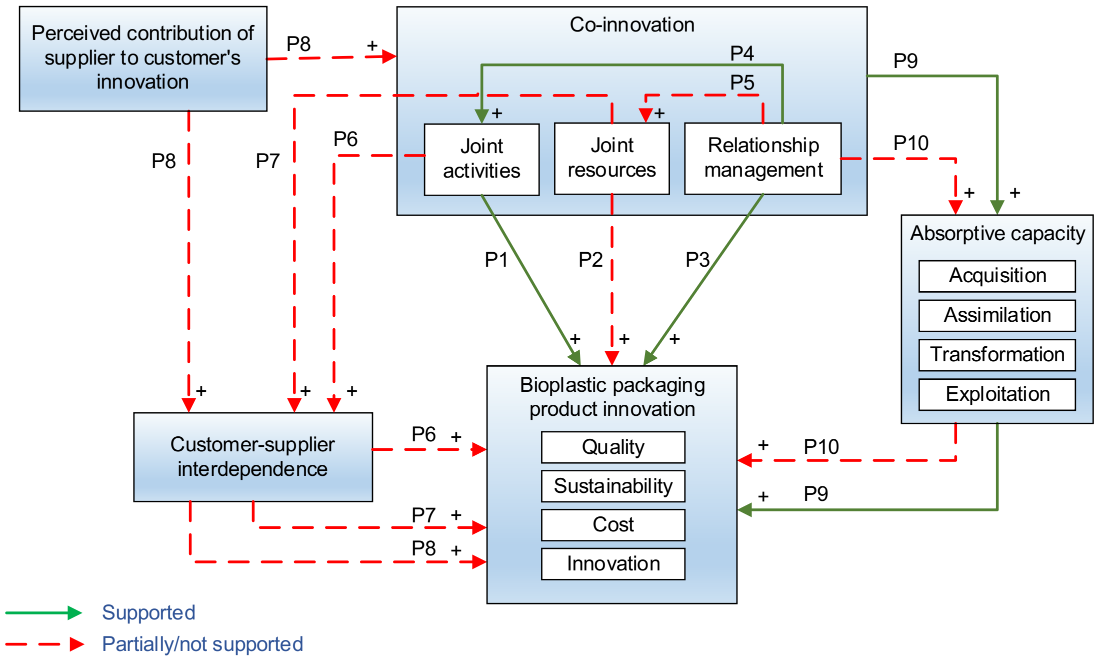


Figure 26 Illustration of the initial framework after the case study

5.5.2. The refined framework of co-innovation (fulfilling RO5)

Figure 27 shows a refined framework, in which only propositions supported by the results of the study are retained and the propositions in the refined framework are given code Pr. Co-innovation consists of JA, JR, and RM as integrated mechanism; JA enables delivery of the outcomes, and JR facilitates JA and RM. Accordingly, the initial propositions P1, P3 are supported, and P2 is partially supported by the findings, but in all cases, JA, JR and RM always exist and work together as the mechanism of co-innovation. Therefore, the refined framework shows that co-innovation delivers bioplastic product innovation, see Pr 1 in Figure 27, and the higher at least one of JA, JR and RM is will strengthen co-innovation and therefore will increase the success of bioplastic packaging innovation. Subsequently, the initial propositions P4 and P5, are given code Pr 2 and Pr 3 in the refined framework.

The findings indicate different levels of absorptive capacity at the supplier and customer, and the supplier's absorptive capacity is more apparent than the customer's. The suppliers were more intensively transformed and exploited the new knowledge from co-innovation to create improved solutions for the customer. A stronger supplier absorptive capacity enables improvement in the material, packaging, process and support to the customer's value chain, and better accommodates the customer's need for the packaging to work in the industry; hence promotes successful co-innovation and gains from that co-innovation.

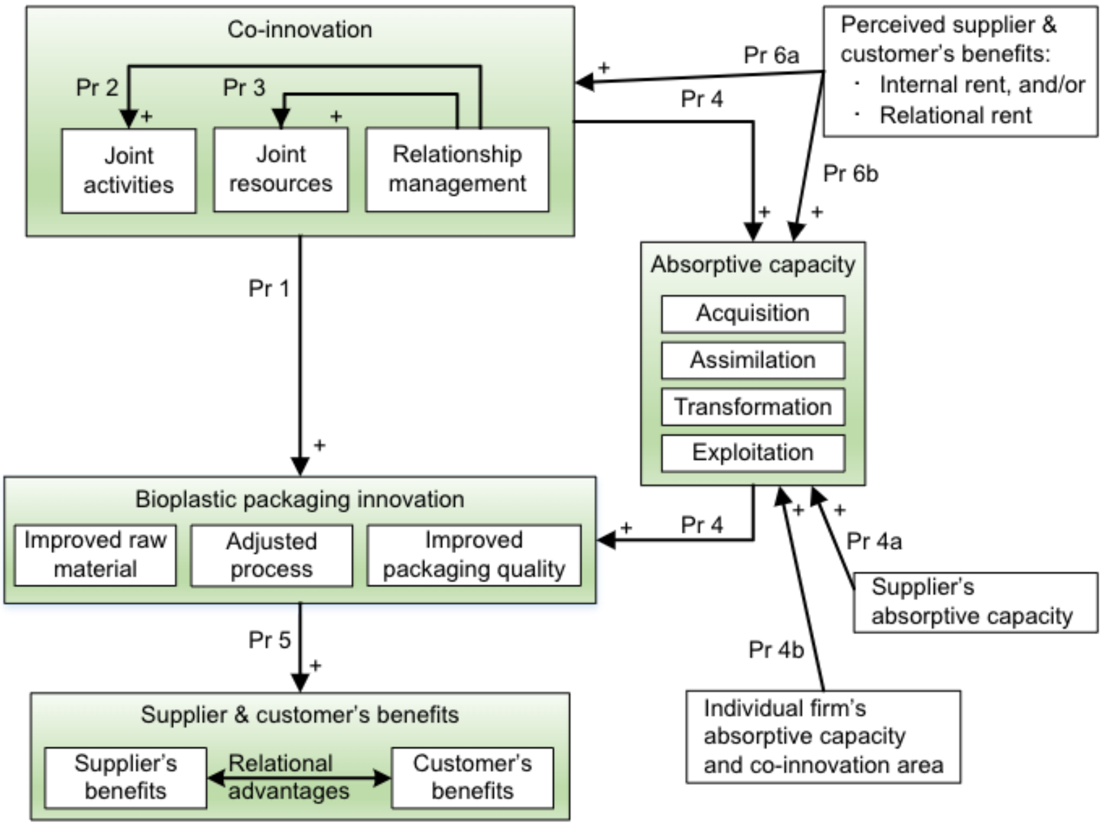


Figure 27 Refined framework of co-innovation in developing bioplastic packaging

Nevertheless, this does not mean that the customer has a lower absorptive capacity. Small/medium product manufacturers show less absorptive capacity because co-innovation aims to implement bioplastic packaging into their products, underlining that packaging is there to support their final product.

Therefore, although the development of environmentally friendly packaging is important, product manufacturers might focus their absorptive capacity on areas that are more relevant to their core business or potentially generate more benefits. Meanwhile, large product manufacturers and converters who collaborate with biopolymer producers show higher absorptive capacity because the project is expected to deliver superior bioplastic packaging that enhances the brand, product image, or places a tick against part of their sustainability agendas.

Hence, the initial proposition P9 is given new code Pr 4, and further explained by the conditions that influence a firm to optimise its absorption capacity, as in proposition Pr 4a and Pr 4b:

- Pr 4a: In the bioplastics packaging co-innovation context, a supplier's higher absorptive capacity will increase the success of bioplastics packaging product innovation.
- Pr 4b: An individual firm's absorptive capacity will be stronger in mediating the relationship between co-innovation and outcomes if the co-innovation area sector has more potential to generate the desired advantages.

The outcome of co-innovation was modified because the initial indicators were limited to bioplastic packaging as the product innovation. The new indicators (see Table 32), present a more comprehensive outcome from co-innovation in developing bioplastic packaging, while also accommodating the initial indicators (see the transformation in Figure 28). The refined indicators include an improved raw material that works better in the customer's process, adjustment of supplier and customer process to work with bioplastic packaging, and improved packaging quality to meet customer expectations. These indicators also include other supplier-customer benefits to each supplier or customer or are shared as relational advantages, all of which follow the successful bioplastic packaging implementation.

Table 32 Refined indicators for the outcomes from co-innovation

Improved raw material	To work with the customer's manufacturing process, to meet customer's expected functionality in the processing and as packaging.	Private benefits, more for biopolymer producer.
Adjusted process	To work with bioplastic material, new packaging design and other technical parameters, to reduce cost and compensating for higher cost of material.	Private benefits, more for biopolymer producer converter.
Improved bioplastic packaging quality	To meet customer's expected packaging functionality and design.	Private benefits, more for biopolymer producer and converter
Other benefits after successful implementation		
Enhances the sustainability credentials/agenda	Such as circular economy, zero waste, net-zero.	Private benefits, more for product manufacturer
Commercial benefit	Enhances the brand, addressing consumer's expectation on sustainability.	Private benefits, more for converter and product manufacturer
	Increases sales, expands product range and market.	Private benefits, more for biopolymer producer and converter
Competitiveness or innovativeness	Joint IP, exclusivity agreement, innovative packaging design or process, enhances capability-related sustainability.	Relational benefits

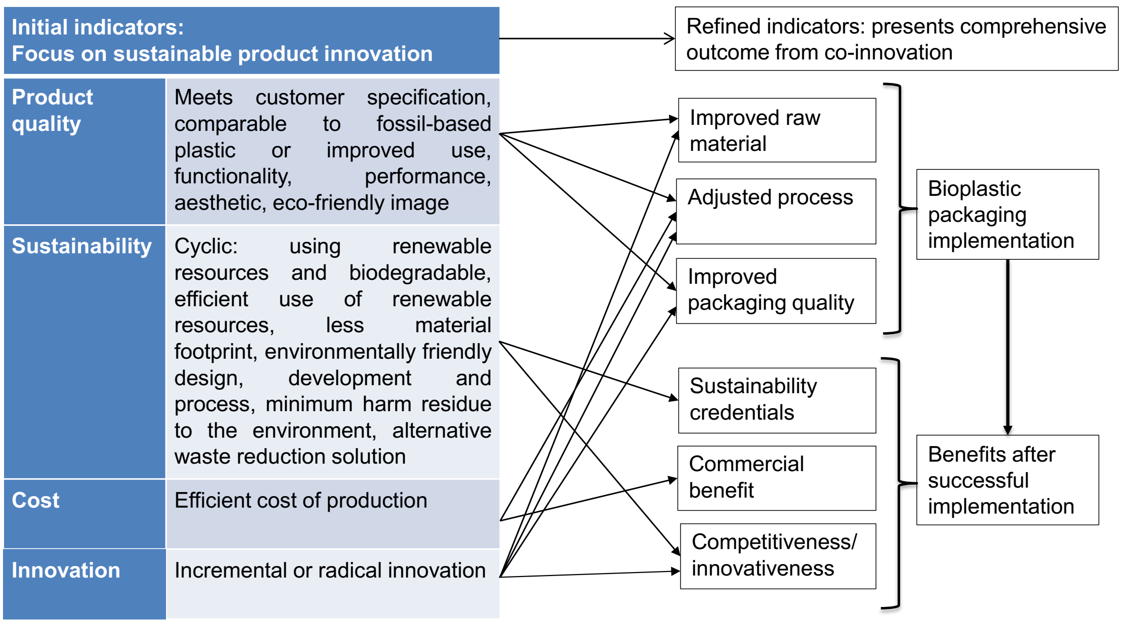


Figure 28 Transformation of the initial indicators to the refined indicators

The evidence from the cases strongly indicates that supplier-customer interdependence would grow if all partners were to gain long-term benefits after the successful co-innovation, once the bioplastic material or packaging has been improved and implemented at the business customers. The supplier-customer benefits consist of internal benefits that go to a specific partner, and common or relational benefits that are shared among partners. Subsequently, the collaboration continues, and the interdependence becomes stronger as co-innovation partners preserve the relational benefits from using bioplastic packaging in the long run. These facts further imply that joint activities, joint resources and relationship management would strengthen supplier-customer interdependence only when relational benefits are achieved. Furthermore, the distribution of these benefits seems disproportionate to different partners and relational advantages are expected to bind in the long-term for all partners. However, a dynamic business environment and the development of new technology affect the relational benefits, either diminishing the values or turn them outdated.

Accordingly, the framework is refined with new proposition Pr 5 to represent the supplier-customer benefits after successful co-innovation:

> Pr 5: *In the bioplastic packaging co-innovation context, the supplier-customer relational benefits are determined by the outcome from co-innovation and higher the bioplastic packaging innovation leads to higher relational customer benefits and partners' interdependence.*

In addition, the findings from the case study do not support the initial proposition (P8), which posits: *In the bioplastic packaging co-innovation context, the higher the perceived contribution of the supplier to the customer's innovation, the more the customer responds more actively to the ongoing co-innovation, the higher the supplier-customer interdependence and, therefore, the bioplastic packaging product innovation*. First, the findings highlight the source of supplier-customer-interdependence from achieving the agreed co-innovation outcomes and relational benefits. Second, the findings from the case study reveal several motives that lead to a co-innovation partnership. Most product manufacturers were looking for sustainable packaging solution as part of their sustainability agenda, addressing their consumers' expectations on sustainability, enhancing their brand or other commercial benefits and they carefully considered the project feasibility, the extent to which the co-innovation project adhered to their sustainability agenda, and the potential to exploit bioplastic technology in the future. The converter cases show similar findings, while the converters also emphasise the potential to increase their sales and expand their market. Hence, it can be inferred that perceived supplier-customer benefits influence the partnership decision, partners' contributions to the joint activities, joint resources and how they manage the partnership. In accordance with the refined proposition Pr 4b, perceived supplier-customer benefits affect how partners share information, build open communication and trust, learn from each other, accumulate joint knowledge and create problem solving, improvement and adjustment.

Therefore, the initial proposition P8 is modified in the refined framework with the following propositions:

- Pr 6a: *In the bioplastic packaging co-innovation context, the higher the perceived supplier-customer benefits, the more like the customer is to respond more actively to the ongoing co-innovation*.
- Pr 6b: *In the bioplastic packaging co-innovation context, the higher the perceived supplier-customer benefits, the higher the absorptive capacity enforced in co-innovation.*

6. Discussion

The findings of this study have been elaborated in the previous section, revealing the process, key mechanisms and key success factors for co-innovation in developing bioplastic packaging. Based on these findings, it can be concluded that co-innovation is an essential mechanism for developing bioplastic packaging and making sure advanced bioplastic packaging is widely used by the industry. Limited references address inter-firm collaboration related to bioplastic packaging, showing a research gap, which this study has addressed. A theoretical framework underpinned by the RV and absorptive capacitive theory has been developed inductively from this study to fulfil the research aim and address the RQ: *How does co-innovation in developing bioplastics packaging work between the supplier and customer?*

The key findings reveal that the overall process in developing bioplastic packaging consists of two major stages: the first is to develop the packaging prototype, the second is to further develop the packaging for certain applications. Next, the key mechanisms of co-innovation are presented in the refined framework, emphasising joint activities, joint resources and relationship management as an integrated element for improving the product and process that will take the bioplastic packaging to implementation at the customers. Knowledge transfer has been the main focus in the co-innovation and is represented in the absorptive capacity, which facilitates accumulating new knowledge that is beneficial for accommodating the customer’s needs regarding material, packaging or process improvement. A relational advantage that binds co-innovation partners develops when the customer gains a commercial advantage from using the bioplastic packaging. The key factors for co-innovation in bioplastic packaging are managing the opportunities and threats, and aiming for industrial-scale feasibility and partnership development with the business customers. Ultimately, the biopolymer producer, converter and product manufacturer roles are strongly influenced by their position in the value chain. Although the biopolymer producers own the technology, the converter and product manufacturer hold the key to bring bioplastic packaging to industrial commercialisation.

6.1. The importance of co-innovation in developing bioplastic packaging

Based on the SLR, previous research showed the importance of co-innovation in other industries, such as automotive, and high-technology to speed up product development, innovation and creating sustainable product innovation. However, co-innovation studies specific to bioplastic packaging are limited; hence this study addresses this gap and provides empirical perspectives on the importance of co-innovation for developing bioplastic packaging. The evidence from the case study strongly indicates that co-innovation brings improvements to bioplastic packaging and other benefits, which are difficult to obtain without co-innovation (Dyer & Singh, 1998); hence, co-innovation is considered crucial in the bioplastic packaging context.

This thesis indicates the difficulties biopolymer producers encountered before co-innovations as having high development costs, problems in implementing the bioplastic material at the customer, needing more expensive new technology, and a lack of understanding of customer needs. These conditions reflect the challenges in producer innovation that cannot be solved alone; therefore, shifting the paradigm from producer innovation to collaborative innovation is advised (Baldwin and von Hippel, 2011). Collaborative innovation, such as open innovation or a hybrid collaborative model, widely applied in IT, helps producer innovators obtain solutions from partners, expand capabilities, and share design costs (Baldwin and von Hippel, 2011). In line with that, the results of this study also support the importance of co-innovation, as the biopolymer producers could share development costs, expand capabilities in packaging manufacturing, improve the bioplastic material and find solutions for its implementation with the customers by involving converters and product manufacturers. However, unlike the open innovation model, which uses information belonging to the public domain and the collaborators often do not have IP rights for the innovation (Baldwin and von Hippel, 2011), co-innovation in the bioplastic packaging context is highly dependent on sharing exclusive information among partners and producer innovators must share IPs with each partner.

This study suggests that co-innovation is an essential mechanism to create higher product performance for bioplastic packaging. Co-innovation among the biopolymer producer, converter, and product manufacturer improves the product and processes, generates commercial benefits, and increases sustainability credentials for all partners. Co-innovation has improved the product's aesthetics and product performance (Farrow et al., 2000). Through co-innovation, suppliers are attempting to meet customer expectations to produce bioplastic packaging that matches the performance of conventional plastic packaging and ultimately succeed in increasing its use and functionality (Lacoste, 2016). Co-innovation increases customer acceptance of bioplastic packaging and improves the raw material, packaging performance, and process, which can be regarded as incremental innovation. Despite the biopolymer producer wanting to reduce production costs through supplier-customer collaboration (de Vargas Mores et al., 2018), there is limited evidence of any significant cost reduction through co-innovation. However, co-innovation partners manage cost efficiency from several aspects, such as using cheaper innovative raw materials, followed by downstream process efficiency.

6.2. The key mechanisms of co-innovation in the refined framework

This study conceptualises the co-innovation mechanism, emphasising inter-organisational collaboration in the value chain and viewing co-innovation as a process and mechanism. Previous research supports this study and shows the need for further exploration to build a robust conceptualisation of co-innovation (Bonney et al., 2007; de Propris, 2002) and the importance of viewing co-innovation from the process perspective or value chain collaboration (Bitzer & Bijman, 2015). Bonney et al. (2007) developed a co-innovation framework based on value chain analysis and suggested exploring more opportunities for co-innovation. In line with Bonney et al. (2007), Bitzer & Bijman (2015) used a case study in the agri-food chain to conceptualise co-innovation dimensions based on the innovation system and value chain analysis. Bitzer & Bijman (2015) suggest co-innovation dimensions comprising complementarity, collaboration and coordination to address the limited information on the coordination among actors, and more in-depth study on the co-innovation process involving actors in the value chain.

This research demonstrates the co-innovation process and mechanisms in the dyad relationship between supplier and customer, showing opportunities for co-innovation and expanding the concept from the agricultural value chain (Bitzer & Bijman, 2015; Bonney et al., 2007) to packaging and sustainability. This study confirms the co-innovation dimensions: collaborative, complementary and coordinated (Bitzer & Bijman, 2015), in the relationship management, in which governance mechanisms occur, as well as joint activities and joint resources (de Propris, 2002), in which knowledge transfer dominates the mechanism. This study extends the early work by de Propris (2002) by demonstrating how joint activities and joint resources influence successful co-innovation by enabling extensive knowledge sharing and improvement to accommodate the customer's needs. The co-innovation framework signifies the importance of knowledge exchange (Bitzer & Bijman, 2015; Bonney et al., 2007) by further showing how firms use their absorptive capacity (Zahra & George, 2002) to create bioplastic packaging innovation.

The following sections elaborate on the key mechanisms of co-innovation, comprising joint activities, joint resources and relationship management as an integrated mechanism. Based on the initial propositions derived from the RV and absorptive capacity theory, the discussion will highlight how these elements work in synergy with the strong presence of absorptive capacity, mediating the mechanisms towards product innovation and relational advantages.

6.2.1. Knowledge transfer as the focus of joint activities and resources

This study shows that knowledge transfer is the focus in co-innovation for bioplastic packaging. Reciprocal interaction of all partners during concept exploration, meeting and discussion between the product manufacturer and the suppliers and the trial at the customer's site becomes a valuable opportunity for assimilation, learning from failure, problems, and absorption of new knowledge from each partner's feedback or troubleshooting then creates specialised knowledge regarding better ways to make bioplastic packaging works for the customer. A similar study (Giacomarra et al., 2020) in sustainable food packaging also emphasised the importance of a knowledge exchange mechanism in the collaboration; their study showed the mechanism of supplier involvement in the R&D, and absorption of information from the external stakeholders, which eventually enabled the creation of new packaging that addresses sustainability. The importance of knowledge sharing in the inter-firm collaboration is in accordance with KSR (Dyer & Singh, 1998), transfer of knowledge and/or the creation of specialised knowledge.

Joint activities found from the case study allow continuous innovation-oriented learning (Chadha, 2011; de Medeiros & Duarte Ribeiro, 2013) and confirm the importance of knowledge transfer activities and the involvement of complementary knowledge representing intangible joint resources. The reciprocal interaction of all partners during concept exploration, meetings and discussion between product manufacturer and suppliers, and trials at the customer's site becomes a valuable opportunity for assimilation, learning from failure, problems, and the absorption of new knowledge from each partner's feedback or troubleshooting, then creates specialised knowledge regarding better ways to make bioplastic packaging work for the customer. This is in accordance with KSR (Dyer & Singh, 1998), transfer of knowledge or the creation of specialised knowledge. Joint activities found from the case study also allow continuous innovation-oriented learning (Chadha, 2011; de Medeiros and Duarte Ribeiro, 2013).

Furthermore, intangible joint resources are more likely to occur, such as sharing information, expertise and knowledge, leading to the creation of specific know-how related to the bioplastic technology and its application, and the joint IPs of packaging design or processing. New knowledge or joint IPs will be applied to generate benefits for each partner, such as being licensed, and commercialised to a broader market and industry. In most cases, joint resources are limited to knowledge sharing and non-capital spending. Seen from the RV theory, the creation of idiosyncratic assets is difficult and unlikely to become the source of relational rent (Dyer & Singh, 1998) that leads to solid and profitable partnerships. This condition is different from a case study in the conventional packaging industry, in which the supplier immersed itself in the customer value chain by building an independent company, wall-to-wall, at the customer's site (Morgado, 2008).

6.2.2. Relationship management fosters joint activities and joint resources

Relationship management in the form of routine communication, coordination of development or trial plans, educating users and managing their expectations, is essential for maintaining and developing a fruitful co-innovation. Managing knowledge flow, and educating customers and their personnel, in terms of environmental knowledge (Dangelico, 2016), were exhibited in almost all cases and for adopting bioplastic packaging; educating users to process the material and work with the production machine was crucial as well. The application of bioplastic packaging is new and not easy, so communicating this to customers at the beginning of the project is vital for the agreement and commitment of all parties (Chen et al., 2017; Dangelico, 2016). Partnership development is essential as the customer thoroughly reviews the supplier's capability. Concept development occurs during the partnership development, in which the biopolymer producer or converter presents the project's feasibility, carefully learns details of the product manufacturer's requirements, and the product manufacturer learns reciprocally (Perez et al.,

2013) about the new technology, with the opportunity to gain advantages through sustainability.

In the co-innovation, the customer is involved in late product development or even implementation. This activity delivers product and process improvement, and also increase the customer's acceptance of the final product. Nevertheless, problems in the extensive scale and scope of its implementation and commercialisation can occur due to the difficulty of the material to be scaled up, and problems at the end-of-life create negative responses that inhibit its commercialisation. Therefore, it is crucial in the co-innovation to involve the customer in the early concept development (Melander, 2018) in providing input about their actual needs, real machinery and manufacturing system needs, and end-of-life (Lacoste, 2016). The supplier believes that a strong business motive impedes the customer's interest, similarly to the product manufacturer or converter's, from becoming involved in product development until they see a clear potential in the market demand and its feasibility. The supplier is also very protective at the initial material development stage and does it internally. These conditions limit suppliers in understanding the customer's exact needs during internal material development, leading to lab-scale prototype failure when applied to actual production. At the partnership development stage, the biopolymer producer receives detailed requirements from the product manufacturer and must improve the material to deliver a specific packaging performance for each type of product, fit in with the product manufacturer's logistics and supply chain, add material certifications and comply with regulations worldwide. Nonetheless, long material development and iterations to apply the material consume many resources, whilst technology, the market, and regulation change faster, hence creating a dilemma.

This study introduces different approaches to engaging a co-innovation partner as part of relationship management (see Table 26), which then implies that partnership development is a crucial point for starting co-innovation in the bioplastic packaging context, in agreement with previous studies (Kleine Jäger & Piscicelli, 2021) addressing the recycled and reusable food packaging for the circular economy. The approaches proposed in this study signify that engaging users is a starting point to create value, which supports Lacoste (2016), suggesting the importance of co-creating value with the customer's customer through an open innovation mechanism. This study shows that engaging key business users such as the product manufacturers, especially industry leaders, would lead to extensive joint activities and joint resources in an extensive and complex development project that takes bioplastic packaging into a wider implementation and commercialisation, and builds relational advantages. Moreover, having the bioplastic packaging used by the product manufacturers would encourage the converter, as the biopolymer producer's direct customer, to enter bioplastic packaging as the potential demand become visible; and this finding indirectly supports Lacoste's (2016) value co-creation framework.

The extensive and complex co-innovation scheme in this thesis also presents similar complexities of partnership development as in a previous study (Kleine Jäger & Piscicelli, 2021), which indicates specific partner characteristics to the circular economy using a recyclable and reusable food packaging context. Although partner selection works both ways, the customers showed more power and put forward rigorous selection criteria to select a biopolymer producer that provides the bioplastic technology to fit the customer's strategy and goal regarding sustainability (Kleine Jäger & Piscicelli, 2021). However, when new technology is involved in circular economy or sustainability, as in the bioplastic packaging co-innovation, this study shows that the biopolymer producer must have the capabilities to operate on a small industrial scale, scale-up their technology, and be sufficiently adaptive to accommodate the product manufacturer's comprehensive needs on functionality and operationalisation in their supply chain. Therefore, this study suggests these capabilities should be considered in the partner characteristics (Kleine Jäger & Piscicelli, 2021) for collaboration in circular economy or sustainability.

6.2.3. The absorptive capacity facilitates successful co-innovation

This study shows that knowledge exchange dominates co-innovation, in which firms acquire external knowledge from the co-innovation partner and transform the combined knowledge to achieve innovation, thus signifying the importance of absorptive capacity (Cohen & Levinthal, 1990; Zahra & George, 2002). This research views absorptive capacity as a process (Easterby-Smith et al., 2008; Murovec & Prodan, 2009; Zahra & George, 2002) in co-innovation to develop sustainable products and illustrate the flow of knowledge from each co-innovation partner being transformed into incremental innovation and values for the business customers.

This finding signifies the mediating role of absorptive capacity in the relationship between green knowledge sharing and green product innovation (Murovec & Prodan, 2009; Song et al., 2020) and provides in-depth understanding based on the case study. Murovec & Prodan (2009) showed the importance of generating information from the suppliers, customers, trends, and other market and industrial aspects, to product and process innovation; however, cooperative innovation was not significantly correlated to demand-pull absorptive capacity, hence needed further exploration. Arguably, this statistical evidence (Murovec & Prodan, 2009) was generated from various industries, while other studies, specifically in the context of the green supply chain and green product innovation, show that a firm's absorptive capacity is highly correlated with supplier-customer knowledge sharing (Song et al., 2020). Similarly, this thesis also shows that knowledge and information provide leading-edge marketing and industrial knowledge. And that customer needs are built from supplier-customer co-innovation and greatly benefit the creation of bioplastic packaging innovation ready for industrial commercialisation.

This study has shown the importance of the supplier's absorptive capacity to accommodate customers' needs and create benefits for the customer. The flow of knowledge from the customer to the supplier is higher than the other way round, which shows a higher knowledge acquisition. The suppliers were found to be more intensively transforming the new knowledge, taking advantage of it to improve the packaging, expand the scope of its application to various packaging, sell to a wider consumer range and finally obtain economies of scale. Nevertheless, this does not mean that the product manufacturer as the customer has lower absorptive capacity. The customer's transformation and exploitation of new knowledge enables them to run the production using the new bioplastic packaging and use it for the final product to improve the brand and product image, and become an achievement within their sustainability agendas. Small/medium product manufacturers show less absorptive capacity because co-innovation aims to implement bioplastic packaging to their products, underlining that packaging supports their final product. Meanwhile, large product manufacturers and converters who collaborate with biopolymer producers show higher absorptive capacity because the project is expected to deliver superior bioplastic packaging that will become a great advantage in the future.

Therefore, in co-innovation, a partner would optimise the absorptive capacity in specific areas that are more relevant to their core business or potentially generate more benefits. The findings indicate that biopolymer producers and converters gain more opportunities to exploit the new knowledge from co-innovation, such as improving the product, scale-up, commercialising, and expanding the market. In comparison, the product manufacturer would benefit from using the packaging to enhance their brand and sustainability credentials. The new knowledge from co-innovation might not be equally beneficial for all partners, and the benefit might not be shared equally after the co-innovation. Lavie (2006) argued that the distribution of relational rent is not evenly distributed among partners. In the case study, the supplier shows higher absorptive capacity, resulting in a higher ability to seize external knowledge and produce gain from co-innovation (Lavie, 2006). Further study is needed on how each partner uses absorptive capacity, how new knowledge and benefitting from its exploitation are shared among partners and may influence their investment or behaviour in the co-innovation, primarily in bioplastic packaging or sustainable product innovation.

6.2.4. The outcomes from co-innovation beyond bioplastic packaging innovation

Although co-innovation is not intended to create novel material from the beginning, it does deliver novel product concepts (Rai et al., 2010) related to the material application, such as the packaging design for new material, and an innovative application for a certain product in the complex and extensive co-innovation. These achievements could promote each partner's credentials in sustainability and innovation. This study shows the gap between the bioplastic packaging value offering and the business customer's expectations, such as the converter's focus on cost efficiency. At the same time, product manufacturers look for sustainable packaging available on an industrial scale, accomplishing their sustainability agenda, addressing consumers' expectations, and enhancing their brand. This finding is in agreement with Dangelico's (2016) study, highlighting the opportunity to bring a competitive advantage from green product innovation by addressing cost savings, increased sales, export and market share, higher productivity and profits, as well as a better reputation. This thesis corroborates the corporate innovation strategy (Dangelico, 2016) through co-innovation, and that it is essential to co-create the value of sustainable innovation beyond cost efficiency with product manufacturers, especially the industry leader, in order to bridge the value offering gap and collaborate with the packaging manufacturers.

This study considers the bioplastic packaging developed from co-innovation as incremental innovation, which is indicated by the creation of a new or improved product or process (de Propris, 2002). The upstream biopolymer production process uses the existing conventional plastic supply chain, and the innovations that occur are incremental (de Vargas Mores et al., 2018). Likewise, the case study shows that subsequent innovations in packaging conversion are also incremental because the converters and product manufacturers are reluctant to have significant changes in their operations, also they expect results similar to those of conventional plastic packaging. Although Chadha (2011) saw biopolymer technology as a potential radical eco-innovation, the plastic industry prefers incremental innovation. This research presents the difficulty of this technology becoming a radical innovation penetrating a well-established value chain and competing with mature products in the packaging industry. Radical innovation that disrupts the established value chain would be difficult as it requires a major change in the existing well-established value chain, such as changing the existing industrial-scale infrastructure, which would require substantial capital and take a longer period to change. Massive behaviour change from business players and end-users is also required but highly challenging due to the way the packaging is used in broad aspects of life. Ultimately, incremental innovation is more appropriate for the bioplastic packaging product development considering its feasibility and higher acceptance by the customer. Hence this study suggests co-innovation mechanisms are directed so that bioplastics can be broadly adopted through incremental innovation.

This study reveals how co-innovation brings improved bioplastic packaging that speeds up its commercialisation, followed by relational benefits (Dyer & Singh, 1998; Zhang et al., 2017) generated for co-innovation partners by using sustainable innovation. Following a successful implementation, relational benefits should ideally be capitalised by all partners in the long-term (Yu et al., 2021), and this thesis further exemplifies the relational benefits to be acquired from co-innovation in developing bioplastic packaging. For suppliers, the benefit lies in being able to sell materials or packaging to a wider market, while for customers, it is improving their sustainability credentials. These benefits appear to be private benefits that return to each partner and are more dominant in simple and narrow co-innovation types. In narrow and simple co-innovation and some extensive and complex projects, relational rent from co-innovation for bioplastic packaging falls into the primary rent category (Zhang et al., 2017). As the alliance is newly developed based on the contract for product development and the intangible management capabilities cultivated, all partners acquire know-how from working with bioplastic packaging, use it for their production units, and generate profits and other benefits, which possibly are unequally shared (Zhang et al., 2017). However, some extensive and complex projects have developed intermediate rent (Zhang et al., 2017) and are more likely to be relational benefits (Dyer et al., 2008), such as exclusivity, joint IPs where new applications of the technology were invented based on the supplier's technology, the converter manufactures similar packaging for different customers with greater efficiency or better problem-solving. The product manufacturers use the bioplastic packaging for their products and gain commercial benefits, competitiveness and innovativeness related to sustainability. Moreover, this study supports Zhang et al. (2017), suggesting that relational rent does not immediately generate economic gains but generates capabilities, followed by sustained competitiveness and innovativeness.

This study presents a possible way to implement bioplastic in the packaging industry through the material, product and process improvement and potential relational benefits for the biopolymer producer, converter and product manufacturers. Co-innovation has addressed the value gaps between supplier and customer based on biopolymer producer, converter, and product manufacturer perspectives. For example, to address the problem at the end-of-life, the biopolymer producer created bio-based recyclable bioplastics with a comparable price to conventional plastics or multiple end-of-life bioplastics that are water-soluble and recyclable, and co-innovated with the converter and product manufacturer for implementation. This study accentuates the challenges in the implementation of the biopolymer as packaging to meet the converter and product manufacturer's needs, working with the existing plastic packaging value chain, especially downstream, including problems with the waste system, all of which currently inhibit commercialisation to an industrial scale (Beltran et al., 2021; Keränen et al., 2021; Sundqvist-Andberg & Åkerman, 2021; Tjahjono et al., 2021). While previous studies (Chadha, 2011;

de Vargas Mores et al., 2018) focused on the biopolymer producer's perspective, highlighting the positive side of bioplastic material as green innovation, capturing more collaboration with the downstream supply chain, while challenges in the implementation at the downstream value chain and diffusion to mainstream (Neutzling et al., 2018) have not really been discussed.

Bioplastic packaging initially entered the market as a niche product, but further penetration into the packaging industry faces highly complex challenges, which are also interrelated, from upstream to downstream. Notable challenges for commercialisation and the broad adoption of bioplastic packaging in the industry (Neutzling et al., 2018) were expressed by all informants in this study and have been discussed in previous studies, for example, limitation on the technical aspects when implemented in the existing manufacturing process and meeting packaging functionality, limited availability and high cost of the material (Beltran et al., 2021; Keränen et al., 2021; Nilsen-Nygaard et al., 2021; Tjahjono et al., 2021; Zhao et al., 2020). Problems in inter-firm scope are possibly addressed through co-innovation because the supplier partnered with business customers to develop the packaging. The supplier attempted to address the customer's needs for a specific packaging, and all partners would tolerate and adapt to a certain point. However, more challenges in commercialising bioplastic packaging are related to the complex value chain and impact different stakeholders (Keränen et al., 2021; Nilsen-Nygaard et al., 2021; Sundqvist-Andberg & Åkerman, 2021; Tjahjono et al., 2021; Zhao et al., 2020).

The outcome of co-innovation in this research could not fully resolve complex problems involving various stakeholders in the industry. Complex problems require coherent actions from various stakeholders in the value chain. For example, problems at the end-of-life impact the waste service, local councils, consumers, standards organisations, and policymakers. Problems occur in relation to sorting and identifying bioplastic over conventional plastics (Nilsen-Nygaard et al., 2021). After using the product, bioplastic packaging must be sorted, separated and disposed of by the consumers. However, consumers have a limited understanding of bioplastic packaging types, become confused over labelling and differentiating bioplastics over conventional plastics, and are often reluctant or feel inconvenienced to do sorting and separating procedures (Beltran et al., 2021; Sundqvist-Andberg & Åkerman, 2021). Albeit the consumers have done their job, the appropriate waste disposal is not always available at their local facilities (Keränen et al., 2021; Sundqvist-Andberg & Åkerman, 2021; Tjahjono et al., 2021). Standardisation and labelling are also related to problems at the end-of-life because labelling varies, and there is confusion for the consumer and non-coherence with the disposal facility (Beltran et al., 2021). Often there is a gap regarding a compostability label or certification, such as EN13432 certification for biodegradation, and the actual performance due to variability of the actual processing environment with the one used in certification (Beltran et al., 2021). In the larger scope, previous studies have highlighted limited infrastructure in the end-of-life processing system on an industrial scale, limited sorting technology (Beltran et al., 2021), and the limited number and capacity of the industrial composting facilities suitable for bioplastic packaging (Tjahjono et al., 2021; Zhao et al., 2020). Consequently, biodegradable packaging is likely to go to incineration or landfill (Beltran et al., 2021), releasing methane in landfills and negatively impacting the environment and health when incinerated (Sundqvist-Andberg & Åkerman, 2021).

The outcome of co-innovation in this study could not completely remove uncertainties in the industry. Uncertainties are high, even though different options of the bioplastic packaging end-of-life, such as mechanical recycling, chemical recycling, aerobic composting, anaerobic digestion or energy recovery, are potentially available, but preferred options remain unclear (Beltran et al., 2021; Sundqvist-Andberg & Åkerman, 2021). Also, leading organisations, such as the Ellen MacArthur Foundation, have changed their recommendations to emphasise recycling and reuse schemes, downsizing the importance of biodegradable plastic to address sustainability or circular economy (Nilsen-Nygaard et al., 2021). These conditions make business players cautious about adopting bioplastic packaging because of the risk of adverse reaction towards their sustainability agenda or public image. Furthermore, economic drivers are weak, making businesses slow to change (Tjahjono et al., 2021). Accordingly, this study also reveals similar facts to the study just referred to, in which perceived environmental benefits of compostable packaging are not yet leading to the majority of consumer's purchase decisions; manufacturers are reluctant to change due to the high cost of the bioplastic material and prefer a cheaper, easier to sell packaging (Tjahjono et al., 2021).

Conflicting views and debates over the benefits of bioplastic packaging for sustainability have signalled more uncertainties for business players to adopt bioplastic packaging. The following issues are captured from the case study and add more evidence to previous studies (Beltran et al., 2021; Keränen et al., 2021; Sundqvist-Andberg & Åkerman, 2021). Food packaging governance through the circular economy sometimes conflicts with different sustainability agendas; for example, reducing plastic waste, and single-use plastics might not effectively reduce greenhouse gas (GHG) emissions and food waste (Sundqvist-Andberg & Åkerman, 2021). Next, biodegradable, recycled plastics for food and beverage are often contradictory to health and safety regulations (Beltran et al., 2021) and possibly reduce other aspects such as convenience and services (Sundqvist-Andberg & Åkerman, 2021). While the biopolymer producer is expanding its feedstock portfolio (Skoczinski et al., 2021) to reduce dependency on the fossil-based source, conflicting environmental and social impacts are likely to arise due to the area used for food production, freshwater usage, interference with natural carbon cycles and soil fertility, primarily if bioplastics are produced on a mass industrial scale (Beltran et al., 2021; Sundqvist-Andberg & Åkerman, 2021). Currently, business players tend to avoid responsibilities and externalise the problems to consumers disposing of packaging waste, and there is a lack of support from policymakers and standard organisations. Skoczinski et al. (2021) highlighted that only a few countries support biodegradable packaging and provide a path for end-of-life. Enforcing law and tax for plastics on producers does not effectively encourage the right actions, contains a political agenda emphasising recycling, reduces support for innovation (Sundqvist-Andberg & Åkerman, 2021) and is not strong enough to induce innovation that changes the plastic packaging regime (Beltran et al., 2021).

This thesis originally proposed initial indicators for bioplastic packaging product innovation as the outcome of co-innovation. These indicators include packaging quality, cost, sustainability and innovation and are based on the case study; this study suggests modifying the initial indicators into product innovation that addresses the broad implementation of bioplastic packaging in the industry and its long-term benefits, with reference to rent (Dyer et al., 2008; Dyer & Singh, 1998). This study also shows that the bioplastic packaging developed from co-innovation could be a promising eco-innovation (Chadha, 2011; de Vargas Mores et al., 2018), and the relational benefits created from co-innovation could spread those benefits among partners and maintain collaboration in the long-term or possibly extend the collaboration to bring bioplastic packaging innovation. Furthermore, this study shows that co-innovation positively impacts business customers adopting bioplastic packaging and is likely to influence the value chain within their closest networks. This small step is essential to diffusing sustainable innovation to the existing value network as in previous studies (Beltran et al., 2021; Keränen et al., 2021). However, the outcomes from innovation are limited in addressing complex challenges beyond the reach of firm-level collaboration as well as eliminating uncertainties within the greater scope of the macro and global environment that involves various stakeholders. As this research focuses on the process and mechanisms of co-innovation, further studies are required to explore how co-innovation would benefit co-innovation partners and, at the same time, become one alternative to overcome these challenges.

This study suggests further research is needed to unravel the path towards bioplastic development, followed by product creation through co-innovation. A clearer path is necessary to minimise the risk of product development heading in the wrong direction and to encourage co-innovation among businesses as the opportunities become visible and project feasibility shows more substantial benefits. Further research is needed to explore the possible path for bioplastic product development, and find opportunities where bioplastic packaging could optimise its benefits for the environment and sustainability (Beltran et al., 2021). This study shows that a co-innovation project is highly possible to be halted because a particular bioplastic material may no longer be interesting, albeit a significant resources have already been spent. Thus, the continuation of a co-innovation project depends on whether the outcome would be relevant in the long-term future. Therefore, a clear path for bioplastic packaging should consider development in a long-term scheme, considering the lengthy development time needed for material, packaging and scale-up. At the same time, organisations or policymakers could avoid changing recommendations or regulations that impact the continuation of co-innovation.

In accordance with Keränen et al. (2021), opportunity creation is essential to diffuse new technology such as bioplastic packaging to broad implementation. This study suggests that suppliers, such as the biopolymer producers, rethink the downstream innovation, innovative product, process, or benefits that foster diffusion through product manufacturers, consumers, and the end-of-life. Bioplastic packaging should bring valued improvement from the business customers' perspective to move from niche to mainstream, and this study suggests that new product development addressing innovation in sustainability should pay greater attention to creating innovative products feasible for a broad implementation at the macro-level (Keränen et al., 2021) and the global scale. This study also shows the importance of engaging product manufacturers, who are also industry leaders, in co-innovation to develop bioplastic packaging (Kishna et al., 2017), and promote diffusion to the supply chain and consumers. Large product manufacturers in this study showed their power to involve their converters and more partners within their supply chain to support their co-innovation project. Accordingly, more studies and actions are needed to extend co-innovation involving various stakeholders whilst taking into account the critical role of the industry leader, for example, a network co-innovation such as a consortium (Keränen et al., 2021; Kleine Jäger & Piscicelli, 2021; Tjahjono et al., 2021; Zhao et al., 2020), to address downstream challenges, the implementation, commercialisation and end-of-life.

6.3. Refined conceptual framework of co-innovation

This study proposes a new conceptual understanding of co-innovation through a process view underpinned by the RV theory (Dyer & Singh, 1998), which provides a valuable theoretical perspective for understanding inter-firm collaboration and has been used in new product development (Neutzling et al., 2018), new technology, high technology industry (Perez et al., 2013; Wu et al., 2017; Zhang et al., 2017), and the automotive industry (Huber et al., 2011; Miguel et al., 2014). (See Figure 29 and the summary in Appendix E). This study also extends the RV theory to inter-firm collaboration in a unique context of niche technology in sustainability to work in the packaging industry with its strong existing regimes (Beltran et al., 2021; Keränen et al., 2021). Previous research in bioplastic collaboration used different theoretical perspectives, such as socio-technical system and multi-level perspectives (Beltran et al., 2021), sustainability transition (Keränen et al., 2021), eco-innovations (Chadha, 2011), sustainable supply chain management (SSCM) (Kishna et al., 2017; Neutzling et al., 2018), institutional theory and other references in organisation alliances (Jeong & Ko, 2016; Kishna et al., 2017; Yeniyurt et al., 2014).

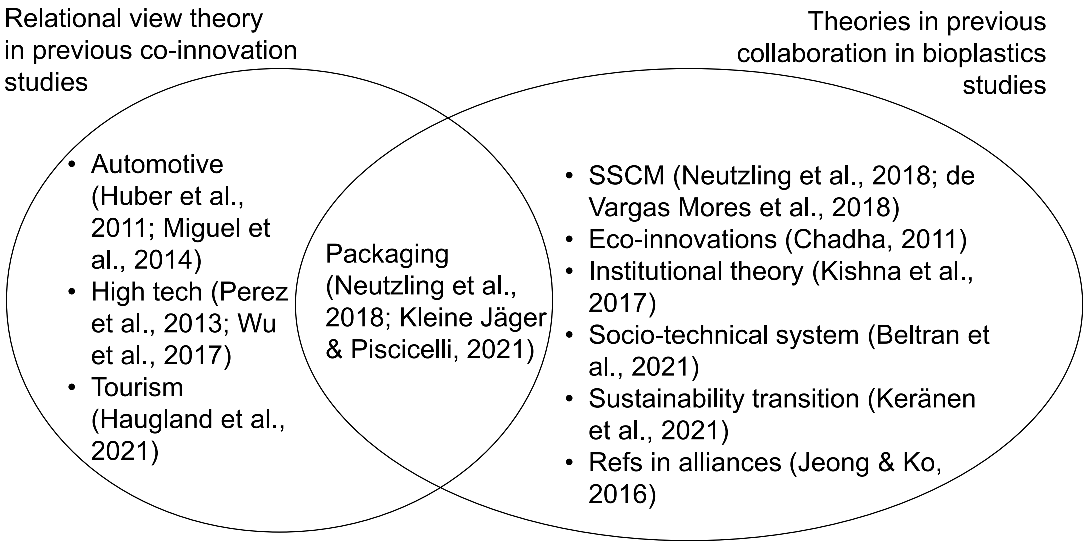


Figure 29 Theories used in previous studies of co-innovation in various industries

The co-innovation framework proposed in this study conceptualises the co-innovation mechanisms from the RV theory (Dyer & Singh, 1998), underlining how combined resources and capabilities from the supplier and customer work in creating product innovation and relational rent from improved bioplastic packaging and commercial benefits related to sustainability. Previous studies have emphasised the importance of companies' capabilities to create sustainable innovation, and this thesis illustrates those capabilities (Chadha, 2011; Hofmann et al., 2012; Lee & Kim, 2011; Melander, 2018) in a process view and builds the supplier-customer co-innovation mechanism. Capabilities such as managing inter-firm alliance and cross-functional collaboration, running the development project and monitoring technology development are crucial for companies to produce green product innovation (Chadha, 2011; Melander, 2018), and these capabilities are translated into joint activities, joint resources and relationship management operating as an integrated mechanism. This supports the conceptualisation of co-innovation beyond partnering to build capability for innovation (Lee et al., 2012), while incorporating a dyadic relationship of supplier and customer to address the importance of the value chain perspective (Bitzer & Bijman, 2015; Bonney et al., 2007).

Co-innovation is built from an integrated mechanism of joint activities, joint resources and relationship management work throughout the co-innovation stages in developing bioplastic packaging. The joint activities consist of knowledge sharing, product development with the customer, extensive mutual adaptation among all partners, and supporting customer's implementation. Joint resources include more intangible resources to be shared and accumulated into new knowledge, and capabilities related to bioplastic packaging and sustainability. Relationship management consists of partnership development, building partners' commitment, followed by communications to educate users and regular communication. Subsequently, these mechanisms strongly present the KSR, complementary resource endowment and effective governance as the sources of competitive advantage (Dyer & Singh, 1998) from co-innovation. This study also indicates that partnership development becomes a crucial starting point to acquire a partner owning a specific technology, and the capability to absorb the business customers' specific needs of functionality, and capability for scaling-up would be advantageous. Consequently, this fact strongly presents the partner scarcity mechanism (Dyer & Singh, 1998) to build a competitive advantage from co-innovation. However, as co-innovation is newly developed and the development is ongoing, other mechanisms such as resource indivisibility, and time compression diseconomies (Dyer & Singh, 1998) are in early development and were not fully visible for the case study, hence this opens an opportunity for exploring these are in future studies.

This research strongly suggests that joint activities, resources, and relationship management should be treated as integrative, and refines the initial framework that first suggested that these elements might work independently (see the refined framework (Pr 1)). The integration of joint activities, joint resources and relationship management has also been suggested by previous studies (Bitzer & Bijman, 2015; Chadha, 2011; Neutzling et al., 2018). Neutzling et al. (2018) developed a collaboration framework in bioplastic technology specific to the Brazilian bioplastic supply chain, exploring resource investment in a co-innovation where the biopolymer producer is the focal company; as their study has not provided extensive details on collaboration outcomes, this thesis extends their work by showing co-innovation mechanisms among the biopolymer producer, converter and product manufacturer as well as providing indicators of the outcomes from co-innovation. Furthermore, this research brings empirical evidence from the case study and supports previous studies (i.e., Neutzling et al., 2018) suggesting the importance of managing relationships related to collaboration in knowledge and capabilities, resource investment in RSA, joint learning process and knowledge exchange, and governance mechanisms from a holistic perspective. Developing competencies and mechanisms in building alliances and collaboration with other firms in joint R&D projects based on new technology exploration and learning from customer problems, interest, and market trends, would overcome competence lock-in and path dependence (Chadha, 2011). This study addresses the need for further exploration on how relationship management works (Neutzling et al., 2018) in co-innovation and posits that relationship management would increase joint activities (Pr 2) and joint resources (Pr 3), thus strengthen the overall co-innovation mechanisms.

This study also highlights different motives for co-innovation in bioplastic packaging from the supplier and customer perspectives. The perceived benefits that encourage customers to engage in co-innovation were slightly varied. However, there was a common ground where the product manufacturer and converter as the customers assessed the project's potential to increase commercial benefit through innovation in sustainability; for example, the converters emphasised sales and market potential, while the product manufacturers were more focused on the brand enhancement and addressing sustainability. Therefore, these findings do not fully support the initial proposition (P8), which posits that perceived contribution to customer's innovation will increase customer's contribution in joint activities and resources. The initial proposition (P8) assumes the higher supplier invests specific resources for the customer, including dedicated human resources and tangible assets such as dedicated equipment (Perez et al., 2013) to support the customer's innovation. In fact, this research finds limited evidence on dedicated tangible assets to support the customers, such as co-location, HR training, Enterprise Resource Planning system (Morgado, 2008; Perez et al., 2013; Slater, 2010). Furthermore, dedicated support is essential during co-innovation to increase the customer's commitment and willingness to adapt, which is in line with Perez et al. (2013), but less relevant to assume as the antecedent to co-innovation, as in the initial proposition (P8).

Co-innovation provides the supplier more exposure to external knowledge sources, complementary information, and expertise from the customer and the customer's supply chain, making co-innovation the antecedent to absorptive capacity (Zahra & George, 2002). Co-innovation allows the supplier and customer to strengthen their absorptive capacity in the area relevant to bioplastic packaging. Most importantly, new combined knowledge was primarily aimed at addressing the customer's needs for improved bioplastic packaging and providing commercial benefits for both the supplier and customer. This finding supports the notion that co-innovation built up each partner's realised absorptive capacity, improved the bioplastic material, packaging and process, and provided indirect financial benefits (Zahra & George, 2002). And therefore, also supports proposition (P9): *In the bioplastic packaging co-innovation context*, *the absorptive capacity mediates the relationship between co-innovation and bioplastic packaging product innovation*.

In the context of co-innovation for bioplastic packaging, the co-innovation mechanisms comprising joint activities, joint resources, and relationship management allow the information to flow to all co-innovation partners to develop and improve the bioplastic packaging. The proposition emphasising that higher relationship management will increase absorptive capacity, and therefore bioplastic packaging innovation success (P10), is not entirely relevant as the absorptive capacity depends on activities intended to accumulate new knowledge (Song et al., 2020; Zahra & George, 2002). To improve bioplastic packaging, the findings show that it is very important to bring the product to the customer, and interactions that facilitate improvement are the key. Improvements were enabled by using complementary expertise to improve the product, such as in trials, continuous learning, exploration of possible solutions or benefits, and mutual adaptation. In our case study, relationship management *per se* does not increase the absorptive capacity that brings product innovation. The evidence shows that joint activities are more likely to promote knowledge flow among partners, enable new learning, and will only successfully deliver bioplastic packaging innovation when integrated with joint resources and relationship management. Accordingly, this study strongly posits that co-innovation builds both supplier and customer's absorptive capacity, enabling the exploitation of this complementary knowledge specific to bioplastic packaging innovation and sustainability.

This study proposes that co-innovation in developing packaging not only brings an improved product but also builds relational benefits (Dyer & Singh, 1998; Zhang et al., 2017) because the benefits from using sustainable innovation, ideally will be capitalised on by all partners in the long-term (Yu et al., 2021). Therefore the initial indicators of the co-innovation outcome are modified from product innovation to covering comprehensive benefits from co-innovation, comprising improvements targeted for implementation at the business customers, and, after successful implementation, internal and relational benefits (Dyer et al., 2008; Lavie, 2006; Zhang et al., 2017) emerge for all co-innovation partners. This thesis exemplifies the potential benefits from co-innovation in developing bioplastic packaging. For suppliers, the benefits include being able to sell materials or packaging to a wider market, while for customers, they mean improving their sustainability credentials. These benefits appear to be private benefits that return to each partner and are more dominant in simple and narrow co-innovation types, while in extensive and complex co-innovation, common benefits emerge (Dyer et al., 2008), such as exclusivity, joint IPs that increase competitiveness, and innovativeness in sustainability, and are not directly financially beneficial (Zhang et al., 2017). Zhang et al. (2017) proposed a new definition of Dyer and Singh's relational rent, formed by economic gains, soft power and science & technology output rather than only created from idiosyncratic joint contributions from all partners, and proposed three types of rent based on empirical evidence tested from high-technology enterprises in China.

This study shows the importance of co-innovation beyond creating superior bioplastic packaging because co-innovation allows partners to use the technology and new packaging to increase commercial advantage and sustainability credentials that show the development of relational rent (Dyer & Singh, 1998). In addition, partners involved in co-innovation can access technology widely from joint IPs related to certain designs or applications of the bioplastic technology. This finding presents empirical evidence that supports a previous study, which uses secondary data, and argues that the alliance in bioplastic technology would generate firm market, social or technology legitimacy (Kishna et al., 2017). Technology legitimacy occurs when co-innovation partners will be able to generate benefits from using the bioplastic technology for multiple applications leading to wider adoption along the supply chains or across industries, and this legitimacy occurs in co-innovations for developing packaging prototypes and in the extensive complex projects involving industry leaders and more stakeholders (Kishna et al., 2017). This legitimacy is likely to be created only from co-innovation and potentially create supplier-customer relational advantages, and also signify the relevance of the RV theory (Dyer & Singh, 1998).

Furthermore, this research found the case of a product manufacturer, also an industry leader, who was interested in the technology and being the leader in sustainable packaging, as well as the potential of commercial benefits from using this new packaging. From the business customers' perspectives, this study confirms Kishna et al.'s (2017) finding that through co-innovation, customers expect to gain market and social legitimacy from using the technology, and the supplier who owns the technology will want to build technology legitimacy. Nevertheless, what to achieve from co-innovation, whether the customer wants to seize the commercial benefits, acquire knowledge or secure the technology, depends on the customer's strategy (Jeong & Ko, 2016). Even though the supplier claims to support the customer's innovation in sustainability (Chadha, 2011; de Vargas Mores et al., 2018; Farrow et al., 2000), business customers tend to avoid the risks in adopting new technology in the early stages, as in bioplastic material, and invest resources only if they see solid technological and economic benefits (Keränen et al., 2021). Accordingly, large product manufacturers in this study were cautious about the impact of bioplastic packaging on their brand and sustainability agenda due to the debate on bioplastic environmental benefits (Sundqvist-Andberg & Åkerman, 2021) and problems at the end-of-life (Beltran et al., 2021), signalling uncertainties for the future of the technology. Hence, the initial proposition (P8) might work when more certainty on the future of bioplastic packaging is visible, and further study is needed to explain this area.

This study supports the applicability of RV theory in the context of bioplastic packaging, particularly the KSR and absorptive capacity, complementary assets, and partner complementarity works. Moreover, this research shows how co-innovation in developing sustainable packaging would then progress into relational rent; however, it also shows a conditional application of asset specificity as a source of relational rent in the bioplastic packaging context. Previous studies also indicate inconsistent findings (Dyer et al., 2018) regarding asset specificity in different contexts (Lotfi et al., 2021; Miguel et al., 2014; Wu et al., 2017). A study of Brazilian product manufacturers in the personal care, food and beverage industry (Miguel et al., 2014), indicates that asset specificity fails to indicate a positive relationship with relational buyer-supplier value. In their research, the relationship with packaging suppliers becomes an important part of the overall buyer-supplier relationship with the product manufacturer (Miguel et al., 2014); and this is very similar to the partner relationship in bioplastic packaging co-innovation, especially with the converter. Miguel et al. (2014) argue that suppliers typically invest in manufacturing equipment that works for many customers and apply specific adjustments in formulations instead of investing in specific equipment or building dedicated plants for a certain customer. Likewise, the bioplastic packaging converter did not establish a dedicated fabrication for bioplastic packaging and used biopolymer in the same process as plastic packaging with adjustments in tools, parts and formulation.

However, other studies show that asset specificity, such as building a dedicated production unit and co-locating to the customer's plant in a supplier-customer co-innovation (Baraldi et al., 2014; Morgado, 2008; Slater, 2010), works in the packaging industry context. Likewise, this study provides empirical evidence that joint resources, particularly the specificity of tangible assets, were created under specific conditions. First, asset specificity was created when a product manufacturer invested financial capital in building a pilot plant to scale-up the bioplastic material. The product manufacturer saw the potential for commercialisation of this material, and that they would acquire 100% access to the material, including exclusive supply to cover their need for bioplastic packaging. In another case, a product manufacturer co-invested in building a dedicated production line with the converter to manufacture the bioplastic packaging after their co-innovation continued for a period of time and developed into a well-established relationship. Therefore, this study argues that asset specificity that potentially disrupts a well-established value chain would be limited, thus showing a conditional application of the RV theory in the bioplastic packaging context. Opportunities for further study in this area are elaborated in the next section.

6.4. Contributions to knowledge

The previous sections have elaborated the importance of co-innovation in developing bioplastic packaging with empirical evidence from the case study. This study also presents the process and key mechanisms of co-innovation, highlighting best practices in the fields. Challenges to implementation and commercialisation exist at the inter-firm level and in a more complex business environment involving various stakeholders. This thesis presents opportunities to bridge gaps in the bioplastic packaging commercialisation at the inter-firm level, emphasising the perspectives of the bioplastic packaging supplier and business customer as the main actors playing important roles to bring bioplastic packaging to commercialisation. The refined framework of co-innovation presents an integrated mechanism of joint activities, joint resources and relationship management, signifying the vital presence of absorptive capacity to facilitate product innovation and relational benefits for co-innovation partners. The following section discusses the academic contributions from this study.

6.4.1. Extending co-innovation concept

Bioplastic packaging started as the producer's innovation and became a close-collaborative project (Baldwin & von Hippel, 2011), in which business users help in sourcing ideas and engagement with users, and initiate an incremental shift towards sustainability practices (Arnold, 2017). Similar to previous studies in co-innovation, which were largely based on open innovation and service-dominance logic (Arnold, 2017; Lacoste, 2016; Lee et al., 2012), co-innovation in this study adopts the creation of innovation from collaborative work. For example, contributors share information and may spread tasks in modular design to allow structured IP acquisition from different partners (Baldwin & von Hippel, 2011). In general, collaboration adopting co-creation and open innovation (Arnold, 2017; Lee et al., 2012) has advantages in engaging more stakeholders, especially the user community, gathering more ideas and needs from the consumers, promoting awareness of a new product and acceptance in the broad market, and creating incremental innovation (Arnold, 2017). However, open innovation also emphasises co-creation with communities (Arnold, 2017; Baldwin & von Hippel, 2011; Lee et al., 2012) and often requires an IT platform for interactions with stakeholders, including the general public (Lee et al., 2012). Furthermore, the information is shared and becomes public or is exclusively acquired by a sponsor in a closely collaborative hybrid model

(Baldwin & von Hippel, 2011). Nonetheless, co-innovation in this study emphasises exclusivity among partners, especially in the way confidential, specific knowledge is shared and exploited exclusively among co-innovation partners, thus stands as the key difference to co-creation based on open innovation with users or user community engagement (Arnold, 2017; Baldwin & von Hippel, 2011).

Co-innovation in this study reflects several co-creations in sustainability underpinned by service dominance logic (Lacoste, 2016), showing that the end consumers become the starting point to create value. Hence, understanding their behaviour, expectations and conditions for the sustainable purchase enable the supplier to improve the fitness of the offering for the direct business customer. Co-creation of value emphasises experience through interactions with the customers (Prahalad & Ramaswamy, 2004) and further development (Vargo & Lusch, 2004) sees value creation through resource integration and the exchange of service among actors. In the bioplastic packaging context, the interactions between the biopolymer producer and product manufacturer in the concept exploration, knowledge-sharing and trial in the joint activities reflect co-creation (Lacoste, 2016). This study shows that co-innovation will increase the success in product innovation, shown from the improved packaging and solution offering that supports the product manufacturer's sustainability agenda and brand enhancement, which is in line with the expected outcome from co-creation in the packaging (Lacoste, 2016).

However, based on the RV theory (Dyer & Singh, 1998), this study considers the outcomes from co-innovation as relational advantages, which are innovative, difficult to imitate, exclusive to co-innovation partners and bind the partnership in the long-term as these advantages cannot be achieved when each partner works individually. While based on service dominance logic (Vargo & Lusch, 2004), Lacoste (2016) considered the improved packaging as the medium of service that helps the product manufacturer increase their commercial benefits and sustainability credentials. Nevertheless, co-creation involving the user community allows a company to source ideas as well as consumers' expectations and awareness towards sustainability. Bringing value co-created into implementation is challenging; in fact, addressing sustainability is more complex and beyond involving user communities in idea sharing (Arnold, 2017). To address this challenge, the co-innovation mechanisms in this study emphasise bringing sustainable product innovation into realisation and a broad implementation by engaging important actors to work together and diffuse the innovation (Keränen et al., 2021). Engaging product manufacturers will bring sustainability packaging into realisation, and product manufacturers will maintain communication with their consumers, address their expectations on sustainability, and educate the consumers about the relevance of bioplastic packaging to sustainability, thus diffusing the innovation.

This study extends the conceptualisation of co-innovation, which has been developed in the previous studies grounded in open innovation, service dominance logic theory and co-creation. Grounded in the RV theory and absorptive capacity theory, this research highlights the relational aspect of inter-firm collaboration in product innovation, learning and exploitation of knowledge among partners, and the creation of relational benefits. Thus, it will be a valuable addition to co-innovation references.

6.4.2. Extending the relational view theory

The RV theory (Dyer & Singh, 1998) underpinned the conceptualisation of co-innovation mechanisms in bioplastic packaging, emphasising the inter-firm collaboration and exclusive benefits. The RV theory (Dyer & Singh, 1998) has also become a powerful theoretical lens in many studies addressing inter-firm collaboration, new product development and innovation in the automotive industry, equipment and heavy industry, high technology firms and tourism (Haugland et al., 2021; Huber et al., 2011; Jeong & Ko, 2016; Miguel et al., 2014; Perez et al., 2013). This study extends the applicability of RV theory to build the framework of co-innovation in bioplastic packaging, which represents unique phenomena, where new sustainable technology is developed as a niche and struggles to diffuse into the mainstream (Beltran et al., 2021; Keränen et al., 2021).

This research extends the RV theory, which originally focused on firms' dyadic relationships, to work in wider inter-firm relationships within an inter-linked network of stakeholders. The RV theory focuses on the inter-firm alliances using the dyadic relationship for the unit analysis (Dyer & Singh, 1998), which is relevant for collaboration involving two organisations. In reality, firms work in an inter-linked network of stakeholders, such as in the automotive industry, whereas the focal firms have to work with suppliers and sub-suppliers (Huber et al., 2011; Jeong & Ko, 2016). Also, in the packaging industry (Keränen et al., 2021), a solid linear link exists between the plastic material producer, converter, and product manufacturer, making the product manufacturer unable to collaborate in developing bioplastic packaging with the biopolymer producer without the presence of the converter. This study explores how the dyadic relationship of supplier-customer works within a triadic embeddedness (Haugland et al., 2021) and demonstrates how the dyadic relationships of biopolymer producer-converter, converter-product manufacturer, and biopolymer producer-product manufacturer work within a network value chain. Thus it extends the RV theory to work in a triadic alliance and opens opportunities for further study to extend the theory into network co-innovation, such as a consortium (Keränen et al., 2021; Kleine Jäger & Piscicelli, 2021).

This study addresses further study as suggested in previous research (Haugland et al., 2021), highlighting the importance of extending the dyadic level of analysis to understand the reality of firms' working in complex and adaptive supply networks, such as co-innovation in the automotive industry and biotechnology (Haugland et al., 2021). These exhibit a significant influence of triadic embeddedness on the source of relational rent (Dyer et al., 2018), cost reduction and product enhancement, while relational-specific assets behave differently. This study provides an in-depth understanding of the dynamics of dyadic co-innovation for bioplastic packaging and the influence of triadic embeddedness, such as when the converter developed a customised bioplastic packaging for the product manufacturer and had to invite the biopolymer producer to assist with technical support specific to the material. Another example was the co-innovation in developing industrial-scale packaging, initially set between the biopolymer producer and product manufacturer, who then expanded the collaboration to involve their converter. The findings of this case study provide insights that within a complex network, relational rent (Dyer et al., 2018) is distributed at dyadic and triadic levels. This study confirms Haugland et al.'s (2021) findings on the KSR and relationship management in constructing the co-innovation mechanisms. In addition, Haugland et al. (2021) identified a gap in relational-specific assets, which has subsequently been addressed by this case study, by showing plausible conditions of limited relational-specific assets due to the complexity of the existing value chain network.

This research indicates some conditional applications of RSA as the source of relational rent (Dyer & Singh, 1998; Dyer et al., 2018) due to a unique context of co-innovation in developing bioplastic packaging compared to alliances in high-tech or the automotive industry, from which most of the arguments of the theory are derived (Dyer & Singh, 1998; Neutzling et al., 2018). Previous studies show inconclusive results on whether RSA becomes a significant determinant of relational rent and competitive advantage (Dyer et al., 2018; Haugland et al., 2021; Neutzling et al., 2018). In the updated version of the theory, Dyer et al. (2018) acknowledge the limitation of the original RV theory in using a static model, as it was derived from the RBV (Barney, 1991); and addressed the dynamics of the alliance over time. Dyer et al. (2018) proposed the conditions where RSA would not be fully applicable, diminishing value creation and relational rent over time as the business environment changes. However, using the bioplastic packaging co-innovation, this study offers various plausible conditions where asset specificity would not be fully applicable as a source of competitive advantage due to the strong existing ‘regime’ of plastic packaging (Beltran et al., 2021) instead of due to alliance dynamics over time (Dyer et al., 2018).

6.4.3. Highlighting issues for further studies in sustainable innovation

This study concludes that the drivers of co-innovation for bioplastic packaging are the market, government support and regulation, and breakthrough technology. According to previous studies on green product innovation, these factors drive green product innovation, and the most important external factor is the regulation (Dangelico, 2016; de Medeiros et al., 2018; Lee & Kim, 2011). The references conclude that environmental regulations are considered the most important factors to motivate companies to innovate in green products because the regulation is viewed as an opportunity, and incentives are given to bring out new products that are better for the environment (Dangelico, 2016; Lee & Kim, 2011). Lee & Kim (2011) argue that stricter regulation will drive product manufacturers to reactively comply or take proactive approaches by integrating green management practices and implementing more innovative efforts to develop conforming products. In the case study, although the biopolymer producers were expecting support from the government regarding regulations and more infrastructure for the end-of-life, the findings indicate that the current regulations, such as fostering tax on virgin plastics (Beltran et al., 2021), are not strong enough to drive businesses to use more bioplastic packaging and consequently innovation in bioplastic packaging. In fact, as the current regulations are not strong enough to drive innovation, the market has become the most critical driver in the bioplastic packaging context because demand and market growth push more development, including co-innovation in bioplastic packaging.

Regardless of the limited environmental regulations supporting bioplastic packaging, this study suggests possibilities for commercial success in bioplastic packaging when product development and co-innovation depend mainly on demand or market mechanisms. The case study shows there is opportunity in the current bioplastic packaging market, where the product manufacturers saw an increase in consumer expectation for a more sustainable product amid concerns over plastic waste pollution. According to previous references, consumer expectation on sustainability and stakeholders' concerns over the environment could pressure product manufacturers to pay attention and take action, hence becoming critical drivers of green product innovation (Dangelico, 2016). The product manufacturers in the case study were motivated to look for a sustainable packaging solution, including developing bioplastic packaging through co-innovation as part of their sustainability agenda and addressing the consumer's expectations. The product manufacturer always looks for environmental and commercial success from co-innovation, and the existence of a demanding customer or market is a signal towards commercial success (Lee & Kim, 2011).

Despite this opportunity, marketing the bioplastic packaging by emphasising sustainability or environmental value is insufficient to penetrate a well-established market and compete with the conventional plastic packaging, the cheaper and high performing incumbent; however, previous studies address bioplastic as a potential sustainable or green product innovation (Chadha, 2011; Dangelico, 2016; Melander, 2018), which emphasises more on addressing environmental concerns, bringing environmental benefits, and reducing the impact and risk to the environment (Dangelico, 2016; Melander, 2018). One example of green product innovation was a 'greener' refrigerator (Lee & Kim, 2012), in which a new component considered more environmentally friendly by having less energy consumption (Dangelico, 2016; Lee & Kim, 2012; Melander, 2018). A green product is often claimed to have a smaller carbon footprint than the previous product, addressing climate change (de Vargas Mores et al., 2018; Melander, 2018) and preventing waste generation (Dangelico, 2016; Keränen et al., 2021). These claims were often made from the supplier's standpoint (Chadha, 2011; de Vargas Mores et al., 2018), based on various modelling approaches incorporating diverse factors, such as in the LCA studies, in which generalisation or comparison becomes problematic (Sundqvist-Andberg & Åkerman, 2021) and is hence debatable from different perspectives, such as from the downstream supply chain, consumer behaviour and waste management. Therefore, this study raised the issues related to industrial aspects, scale-up and commercialisation to the industry, problems at the end-of-life and overall LCA, which are often overlooked in previous studies, to be addressed in future studies.

Previous studies in green product innovation have shown factors driving green product innovation and the importance of capabilities in inter-firm collaborations. However, they have not thoroughly addressed the complex challenges in commercialisation that impede the diffusion of sustainable innovation and its benefits to the greater society. This study reveals the complexity in engaging key customers, i.e., the converter and leading product manufacturer, in co-innovation due to gaps between the supplier's offering and the customer's expected value. This study further exhibits that co-innovation challenges were often related to implementation in the existing production system, flexibility to adapt to different technical parameters of different types of packaging or machinery and scale-up of the biopolymer to industrial-scale compatibility with the existing waste stream. Subsequently, this research addresses the need to explore how biopolymer technology is developed into eco-innovation (Chadha, 2011; de Vargas Mores et al., 2018) and looks at how capabilities are operated to develop bioplastic packaging, bringing biopolymer technology nearer to the implementation stage regarding business customers, scale-up and commercialisation. This study synthesises the essential capabilities in green product innovation (Arnold, 2017; Dangelico, 2016; de Medeiros et al., 2018; Lacoste, 2016; Yu et al., 2021) into a supplier-customer co-innovation framework, adding a valuable addition to previous studies on green products and sustainable innovation. Further studies are needed to test the co-innovation framework involving more respondents representing the bioplastic packaging industry and business users in various industries. This framework is limited to co-innovation among the biopolymer producers, converter and product manufacturers, and further studies could expand the framework to cover co-innovation with other stakeholders in a wider scheme.

6.5. Implications for practice

Co-innovation among the biopolymer producer, converter and product manufacturer opens the opportunity to bring bioplastic packaging to implementation at the business customers. This study provides a valuable reference for managerial practice in developing bioplastic packaging through co-innovation. This thesis has shared the process and mechanisms of co-innovation in developing bioplastic packaging prototypes and further development to accommodate industry needs based on best practices in a complex and extensive co-innovation project as well as in a simple and narrower scope. In addition, a co-innovation framework is provided for practices to integrate joint activities, joint resources and relationship management with co-innovation partners to achieve product innovation and relational benefits. This study identifies problems in the existing co-innovations and suggests possible approaches for improvement.

This study noted that biopolymer producers have developed bioplastic packaging but have difficulties engaging co-innovation partners for further development and commercialisation. Several reasons inferred from this study are: first, there is a gap between the value offering of biopolymer producers and the value expected by business customers. The early development at the biopolymer producers has not adequately addressed the feasibility to scale-up various implementations at industrial scale and complexity in the downstream value chain. For example, some feedstock might be difficult to extract, there are limited downstream suppliers with the industrial capacity, and also problems during implementation at the business customers and with the existing waste stream. The early development of bioplastic material mainly relied on internal R&D, often lacking insights from the industry and value chain (Neutzling et al., 2018). This is also reflected in the case study, showing many iterative works to manufacture the bioplastic packaging at the converter and another lengthy iterative work on material improvement before implementation at the product manufacturers. Second, co-innovation should increase more relational benefits to all partners from joint development, such as commercial benefits from using the bioplastic packaging, contribution to partners' sustainability agenda, shared IPs and exclusivity for all partners in the long-term. Relational benefits are more beneficial than short-term arms-length transactional relationships, as the former benefits potentially sustain the collaboration in the targeted time and are re-evaluated to enhance partners' capabilities and competitive advantage. This study suggests issues with the value gaps to be addressed since early product development, such as expanding co-innovation involving various stakeholders, addressing complexity at the downstream, and business partners should explore more relational benefits to be shared from co-innovation.

This study shares possible approaches to engage co-innovation partners from best practices in the case study, especially industry leaders, who potentially expand the co-innovation to involve supply chain members, especially the converter. This strategy is in line with the situation that often occurs in packaging where leading product manufacturers are considered key partners (Slater, 2010) who drive the suppliers, including the packaging manufacturers, to be more aware of sustainable practice and work with the sub-suppliers to provide the sustainable solution needed by the product manufacturer (Giacomarra et al., 2020). This condition needs to be considered an opportunity to rethink a long-term co-innovation approach by integrating sustainable packaging innovation with the converter's co-innovation that focuses on high-level services, collaborating with the converter to add complementary expertise in packaging manufacturing to develop the packaging, and having the capability to create an integrated value offering with the product manufacturer. In addition, this thesis suggests an approach for the biopolymer producer to introduce bioplastic packaging into a new market by building the customer base for the targeted direct business customers, i.e., the converters. This strategy was exemplified by the ChemiCo and CbagCo cases by operating a small industrial scale of packaging manufacturing to introduce bioplastic packaging to product manufacturers and retailers to increase awareness and build a bioplastic packaging market. From this point, the biopolymer producer could approach the converter by showing the packaging manufacturing and real market potential.

This study brings forward the importance of extensive and complex co-innovation to develop a value offering that prioritises sustainable innovation and integrates key values in the packaging industry, comprising functionality, efficiency, and availability (Baraldi et al., 2014; Morgado, 2008; Slater, 2010) and suggests it would be a strong competitive advantage. Extensive and complex co-innovation with the industry leader is more likely to create bioplastic packaging innovation, agreeing with Giacomarra et al. (2020), and arguing that co-innovation involves the supplier, sub-supplier, and other stakeholders and is considered the key to addressing sustainability challenges. This study agrees with the previous studies emphasising the principle of co-innovation in packaging, where suppliers seek to legitimise customers' demand as widely as possible (Baraldi et al., 2014; Morgado, 2008; Slater, 2010). The biopolymer producer who demonstrates the co-innovation project feasibility, industrial-scale availability, and accommodates the needs of product manufacturers along the supply chain, is likely to engage leading product manufacturers for extensive co-innovation. Full support to customer demand is shown by supporting customer's packaging innovation, understanding customer needs, providing technology or technical support and assuring solutions (Morgado, 2008; Slater, 2010), and was also exemplified in the case study.

Nevertheless, modification is needed for the implementation at the product manufacturers and accommodating industry leaders' specific bioplastic packaging needs. Consequently, this study suggests combining expertise in technical packaging manufacturing from the converter and material engineering from the biopolymer producer and exploring a win-win relational benefits scheme to encourage the converter's involvement in bioplastic packaging development from the early material development stage. The case study highlights the critical role of converters as packaging experts and connectors to business users. Converters, who have been in the industry and established long-term relationships with business customers, have built trust and a significant degree of influence on business customers' choice of packaging. All packaging manufacturers in the case study perceived the converter as the expert in packaging manufacturing and capable of delivering product innovation and a complex service; as a result, there was high interdependency between the converter and product manufacturer (Baraldi et al., 2014; Morgado, 2008; Slater, 2010). However, barriers to involvement in co-innovation exist among some converters as they look for cost efficiency when evaluating the feasibility of a bioplastic packaging co-innovation project. Therefore, support from the product manufacturers, especially industry leaders, could signal demand, shift the converter to view that sustainability could bring commercial benefits by offsetting profit and efficiency, and encourage the converter's involvement in co-innovation in bioplastic packaging.

As a final point, this study acknowledges the challenges in developing and commercialising bioplastic packaging due to the complexity in its implementation, and penetrating a well-established packaging industry regime dominated by plastics. Co-innovation at the firm level among the bioplastic packaging producers and packaging manufacturers *per se* is insufficient to address these challenges; therefore, this study suggests synchronising interests and actions from stakeholders along the value chain to support the development of sustainable packaging. Bioplastic packaging is a potential alternative to sustainable packaging to work along with reduce, reuse and recycling schemes. In agreement with a previous study (Beltran et al., 2021), this study emphasises the imminent need to build the path for bioplastic packaging that eventually will shed light on future co-innovation. Moreover, fostering incremental innovation to working as much as possible in the existing plastic packaging value chain would facilitate adoption and reduce conflict with other stakeholders. This study provides some examples of bioplastic packaging implementation in a close-loop food service, adding the collection and composting of bioplastic packaging along with food waste, as shown in the ServpakCo case. Another example is using compostable packaging for food and beverages such as teabags and coffee pods, as shown in the TeaCo, CoffeeCo, and ConveCo cases, as food contamination is inevitable, hence reuse, or recycling is less feasible.

In addition, this study encourages policymakers, local councils, waste services, organisations, and stakeholders in the packaging value chain to support and expand co-innovation, creating a collaboration forum to unravel the complexity, create solutions and improve the system. Extensive co-innovation should first facilitate dialogue to identify opportunities and possible paths for bioplastic packaging, followed by product development optimising knowledge sharing, joint activities and joint resources towards innovative solutions. Policymakers could support with regulations, incentives for innovation, and education for consumers. Standards for conventional plastic cannot be directly applied to bioplastic packaging; therefore, specific standards, such as food safety, industrial or home composting, are required for bioplastic packaging, followed by labels and communications to users. Finally, through extensive co-innovation, stakeholders at the end-of-life of bioplastic packaging, such as waste services and local councils, could contribute to organising disposal paths for recycled bioplastic with other packaging or the compostable bioplastic with food waste. Organisations should play a greater part in educating consumers and changing behaviours by providing a more balanced judgement on bioplastics packaging and other schemes, as well as engaging businesses and stakeholders to participate in sustainable packaging innovation.

7. Conclusions

This chapter concludes this study by explaining how the RQ and objectives have been addressed. This thesis seeks to understand further how co-innovation should be implemented to address problems in its implementation at the business customers and address the research gap found from the SLR. It focuses on the B2B relationship between the bioplastics packaging manufacturer as the supplier and the product manufacturer as the customer, and aims to inductively develop a conceptual understanding of the process and mechanisms of co-innovation. It has also developed an initial framework, grounded in RV theory, absorptive capacity theory, which was then used in the exploration using a multiple case study as the research strategy. The relationships among the biopolymer producer, converter, product manufacturer, supplier-customer relationship in the co-innovation were analysed using thematic analysis, and the findings were presented to address the research objectives. The refined co-innovation framework was developed based on the process view, presenting the key mechanisms comprising an integrated mechanism of joint activities and joint resources, which also extends the conceptual understanding of co-innovation. In addition, this study presents the significance of absorptive capacity facilitating co-innovation towards outcomes, comprising the direct outcome, i.e., improved material, packaging and process adjustment, and after the implementation is successful, relational benefits are distributed among partners.

The findings regarding the factors influencing co-innovation and the role of actors in co-innovation have extended the understanding that supplier-customer co-innovation is part of a bigger landscape. This study highlights the importance of co-innovation in product development and diffusing the technology to business customers. It also looks at the role of converters as connectors to more business customers and creating interdependence, and the role of industry leaders to set an example, communicate with and influence their supply chain as well as their consumer base. However, external factors in the packaging industry, disconnected initiatives and actions of stakeholders in the packaging value chain create hyper-complexity in resolving plastic pollution, and impede innovations and co-innovation for sustainable packaging. Nevertheless, this study reminds stakeholders, especially in the downstream value chain, end-of-life and policymakers, to harmonise views and actions, unravel the complexity and simplify the implementations for business and consumers. Bioplastic material improvement is critical, producers are racing, and those who could accommodate the complexity of the industry and its value chain are likely to win by presenting feasible solutions for business customers' sustainability agenda. In the meantime, co-innovation would be a good strategy for the material producer to absorb more knowledge from the packaging industry to improve their value proposition. Ultimately, co-innovation is a potential starting point to bring the bioplastic to implementation at the business customer and also for commercialisation.

The following sections further describe the key limitations and avenues for future research to take this thesis forward.

First, the SLR was employed to review the phenomena around bioplastic packaging development and the existing studies on co-innovation in this area. Although the SLR is more likely to minimise bias compared to a narrative review, through the rigorous methodology in the article search and inclusion, there is always a possibility that some relevant articles are not captured from the databases due to the rigid search strings, the choice of databases, or the filters employed in the search strategy of this SLR. The search process is carefully designed to mitigate this issue using combinations of keywords, stemmed words and Boolean operators such as AND, OR, and NOT to narrow or expand the search (Galvan & Galvan, 2017), and relevant articles have also been added manually through cross-referencing. Furthermore, references from the SLR were analysed using thematic analysis that allowed the researcher to capture patterns arising from the data extraction, but themes that emerged and presented were purposely focused on addressing the research aim. Hence, future research can enhance the review process, search procedure or expand the review to address current issues.

Second, the multiple case study allows the researcher to obtain an in-depth understanding of the process and its outcome, and is relevant to address the objectives of this study. The multiple case study strategy has provided an in-depth comprehension that helps refine the framework based on empirical evidence. The case selection considered elements of the theory in the context of bioplastic packaging co-innovation, and the selected cases have accommodated the information needed to answer the RQ. Nevertheless, there were shortcomings in selecting cases that demonstrate simple co-innovation as they showed less intricate mechanism, bioplastic packaging application to a product and supplier-customer dynamics. However, these cases were valuable for revealing how supplier-customer interdependence developed from the long-tracked business relationship and highlighting the converter's role in market penetration by connecting and promoting bioplastic packaging to business customers. Next, the semi-structured interview helped the researcher and the informants explore issues more openly while preserving the focus within the interview guidelines. However, the information shared might be limited to the best of the informant’s experiences and understanding, and confidential project details were not shared, such as formulation, design, development plan, innovation roadmap, investment and financial aspects. Hence, this study added secondary data to triangulate and support the credibility of the data used for the analysis. Therefore, future research could improve the internal validity, and further research is suggested to consider the differences between the simple narrow projects and extensive co-innovations, explore topics relevant to simple co-innovation with smaller companies, such as exploring strategy to market penetration and commercialisation by optimising the role of converters, and understanding small business customers’ behaviours.

Furthermore, the nature of a multiple case study is to obtain theoretical generalisation in preference to statistical generalisation. The findings from this study represent co-innovation in developing bioplastic packaging, which to a certain extent are affected by unique phenomena in each case and do not represent the whole population. Therefore, the transferability potentially can be applied with careful consideration to similar settings, and generalisation can be obtained in a similar context. Future research could expand the exploration to include more cases from other industries that use bioplastic packaging, such as in cosmetics, hospitality, or the fashion industry, extending Friedrich (2021). Alternatively, future research could test the proposed framework to obtain a statistical generalisation by adopting a large-scale survey or a mixed methods research design to provide robust conclusions that balance the limitations of quantitative and qualitative approaches.

This study presents unique phenomena in the bioplastic packaging development context, where new technology aiming for sustainability encounters difficulties in the implementation at the business customers, so further developed with the business customers through co-innovation. The RV has become the theoretical lens that builds the co-innovation mechanisms and conceptualises the co-innovation elements that focus on the inter-firm collaboration and expands the existing concept of co-innovation, which is mainly grounded in the co-creation and open innovation theory. However, the following areas of the RV theory have not been fully understood from this study and have become potential avenues for further research. First, the asset specificity is limited to a couple of cases, showing co-investment in a production plant and manufacturing equipment, while the rest of the cases showed the reluctance of business customers to build specific assets for bioplastic packaging. Although the discussion section has elaborated plausible explanations on this issue, there is a possibility that the number of cases in this study is limited whilst most of the bioplastic packaging in the cases is mainly used for fast-moving consumer goods, food and beverages, hence could not fully capture the phenomena on asset specificity. Therefore, more research is needed to shed light on the main factors behind limited asset specificity, i.e., whether it is due to the well-established packaging value chain and strong industry regime, the behaviour of the actors in the value chain, limited returns in investing for sustainability, or the specific nature of the bioplastic technology. Future research is suggested to expand the investigation covering more co-innovation projects in bioplastic packaging, such as in cosmetics or hospitality, and possibly to explore co-innovation in various implementations of bioplastic in different industries, such as in fashion, medical and automotive.

Third, this study has captured the co-innovation process in the past, present and future based on the informants' perspective and experience. However, it is limited in capturing co-innovation dynamics and how relational benefits are preserved or enhanced over time based on direct observation. In some cases, the co-innovation project was ongoing, and the product was not launched; hence the relational benefits were not yet realised. At the same time, other cases showed that relational benefits from co-innovation were newly developed. Furthermore, relational benefits inferred from this study, comprising technology leadership, innovation, and commercial benefits, are likely to increase profit and sales or other financial performance measures indirectly. Relational rent was referred to as "supernormal profit" in the RV theory, and often measured in financials. Therefore, investigating the co-innovation dynamics and how relational rent is built among partners would be an interesting avenue for future research, which could also possibly extend the RV theory (Dyer & Singh, 1998). Future studies could expand the relational benefits from co-innovation in bioplastic packaging, investigate how relational benefits develop over time, preserved or enhanced, and this can be explored through a longitudinal study. Alternatively, further research could find opportunities to integrate the sustainability value as relational rent, look at how relational benefits are distributed among partners in dyadic relationships or how triadic embeddedness affects relational rent as the co-innovation expands to more partners. These are also avenues for future studies to expand the RV theory in triadic embeddedness or network collaboration.

As bioplastics technology continues to grow, the mechanisms of supplier-customer co-innovation in bioplastic packaging will remain open to adjustment. Further research is needed to expand the conceptual understanding of co-innovation at the inter-firm level, and test and enhance the framework. The co-innovation framework in this study is developed using dyad unit analysis, which captures dyadic supplier-customer collaboration where, in some cases, the co-innovation expanded into triadic embeddedness. Hence future research could expand the framework to accommodate network co-innovation in developing bioplastic packaging involving more stakeholders, the end-of-life waste provider, standard body, local council and central policymakers. In addition, co-innovation in bioplastic packaging is affected by external factors in the immense landscape. Uncertainties remain high, and some product manufacturers are cautious of bioplastic packaging, avoiding any backlash after lengthy, expensive development. This study urges further research followed by actions to unravel the path and provide clearer directions to encourage innovation and more development through co-innovation. Opportunities remain open to answer how bioplastic packaging contributes to sustainability, minimises plastic waste, and complements the other scheme: reduce, reuse, and recycle.

As a final point, future research integrating knowledge from the industry, macro environment in bioplastic packaging development and strategies for penetration and commercialisation in the packaging industry, would be valuable for knowledge and business practice. Reflecting on this study, complex problems in a well-established packaging value chain hinder bioplastic packaging co-innovation. Future research could extend this research, find specific industrial knowledge beneficial for bioplastic packaging development, and develop co-innovation strategies and business models integrating the downstream value chain.

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APPENDICES

Appendix A: Ethical application detail

Medium Risk Research Ethics Approval

Project title

Co-innovation in Bioplastics Packaging: An exploratory study of the supplier-customer collaboration for product innovation

Record of Approval

Principal Investigator

I request an ethics peer review and confirm that I have answered all relevant questions in this checklist honestly.	X
I I confirm that I will carry out the project in the ways described in this checklist. I will immediately suspend research and request new ethical approval if the project subsequently changes the information I have given in this checklist.	X
I confirm that I, and all members of my research team (if any), have read and agreed to abide by the Code of Research Ethics issued by the relevant national learned society.	X
I confirm that I, and all members of my research team (if any), have read and agreed to abide by the University's Research Ethics, Governance and Integrity Framework.	X
I understand that I cannot begin my research until this ethics application has been approved.	X

Name: Liliani Liliani (FBL-PHD)

Date: 28/01/2021

Student's Supervisor (if applicable)

I have read this checklist and confirm that it covers all the ethical issues raised by this project fully and frankly.I also confirm that these issues have been discussed with the student and will continue to be reviewed in the course of supervision.

Name: Prof. Benny Tjahjono

Date: 26/01/2021

Reviewer (if applicable)

Date of approval by anonymous reviewer: -

Appendix B: Interview guide

INTRODUCTION

Thank you for making time to participate in this interview. Please find the following introduction to give you a general picture of the topics to be discussed.

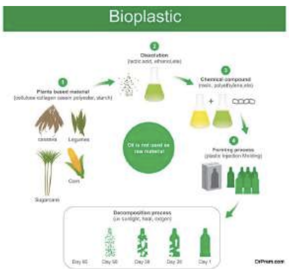
Aim of the interview:

We are keen to hear your thoughts about your experiences/opinions in developing bioplastic packaging and how you work together with your supplier/customer along the supply chain in that process. Secondly, the outcomes of this co-innovation, in particular, the bioplastic packaging that satisfies both you and your supplier/customer. Last, we'd like to know further about the challenges and the uniqueness of co-innovation for bioplastics packaging.

We will use the term of ***Co-innovation*** in this discussion to indicate an inter-organizational collaboration mechanism and process to deliver significant value creation for customers that are difficult to imitate by competitions.

Key points brought in the discussion:

1. The process of co-innovation for bioplastic packaging product development and the involvement of your supplier/customer in that process:
    a. Steps from the beginning to implementation/real production;
    b. The activities and resources put into the collaboration;
2. The relationship with your supplier/customer and contribution from each partner;
3. The learning from each partner and its impact the product development;
4. The outcome of co-innovation specific to the advancement of the bioplastic packaging;
5. The specific challenges and key success for developing bioplastic packaging through co-innovation.



Discussion/interview steps:

1. Introduction;
2. Filling consent/admin forms;
3. Discussion;
4. Closing;
5. Walk-through (subject to agreement)
6. Follow-up interview (if applicable)

Ideally, the interview will be audio recorded (subject to agreement) to help the researcher to get the best in-depth understanding due to the broad area covered in the interview.

Research is to see what everybody else has seen, and to think what nobody else has thought.

Albert Szent-Gyorgyi
Hungarian biochemist, 1937, Nobel Price for medicine

Contact us:

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Interview Guide

Objectives	Guidelines/Questions	Time	*Check*
Introduction	• Name and status of the researcher/interviewer, show introduction leaflet • Recording: o Anything said will be treated as confidential and anonymous/ your personal data will not be passed on to anyone else; o I'm interested in your thoughts, experience, honest views about the topic. • Before we start, please fill in the consent form.	3	
Warming up	Please tell me a little bit about yourself/let's start by discussing your background, your position, responsibility/role in developing bioplastic packaging. Do you have any knowledge/experiences in the product development that involving interaction with the external/customer/supplier? • Most/less successful: with who, what product, when	3	
The process of co-innovation for bioplastic packaging product development and the involvement of your supplier/customer in that process:			
	Steps from the beginning to implementation/real production; how long for each stage • What/which stages are crucial for the bioplastic packaging product development? why? how does it work?	5	
	The activities and resources (tangible and intangible) put into the collaboration: • shared, done together • individually; • which <u>activities are crucial</u> for the bioplastic packaging product development? why? how does it work?	10	
	The relationship with your supplier/customer and significant contribution • The role of you and your supplier/customer in the co-innovation? • The dynamic, daily ups and downs when working with your supplier/customer? • Significant contributions from your supplier/customer,	5	
	The learning from each partner and its impact the product development; • What do you learn? • Implementation to the product • Other impacts	5	
The outcome of co-innovation specific to the advancement of the bioplastic packaging;			
	The product: bioplastic packaging that has been developed: • Advanced features • What could indicate the successful co-innovation	5	
The specific challenges and key success for developing bioplastic packaging through co-innovation.			
	What makes co-innovation in bioplastic packaging different from other industries like IT, software development, aeronautics, etc • Key to success • Driver /factors that enhance these?	5	
Reaffirm co-innovation	So... we get to the last part of the discussion and to conclude, what are the benefits of this collaboration? What if you hadn't collaborate with your customer/supplier for developing Bioplastic packaging?	3	
Closing	Is there anything you want to add? Ask to fill in participant profile form and walkthrough (if applicable) Thank and close	3	

Appendix C: Coding template used in the case analysis

1 Process of co-innovation (RO2)		
	Adjustment and improvement Approaching partner Design phase for packaging application Further development and customer testing Initial assessment Initial product prototype Internal R&D for early stage Trial on customer's machine	
2 Mechanisms of co-innovation (RO2)		
	Absorptive capacity	
		Acquire Assimilate Exploit Transform into understanding
	Joint activities	
		Give solution to processing condition Concept exploration Many trials and feedback Share confidential information Mutual adaptation
	Joint resources	
		Dedicated team Share expertise Bioplastic technology Financial capital R&D facilities
	Relationship management	
		Agreement and commitment Build long term relationship Approaching co-innovation partner Educate the customers Conditions for close collaboration
3 Outcomes from co-innovation(RO3)		
	Performance Cost Environment Innovation Other outcomes	
4 Key factors of co-innovation (RO4)		
	Future potential of the material Infrastructure available for end of life Market and demand Need pressure from the government Willingness to change	
5 Dynamic roles of supplier & customer (RO4)		
	Product manufacturer Converter Biopolymer producer	

Appendix D: The spreadsheet template for data extraction

Topics		Interview quotes/ summary	Questions for a follow-up interview
The process of co-innovation for bioplastic packaging product development			
	Steps from the beginning to implementation/real production; how long for each stage? What/which stages are crucial for the bioplastic packaging product development?		
	The activities in the collaboration: - shared, done together - done individually The resources (tangible and intangible) put into the collaboration: - shared, done together - done individually Which activities and resources are crucial for the bioplastic packaging product development?		
	The relationship with your supplier/customer and significant contribution The role of you and your customer in the co-innovation The dynamic, daily ups and downs when working with your customer Significant contributions from your customer		
The learning from each partner and its impact on product development			
	What information do you need? How do you learn? Any activities/routines? What do you understand/learn that helps in developing/improving the bioplastic packaging? What are the implementations of that understanding into actions or the product?		
The outcome of co-innovation specific to the advancement of the bioplastic packaging			
	Advanced features in general and which are obtained from co-innovation with the customer What would the advanced bioplastic packaging be/look like? E.g. the features, other indicators?		
The specific challenges and keys to success for developing bioplastic packaging through co-innovation.			
	Keys to success Driver/factors that enhance these?		

Appendix E: Summary of the references in Figure 29

Refs	Summary	Collaboration context	Theory
(Huber et al., 2011)	Knowledge sharing, partner's absorptive capacity, in the context of the automotive industry: OEM and part supplier	Automotive	RV
(Miguel et al., 2014)	RV in consumer's product and how it doesn't fully reflect the theory, which mainly refers to the automotive industry. Source and mechanisms such as asset specificity, knowledge sharing and complementary resources are not fully applicable, showing conditional application of RV.	Automotive	RV
(Perez et al., 2013)	Framework, process view, value creation through knowledge sharing, learning by interacting: exposure to new markets, endorsement from industry leaders, access to complementary resources. Firms need to learn how to engage partners and accommodate the customer's needs and requirements. Phase of learning about the customer, building interaction, co-investing, co-innovating.	Start-ups, high tech	RV
(Wu et al., 2017)	Using RV to test inter-firm co-innovation, based on R&D, collaboration governance, asset investment	High-tech enterprise	RV
(Neutzling et al., 2018)	A framework, biopolymer producer's perspective, Brazilian, resource investment in RV, collaboration, governance mechanisms, joint activities, resources and relationship management should be treated as an integrated analytical framework. Provide evidence on limited knowledge sharing during material development. The authors acknowledge challenges in the implementation and legitimacy in new market, but do not provide in-depth details on the outcome from collaboration.	BPP, Braskem, Mercur, Brazilian	RV and SSCM: Sustainable-oriented innovations
(Kleine Jäger & Piscicelli, 2021)	This study reveals partner roles and characteristics important for partner selection and proposes a framework for establishing collaborations for circular food packaging involving actors in the reusable and recyclable packaging value chain; data were collected from food	Consortium	Organisation alliances, RV

	companies in the EU and circular packaging experts.		
(de Vargas Mores et al., 2018)	Single case study, Braskem, innovation process of biopolymer PLA, supply chain collaboration, focus on downstream.	Bioplastics	SSCM
(Chadha, 2011)	Biopolymer producer's perspective. Competencies for development of biopolymer technology, avoiding competence lock-in related to the plastic industry. Acknowledged challenges in the implementation and commercialisation, but less attention given to different industry backgrounds between automotive and packaging.	Bioplastics, in automotive, packaging, raw material supplier	Eco-innovations
(Beltran et al., 2021)	Transitions from niche to circular bioeconomy of biodegradable biobased plastic food packaging, viewed from niche-regime-landscape. Niche innovations such as biobased biodegradable plastic need to build momentum related to waste management.	Bioplastic packaging	Socio-technical system, multi-level perspective
(Jeong & Ko, 2016)	This study identifies partnership strategies based on the database of the bioplastic alliance of Hyundai and Toyota: acquire knowledge or secure technology and further show co-innovation of bioplastic used in automotive, relying on high patent, high collaboration.	Bioplastics in automotive	References in alliances
(Keränen et al., 2021)	Diffusing bioplastic packaging to the mainstream, main challenges with the existing industry regimes (well-established value chain, including technology and business process, high investment in tangible assets specific for plastics, established actors with a strong relationship over the years, limited collaboration, high confidentiality, highly competitive industry.	Bioplastic packaging	Sustainability transition
(Kishna et al., 2017)	Qualitative study, based on secondary data: database of bioplastic alliance. How bioplastic packaging contributes to legitimacy, from market and social legitimacy to technology legitimacy.	Bioplastics packaging	Refs from strategic management, organisational economics and institutional theory

Appendix F: Detailed case analysis

Appendix F-1: Biopolymer producer case: SoluCo

SoluCo is a resin polymer producer located in the UK. SoluCo product is a water-soluble polymer, which was actually a reinvention of an old polymer. SoluCo managed to improve the processing of the material and bring back this material to the industry for various specialist applications. A few packaging applications that suit SoluCo biopolymer are lamination to a paper pouch, shopping carrier bag, fashion garment wrap, and several other flexible film packaging applications.

SoluCo product has several advantages, one of which is having highly functional properties, such as clarity and high barrier properties. SoluCo's bioplastic material has a multi-end of life options, which include easy to recycle, either on its own or in combination with others, compostability or anaerobic digestion and breaks down in marine or freshwater. This material is also non-toxic in the environment, and most importantly, SoluCo product works accordingly to the circular economy principle.

1. The process of co-innovation

SoluCo started an internal R&D, which took about ten years to develop the base and early-stage material. Next, SoluCo started to build the factory to produce the material, and at the same time, opened discussions with the supply chain. SoluCo approached manufacturing partners, such as film manufacturers, extrusion counters, injection moulders, to manufacture the material into packaging, also approached the brand owner and retailers to offer packaging solutions.

SoluCo conducted an initial assessment, which included selecting a brand owner whose product could fit SoluCo packaging solutions; for example, SoluCo offered to simplify the packaging for products using multi-layered unrecyclable packaging. SoluCo intensified the approach to the brand owners and retailers by presenting an extensive demonstration, highlighting the gain in functionality, end of life options and a message to the consumer regarding sustainability or circular economy. The demonstration also covered processes at the converter, such as equipment installation, processing the material into packaging, and application to the product. During the initial assessment, SoluCo should be able to present the route to supply and feasibility of using the material in different countries where the brand owner's products were to be launched.

> *"so we picked certain brand targets for the packaging. Classically, things that they'd have a problem with. So, multiplex packs, that sort of…" (CTO-S-21208)*

> *"…actually, you know what, we're going to launch this in Malaysia. We're not going to launch in Europe at the moment. So, what's your route to supplying is that in Malaysia…" (CTO-S-21208)*

When SoluCo and the brand owner agreed to proceeds, the brand owner would open access to their converter, packaging designer, and other relevant parties in their supply chain.

2. Mechanisms of co-innovation

CTO-S-21208 explained that SoluCo first approached the converters directly before the brand owner. However, this approach did not work quite for some reasons, such as the converters got so close to their existing materials and reluctant to change, or they were involved in certain projects that made it difficult to handle a new project with SoluCo. And according to CTO-S-21208, the best mechanism of co-innovation that work for SoluCo was by approaching the brand owner and demonstrating the potential of using SoluCo's material, including the feasibility of the implementation, scale-up, and benefits, such as improving the brand owner's packaging, other commercial benefits or addressing the circular economy. Subsequently, the brand owner would ask their packaging manufacturer or other suppliers to support this move, and therefore, these upstream supply chains would address this demand as it came from their customer.

> *"So what we found was that the best way of doing it was to actually go directly to the brand and and demonstrate. So we had to do a lot of an awful lot of demonstration." (CTO-S-21208)*

2.1. Joint activities

CTO-S-21208 explained that SoluCo mostly did the initial development until reaching a stage where the product is ready to be presented to the brand owner. SoluCo must present data and evidence to convince the brand owner to proceed to a joint development project when introducing relatively new material. SoluCo did massive early work to demonstrate the processing from material to packaging, many trial and error when processing the new material at the machinery, which normally should take place at the converters. SoluCo also conducted many end-of-life tests to prove marine safety and compostability and presented the test result and certifications to the brand owner.

> *"so you have to do a lot of hard work behind the scenes yourself in terms of picking deliberate targets, and then putting that* construction *together and saying, Here you are, including all the end of life data…" (CTO-S-21208)*

SoluCo offered a packaging solution in which the brand owner would not lose functionality and get multiple end-of-life options as well as commercial advantages. And for that, SoluCo needed to consider the brand owner's direction and agenda related to packaging, problems with the current packaging, possibilities of having a solution without changing the material.

> *"So part of it is, is fitting into the direction of travel. What is it, they want to do. What is it, they have a problem with…" (CTO-S-21208)*

After the brand owner and SoluCo agreed on a joint development project, the brand owner became open to sharing confidential information and providing access to the brand owner's facilities, equipments and supply chain, such as the converter and laboratories that already worked with the brand owner. Moreover, the brand owner opened their other development partner to facilitate more synergistic development.

> *"…all the information that they have all that. All access often to their, their equipment, pilot equipment, test equipment, their connections with independent laboratories and other development partners." (CTO-S-21208)*

CTO-S-21208 added the mutual adaptations from the brand owner accepting higher cost when offset with other benefits that could be gained along the supply chain, such as multiple end-of-life options and significant market potential. According to CTO-S-21208, converters were often reluctant to work with bioplastics due to cost, conversion rate and waste recovery; therefore, SoluCo also presented technical alternatives in processing to address cost and waste recovery. In CTO-S-21208 experience, collaborating with the brand owner could help push the converter to accept the cost.

> *"Twice the cost. But if, but if I can half the gauge of the film, and give you something that you can recover at the end of life where you currently can't…" (CTO-S-21208)*

> *"…the brand owner might actually say, I don't care, that's fine. Because you have actually, the market potential for this is so much bigger than the original thing, we carry on" (CTO-S-21208)*

2.2. Joint resources

The resources for co-innovation includes contributions from SoluCo, brand owner and converter. SoluCo invested a lot of work and resources in the initial development of the material, and inferred from the interview with CTO-S-21208, their resources included technology and expertise in developing the material, financial capital and other resources to run the operations, testing, certification, building demonstration plant, machinery installation. The brand owner contributed their resources after the joint development had been agreed and they provided information, access to facilities and networks in the supply chain, also financial capital to cover part of the development cost and gain exclusivity.

> *"So you construct a joint development agreement, and they pay an element of the costs of that development if they want that level of exclusivity within a second." (CTO-S-21208)*

On the converter side, they provided access for trialling the material on their machine. CTO-S-21208 added that SoluCo used the converter's machine to test the material in a real production setting to demonstrate and engage the brand owner. And during the joint development project, the converter worked together with SoluCo to produce the packaging to meet the brand owner needs or specifications.

2.3. Relationship management

The important phase in the relationship management is to get into an agreement for joint development is the partner selection, in which both SoluCo and the brand owner considered partners capability and project long term feasibility. SoluCo looked for certain brand owners with relevant packaging problems for changing into bioplastic packaging compared to other solutions such as reducing or eliminating unnecessary packaging. SoluCo prioritised brands that were relatively large and had innovative projects. SoluCo's solutions and capabilities must align with the brand owner's sustainability agenda, the innovation that the brand owner expects. On the other hand, the brand owner would continuously filter offers based on the suitability of packaging solutions with a sustainability agenda, innovative direction. Then the brand owner reviewed the offer from SoluCo in detail, including supporting data, material capabilities, partner's capability, validation and certification from third parties, for example, compostability or food safety.

> *"…part one of the filtering mechanism is, does it fit into the project profile directions and they've already put in play or innovative direction." (CTO-S-21208)*

After the joint development agreement has been settled, the brand owner would open access to confidential information, facilities, technical, commercial or other functional teams so that SoluCo could understand what was really needed. The brand owner also opened access to a wider network, such as converters, labs for testing, and existing development projects, to create synergies and acceleration.

> *"…once they sign the JDA. Then, once you get much more information, you get complete access to their technical and commercial teams, and you get exactly what they've worked on…" (CTO-S-21208)*

Based on previous experience, CTO-S-21208 saw that converters were not quite interested in collaborating with SoluCo to develop bioplastic packaging.

Co-innovation with the brand owner finally bridged the collaboration with the converter.

> *"The brand would then get interested, would adopt as a project. And then, we will be directed to today converters that they would normally use to develop their packaging." (CTO-S-21208)*

CTO-S-21208 emphasised that both SoluCo and the brand owner aimed for long term close collaboration because, in the end, the bioplastic packaging will only be launched to the market within the next three to four years.

2.4. Absorptive capacity

Through co-innovation, SoluCo acquired more information on the critical feature of the brand owner's process. CTO-S-21208 exemplified the valuable information included technical and commercial aspects, equipment, pilot equipment, test equipment, third parties laboratories and ongoing development projects. Moreover, CTO-S-21208 added that the learning process happened through sharing information, collaborating with the brand owner functional team and wider network. By sharing information and issues with more partners, CTO-S-21208 noticed that everyone who usually focus on their interest, cost and development would get a comprehensive understanding of the whole supply chain and work towards a resolution.

> *"…all of us are guilty of sitting in our own silos. You know, looking at our own costs looking at our own developments etc. But sometimes it's really difficult to put it into the context of the whole of that supply chain." (CTO-S-21208)*

These processes also enabled SoluCo to understand more about what exactly the brand owner is looking for, the direction of the project, and how the brand owner approaches and communicates sustainable packaging to their consumers. CTO-S-21208 also added that the converter got a new perspective to cost and benefit for developing bioplastic packaging, especially in offsetting the increase in cost with a bigger opportunity to support the brand owner's sustainability direction.

Eventually, the assimilation process and new understanding help accelerate the bioplastic material development as well as the packaging and its implementation for the brand owner. CTO-S-21208 mentioned that SoluCo had multiple routes operating in parallel and focused on an organised project plan and deliverable agreed with the brand owner; thus, moving the project on much faster than it would have been in normal circumstances.

> *"you can put a properly organised project plan in place in place. You know the costs are covered because you've got those covered on the JDA …So you suddenly end up in a situation where all those things are happening at the same time…" (CTO-S-21208)*

3. The outcomes of co-innovation

Before co-innovation, SoluCo has got an initial product to offer. The material has several advantages such as clarity, barrier properties and more efficient processing than other bioplastic materials. It also has multiple end-of-life options, compostable, water-soluble, recyclable, and leave no harmful residue to the environment. And CTO-S-21208 stated that co-innovation not only speed up the development and implementation but also support the brand owner in achieving their sustainability agenda and getting exclusivity to use the material. CTO-S-21208 added that SoluCo carefully manages the exclusivity and avoid overlapping among brand owner.

> *"So you construct a joint development agreement, and they pay an element of the costs of that development if they want that level of exclusivity …Each in different areas. And clearly, you know, you've got to be careful you don't overlap..." (CTO-S-21208)*

4. The drivers and success factors

Inferred from the interview with CTO-S-21208, the key factors to engage with the brand owner for co-innovation are to offer suitable solutions and commercial advantages, supported by comprehensive data, demonstration of evidence and capability. SoluCo put a lot of hard work behind the scenes to prepare a specific proposal for targeted brand owners. Furthermore, SoluCo ensured the capability to scale up, availability and continuous supply to the brand owner. CTO-S-21208 added that often small biopolymer producers who actually got outstanding products for certain applications were unable to scale up due to limited raw material. And therefore, SoluCo has the advantage of developing bioplastics which the raw material is available in millions of tonnes.

> *"I think fundamental point is scale. You've got to be able to produce material and reasonable scale reflects the demands in questions from the market." (CTO-S-21208)*

> *"And the problem with many bioplastics is they're not at sufficient scale… The advantage, I think from our perspective, we have is, we started with material whether it was already 3 million tons of it available. (CTO-S-21208)*

According to CTO-S-21208, different approaches were needed to push innovation, for instance, drive a circular economy by providing an incentive to circularity. While applying tax for plastic might not be an effective approach because rather than working on innovation, the producer most likely resolves the tax burden by increasing the packaging price that consumers would eventually have to pay.

> *"…if you put a stress point on the brand, the brand got a choice. You know, they could pull out the market. They can increase the price, which is probably the most likely, or they can take the hit, or they can innovate, ...these penalties fit with the Treasury bit, not the innovation. (CTO-S-21208)*

5. The dynamic roles of customer and supplier

In the SoluCo case, the biopolymer producer role is to initiate innovation through the material and provide technology and technical expertise. The brand owner is the adopter who also has more power in selecting partners, alternative solutions, and defining the specifications. The brand owner also becomes a connector between the biopolymer producer, the converter and the wider supply chain. CTO-S-21208 exemplified one of the dynamics when working with brand owners: synchronising the speed for communication and coordination, and SoluCo has to be more patient when dealing with the brand owner who also tends to be larger companies.

> *"…the speed that they move back in comparison to the speed that an SME wants to move back. …And whereas a brand owner will often take time." (CTO-S-21208)*

Furthermore, the converter might be difficult to get engaged in co-innovation unless there is significant pressure from the market. According to CTO-S-21208, the converter is convenient with the existing conventional plastic, focused on efficiency, and sees bioplastics as having limitations in this area;

therefore, they are reluctant to change. Thus, the brand owner, who is the converter's customer, could push the converter to become involved in a joint development project.

> *"The slowest and rate determining step the least innovative to be perfectly honest are the converters. Because they they would much prefer to carry on doing what they're doing. And it's only the pressure from the market, and therefore the pressure on the brand that is causing this shift this dynamic change…" (CTO-S-21208)*

Appendix F-2: Biopolymer producer case: ChemiCo

ChemiCo is a startup company, a pioneer in innovative renewable and sustainable chemistry operating in the Netherlands. The company developed a new bioplastic material from plant-based fructose syrup with a unique molecule. This material can be used to produce packaging for various consumers products with carbon footprints that are significantly lower than conventional plastic. This material is also recyclable and biodegradable, as well as it embracing the principles of the circular economy. Its performance is also equal to or better than conventional PET plastic.

ChemiCo has collaborated with several brand owners and is currently preparing for scaling-up and commercialisation. ChemiCo has built a pilot plant for trials and demonstrations and another plant for small industry-scale operations. Over time, ChemiCo has improved the material performance for many industries, including the pharmacy, food, and beverage industry.

1. The process of co-innovation

Biopolymer development at ChemiCo was conducted in two phases: internal development and commercialisation. ChemiCo started with internal development, aimed to develop new materials and generic prototypes. The internal R&D team mainly worked with converters to learn about the fundamental phase in the application. TAP-S-21209 explains the next level, the commercialisation stage, in which Chemico approached brand owners and demonstrated the new material's potential in supporting the brand owner's packaging.

TAP-S-21209 mentioned that the crucial stages involve a successful business case presentation, packaging prototype creation, further technical development and user testing, and commercial discussion.

"We then connect with brand owners, and other people who want to apply. We also create more sort of appropriate products for the brand owners and companies." (TAP-S-21209)

A strong business case is needed to demonstrate the potential benefits of using new materials to the brand owner. It was also important for ChemiCo since they offered new materials with new technology at a higher price than similar bioplastic materials on the market. TAP-S-21209 showed the importance of demonstrating economic feasibility to brand owners, especially the cost-effectiveness of shifting to more expensive materials. Presenting a business case is one part of the initial assessment carried out by the two parties to explore partnership potentials and the feasibility of the project before deciding to co-innovate in a project.

"…to make sure that what we plan to do is going to be cost-effective. …before we do anything, we have to work out the business case and remember that the rough economics of the projects are extremely important." (TAP-S-21209)

In the next stage, ChemiCo developed the packaging prototype and more advanced technology before conducting customer testing. ChemiCo collaborated with the converter to develop a prototype based on assumptions and then produce it on a small scale. Subsequently, ChemiCo carried out further technical development for packaging applications such as design iterations, adjustments, and improvements for packaging prototypes which were then produced on a larger scale. TAP-S-21209 provided an example of an improvement in the mechanical properties of bottled beverage packaging to achieve the shelf life that brand owners expect. They also made internal tests, consumer perception tests, and marketing communication. Lastly, they finalised the co-innovation and moved to the commercialisation stage while performing further development when necessary.

"The customer or brand owner would do some of their internal testings. So maybe a consumer perception test. And then, we would help them prepare the storyline …start to discuss commercialisation timelines after that. And further developments that are required." (TAP-S-21209)

2. Mechanisms of co-innovation

2.1. Joint activities

Co-innovation between ChemiCo and brand owners also involved converters and all parties supporting the packaging development through various joint activities. ChemiCo explored packaging applications for their new material, took into account complex requirements for the applications and offered a comprehensive sustainable packaging solution for the brand owner. ChemiCo shared the knowledge of the material, gave solutions to processing conditions and the brand owner supply chain, and helped the brand owner create marketing communication for new packaging materials.

> *"What we work to the extent that we really provide, not just the material itself, but also the knowledge that we have on the material properties and the processing. That way, we can help the converter get the most out of the polymer in the required design." (TAP-S-21209)*

> *"…we take a very creative, but data-driven approach to help position the "material" as a new Polymer. It's a more sustainable circular way, too." (TAP-S-21209)*

All partners were involved in the knowledge sharing and shared confidential information. During concept exploration, the converter and the brand owner gave feedback to ChemiCo to improve the prototype. The converter collaborated with ChemiCo in prototyping, adjusting the package design, and changing manufacturing tools to fit the new material better. TAP-S-21209 explained that changing the bottle design, changing the thickness of the film, or buying new moulds were sometimes required to get the optimal behaviour of the material.

> *"…our converters are experts in plastic moulding and processing. So we can combine the knowledge on that side and our knowledge on the fundamental polymer behaviour..." (TAP-S-21209)*

The co-innovation involved many trials and mutual adaptations with the converter in the material and further packaging development to achieve the desired packaging application for the brand owner. TAP-S-21209 added that the brand owners also adjusted their brand images and made some changes to the consumer base and the supply chain.

"At the brand owner, it might be changing their brand image slightly… They need to have their marketing story aligned. And of course, you know, they probably will need to ramp up…" (TAP-S-21209)

2.2. Joint resources

TAP-S-21209 explained that all partners provided equal contributions to the co-innovation by investing financial capital and sharing resources for the project. ChemiCo supported the material development, invested their financial capital and other resources in developing the material, created the prototype, and built plants. According to TAP-S-21209, ChemiCo built a pilot plant and flagship plant for development purposes and approached the brand owner. The pilot plant was intended to produce materials at a ton scale to prove the scalability from the lab size and demonstrate the packaging application when approaching the brand owner. The flagship plant would produce up to 5,000 kilotons of materials to prove that the technology can be scaled up to a commercial scale and allow ChemiCo's customers to launch products using the new packaging to test the market.

> *"We have a pilot plant where we make on a ton scale material at the moment. So that has enabled us to really prove that the technology can be scaled up…" (TAP-S-21209)*

> *"…this first factory is really to prove the viability …from an engineering and a commercial point of view …They see a fully functioning, commercial-scale factory, and they see products on the shelf in the supermarket packaging. " (TAP-S-21209)*

Co-innovation partners also shared their expertise in material development and packaging application. ChemiCo shared its knowledge and technology on the project with its partners. ChemiCo has a great base of fundamental knowledge on the polymer, a network with universities to support scientific studies, and a team of experts and researchers. When working with the converter, ChemiCo shared their knowledge of fundamental polymer behaviour, while the converter shared their expertise in plastic moulding and process.

> *"…We make very small quantities so, at the moment, the material we have for prototyping is quite expensive, but we support that with the amount of knowledge that ChemiCo can bring…" (TAP-S-21209)*

"We take that knowledge of material properties and work with the converter … they are experts in plastic moulding and process. So, we can combine the knowledge..." (TAP-S-21209)

TAP-S-21209 added that the prototype was very expensive; therefore, ChemiCo expected equal contributions from all partners in the form of employee work time, machine uptime, and new conversion process tooling.

"...we would expect equal contributions from all of the partners …time on equipment, or I guess people time…" (TAP-S-21209)

2.3. Relationship management

ChemiCo's relationship management was reflected in the way they approached the brand owners. TAP-S-21209 explained that ChemiCo had demonstrated evidence of material development, project feasibility, and future potential by using a data-driven approach to build a business case suitable for each brand owner. They then built a pilot plant to demonstrate the material application directly into the packaging and scale-up capability. With this approach, ChemiCo proved that the technology worked in fully functioning commercial-scale plants and convinced brand owners to choose potential partners and invest.

"…If they invest and buy a license for the technology, they will be able to make money as well. So it's really all about proving the technology, proving the product." (TAP-S-21209)

TAP-S-21209 noted that not all companies had had the ability to collaborate and adopt ChemiCo's technology. TAP-S-21209 added that not every company was innovation-driven; some only claimed sustainability in the company profile. Therefore, ChemiCo prioritised like-minded partners focusing on innovation and a high commitment to carry out good sustainability practices. For example, ChemiCo prioritised partners who had a good attitude and commitment to be the first to have sustainable bioplastic products in the market.

"Not every company would be able of co-innovate with ChemiCo … So we really look for like-minded parties that want to move forward." (TAP-S-21209)

"… it's really important to find these companies who do more than just put a sustainability claim on their website, they really live it …They want to be first to have a sustainable bioplastic product on the market." (TAP-S-21209)

The collaboration with the brand owner was regulated in the partnership agreement. TAP-S-21209 explained that in addition to selling license for the technology, ChemiCo worked a lot with material transfer agreements to ensure the protection of intellectual properties for ChemiCo's technology whilst allowing the brand owner and converters to get their sector-specific IP. ChemiCo has built an IP portfolio over the years and ensured broad coverage to facilitate market adoption of the material and allow their partners to patent their invention from this co-innovation.

"Converters and brand owners, they often want pieces of IP to protect their invention. So we ensure that we have the coverage necessary to bring the material into the market, but for any sector-specific IP, the departments have full rights to file." (TAP-S-21209)

Apart from converters and brand owners, it is also important to collaborate with a number of different partners. TAP-S-21209 provided an example of co-innovation in an EU flagship subsidy project, in which ChemiCo worked towards commercial scale and operated with partners from the value chain. In this project, ChemiCo worked with raw material suppliers, engineering partners, downstream partners, and many others.

2.4. Absorptive capacity

ChemiCo showcased how the biopolymer producer acquired information and knowledge from the co-innovation partners. TAP-S-21209 showed the importance of acquiring information regarding the development timeline, the amount and grade of the required material, the expected performance, and other required details. ChemiCo also needed to know when the customer planned to commercialise a product, which material they would need, and in which country the packaging would be used. This information was needed to develop the packaging that meets the customer's requirements, address regulations and compliance for a particular area, ensure that the product was delivered on time, and ensure the availability of supply by reserving the production far in advance.

> *"…they will say I want to launch a flexible packaging in North America, so that you know you will need to make sure you have the right food approval, you would need to have the right recycling approval..." (TAP-S-21209)*

From the discussion with TAP-S-21209, it could be inferred that ChemiCo had learned from the co-innovation partner through interactions during the trial and feedback and participation in a research project with the whole supply chain. The involvement of various actors in the supply chain helped ChemiCo understand the whole supply chain. For example, ChemiCo could learn how sustainability was applied in sourcing raw materials by working with sugar suppliers.

> *"We learn constantly from our partners. And that's why we partner …we are right up at the upstream in the development chain, so it's really vital to work with other parties." (TAP-S-21209)*

ChemiCo learned a lot from brand owners about industrial aspects, market dynamics, and consumers' wants. TAP-S-21209 exemplified that the current industry focused on plastic waste, so ChemiCo added this aspect in the business case, built a relevant story for marketing communication, and gathered more data on recycling. Co-innovation enables ChemiCo to understand the details about the brand owners' needs and address those in the next iteration of the material. Co-innovation also enables ChemiCo to become more flexible and adaptive to brand owners with different needs.

> *"…every customer and every partner and every single project is different. And every time we need to adapt, there is no set way of doing things. It's all about being adaptable and flexible, especially when we're bringing a new product to the market." (TAP-S-21209)*

Besides studying the material, ChemiCo also learned different methodologies and technologies from the wider supply chain, which were then integrated into their technology. TAP-S-21209 exemplified that ChemiCo learned about LCA studies from the co-innovation with an EU consortium, which enabled them to understand different perspectives in the assessment. Therefore, ChemiCo plans to use its LCA as a basis for future technology development and license agreement.

> *"We can look at these demonstration articles that have been made by our partners. We also plan to use our LCA as a basis for future technology development to guide us… We want to grow the technology and license it." (TAP-S-21209)*

3. The outcomes of co-innovation

Before the co-innovation, ChemiCo had developed a new material with a unique molecule and excellent gas barrier properties, which did not require an extra barrier layer that was difficult to recycle. Apart from being bio-based and recyclable, the newly-developed material also had a mechanical performance similar to PET and was more efficient in its use, one of which was the substantial value propositions.

> *"You can use less …compared to PET, to get the same mechanical properties. You don't have to sacrifice your container performance when you are light-weighting, for example. So we see that there is a very strong value proposition." (TAP-S-21209)*

Through co-innovation, ChemiCo was able to further develop materials according to the exact need of every brand owner, making it 'fit for purpose' with excellent performance.

> *"Biobased is more of a secondary attraction, than... you know the main selling point. The plastic has to be fit for purpose, and it has to have performance characteristics." (TAP-S-21209)*

From the discussion with TAP-S-21209, it was evident that the material developed by ChemiCo was more expensive than conventional plastics, but ChemiCo balanced the price point with performance and other commercial benefits, all of which were proposed to the brand owner in the business case.

> *"the performance quality has to be there, …the right story…the right performance, and it has to have the right price point." (TAP-S-21209)*

From an environmental perspective, TAP-S-21209 explained to the brand owner that bio-based and biodegradability were, in fact, not the main selling point. Therefore, ChemiCo presented how the materials met the circular economy principles. TAP-S-21209 explained that packaging made with

ChemiCo's material could be recycled without contaminating the PET recycling and reused, thus closing the loop.

> *"A more circular way …It can actually go into the PET recycling stream without affecting the quality of the recycled PET that comes out the other end." (TAP-S-21209)*

TAP-S-21209 explained that ChemiCo received support to achieve commercial scale and operations through co-innovation with a broader supply chain. This broad co-innovation enabled ChemiCo to understand how environmental processes worked, such as sourcing sustainability and environmental processes at the sugar supplier. In addition, ChemiCo could also see the environmental impact based on the LCA of the whole production and compare it to the conventional packaging. ChemiCo then used the LCA analysis as a basis for future technology development to then licensing it.

> *"We have an EU flagship subsidy project… We also work with a number of different partners, with the aim of getting our first commercial-scale farm built and operated." (TAP-S-21209)*

ChemiCo shows that co-innovation outcomes include to material improvement, packaging application, exclusivity for the brand owner, as well as facilitating further technology development and inventions. TAP-S-21209 added that ChemiCo allowed the co-innovation partners to get the sector-specific IP as part of their contribution in developing or discovering, for example, in the aspect of packaging design. ChemiCo also plans to develop LCA-related technology and offer the licenses to a broader industry.

> *"I think it's more than fair that brand owners and converters have the right to protect their discoveries as well …design aspects of the package …" (TAP-S-21209)*

4. The drivers and success factors

TAP-S-21209 explained that partner selection was one of the key drivers for co-innovation. ChemiCo looked for like-minded partners who were willing to move forward with a focus on innovation and to implement sustainability in their business practices.

> *"So what we find that it's really important to find these companies who do more than just put a sustainability claim on their website, they really live it…" (TAP-S-21209)*

TAP-S-21209 added that the key to the success of bioplastic packaging commercialisation was the right combination of performance, commercial benefits, and price. Bioplastic packaging can be offered at a higher price than conventional plastic, but it must be able to reach the quality performance expected by the brand owner, which can be communicated to support their sustainability agenda. Therefore, a persuasive business case is an essential tool to convince brand owners.

TAP-S-21209 also observed that the market was changing and should be anticipated by biopolymer producers. For example, in the last ten years, the focus on bioplastic materials, in general, has changed from biodegradability to recyclability. Additionally, having a bio-based material is not the main selling point anymore. The industry wanted biodegradable bioplastic packaging but is now concerned about contamination in the existing recycling infrastructure.

> *"a little bit of a bad reputation …What we have seen in the last ten years. Ten years ago everybody wanted biodegradability." (TAP-S-21209)*

> *"Biobased is more of a secondary attraction… The plastic has to be 'fit for purpose', and it has to have performance characteristics." (TAP-S-21209)*

5. The dynamic roles of customer and supplier

ChemiCo, as a biopolymer producer, has initiated the innovation by bringing a new polymer to the market with a better approach to the circular economy principle. It can be inferred from the interview that the brand owner adopted the technology and co-innovated in further development. One of the dynamics in the relationship with the brand owner, TAP-S-21209 recalled, was during the partner selection. At this stage, positioning the offer could be challenging as there are other technology alternatives in the market. The brand owners might look for other suitable solutions and co-innovate with more than one technology provider.

> *"There are multiple new technologies, and quite often brand owners are working with two or three technologies to see which one is best… positioning is the very key." (TAP-S-21209)*

TAP-S-21209 also added an example of dynamics when working with the converter. Some converters may be more innovation-driven than others, but sometimes ChemiCo finds a few difficulties in getting the converter to focus on and prioritising the co-innovation. ChemiCo realised that bioplastic packaging is only a small part of the packaging market, and the converters have to manage the co-innovation to work with other priorities. For example, when the pandemic started, ChemiCo converter partners focused on producing packaging, masks, protective equipment; and therefore, they put the bioplastic packaging innovation project with ChemiCo to a lower priority.

> *"All of a sudden… innovation is not key in that sort of time. … that's one of the things that we do face is prioritisation. Innovation is often a lot lower down the priorities." (TAP-S-21209)*

Appendix F-3: Biopolymer producer case: CbagCo

CbagCo is a biopolymer producer and bioplastic converter, located in Indonesia. CbagCo was established in 2017 as a subsidiary of a corporation known as the leader in plastic industry in Indonesia, particularly in polymer manufacturing. CbagCo has been developing biopolymer compounds since 2007 and launched the bioplastic product range in 2011 when it was a smaller division of the parent's company.

CbagCo pioneered the development of bioplastic packaging in Indonesia from the research and development, large scale manufacturing to introduction of bioplastic packaging to the Indonesian market. CbagCo has acquired ISO for good quality and environment management systems; not only that, it has received several awards for its innovation and environmentally friendly product from the Indonesian government.

In brief, the manufacturing process in CbagCo started from the production of the biopolymer compound using starch as the raw material. The biopolymer compounds were made in pellet form, then converted into flexible film used for carrier bags, electronic wraps, and other packaging. CbagCo serves large and small business customers in Indonesia and has exported its product globally.

1. The process of co-innovation

In the first interview, PRESDIR-S-0211 stated that the company conducted an in-house R&D supported by external experts. The product development from biopolymer development to packaging was carried out by different divisions within one company, and CbagCo has not involved customers in the product development. Therefore, this section will explain the product development process in the processing section that processes raw materials into biopolymers with the conversion section that processes biopolymer pellets into flexible films, carrier bags and other packaging.

PRESDIR-S-0211 explained that the product development involved iterative processes, machinery, and manufacturing. The first step was designing the material formulation, followed by creating the pellet prototype for a small-scale trial on the machine. The process was not straightforward, and it took years of development to go back and forth, around in circles of from design, trial, re-design, or improvement to get the desired product. PRESDIR-S-0211 shared an example after the CbagCo finished with the formulation; CbagCo tried the pellet in the blown machine, observed the process and result. When the process was not smooth and the product output was not uniform, then process or machine adjustment was carried out, such as changing the dies plate or other settings. Subsequently, CbagCo ran another trial and observed the result, which might show problems with the bioplastic film, then went back to improve the formulation and did another trial.

> *"The process took years, so it was a long process to change the design of the machine and formulation." (PRESDIR-S-0211)*

PRESDIR-S-0211 expressed that the adjustment made for improvement consisted of re-designing the material formulation, adjusting the machinery, and the manufacturing processes were very complicated and exhausting. The most difficult part, also the critical process, was the formulation to get mixtures of a large number of compatible materials, worked in the manufacturing process as well as an added value to the final product. Although CbagCo designed the formulation carefully, involving knowledgeable researchers from the internal company, numerous trials and errors were inevitable.

> *"The formulations trials used various ingredients... especially in creating the compatibility and an added value to the product... Very tiring." (PRESDIR-S-0211)*

2. Mechanisms of co-innovation

2.1. Joint activities

Although the development of bioplastic packaging at CbagCo is done in-house, this development involves the collaboration of different parts within the company. Therefore, this section will explain joint activities between the material processing and conversion to illustrate the essence of joint activities between biopolymer producer and converter.

CbagCo's product development activities were carried out by the R&D and a converter, also involving a third-party machinery workshop. The R&D section, which was a division under one of P0211's subsidiaries, developed bioplastic raw material from design, formulation of the cassava starch and a mixture of other materials, produce the pellets for the next conversion process. The converter was also owned by P0211, functioned as a "Live Showroom" to show the production process and conversion of bioplastic packaging, giving an overview of manufacturing bioplastic packaging to the customer. In addition, the converter section also sold carrier bags produced to individual consumers, retail, or other business customers. Furthermore, the machining workshop, which was located not far from the company's location, built and modified the conversion machinery as requested by the R&D division.

> *"We don't actually build the packaging factory. But we build it to provide a "live showroom" to the customer." (PRESDIR-S-0211)*

Joint activities between R&D, converter and machinery workshop were directed by the R&D department. PRESDIR-S-0211 exemplified that a machining workshop worked upon requests from R&D to modify air pressure, blowing ratios, adjust gaps for dies tooling, or other requested work. This process occurred many times until the desired results were obtained. Furthermore, joint activities with the converter were related to trials of materials with a larger production scale. PRESDIR-S-0211 explained that scale-up from lab scale to production scale was not an easy process, did not straight away produce an identical result as the lab-scale prototype. For this reason, the R&D section directed the adjustments that need to be made by the converter, for example, speeding up the engine, changing the temperature and air blowing pressure. Often, R&D would also have to revise material formulations as necessary. These trials and improvement processes occurred many times among the R&D department, converter, and a machining workshop.

> *"We repeated the trial in the showroom using a larger volume. From the small scale to the large, the results cannot always be identical. So, when there are problems at a large scale, we have to go back until we get a formulation that works on a larger scale." (PRESDIR-S-0211)*

Additionally, CbagCo provided licensing scheme on its conversion operations to packaging manufacturers, in which joint activities such as knowledge transfer intensively occurred among CbagCo with the customers and provided technical support to CbagCo's customers. These activities facilitated CbagCo in introducing the bioplastic products, helping the customers to use the product, facilitating the acceptance to the product as it included its limitations, all of which helped CbagCo penetrate the market. PRESDIR-S-0211 explained that the customers who took the licensing program received training to produce bioplastic packaging properly. The customers needed to send personnel to be trained about operating the machine to maintenance in the CbagCo converter showroom. Furthermore, the machines used during training were then purchased by the customer and used for production at the customers' plant. After that, CbagCo continued to provide advice and support related to technical matters to ensure customers could use the machine and produce carrier bags correctly and, if necessary, transferred some of the retail customers or users to plastic factory customers. CbagCo also allowed the packaging manufacturer customers to copy, modify and duplicate the conversion machine as freely as possible without paying royalties or similar fees.

> *"Their technicians practised at our facility, we trained them to run the machine, how to operate, also perform the maintenance. Then they purchased the machine." (PRESDIR-S-0211)*

> *"Basically, when they buy the machine, they are free to copy… please feel free." (PRESDIR-S-0211)*

2.2. Joint resources

When developing bioplastic packaging, CbagCo invested resources for R&D, material testing and creating a specific conversion machine. PRESDIR-S-0211 added that CbagCo was selective in assets investment by outsourcing expensive and or rarely used assets. For example, CbagCo outsourced machinery development to a third-party workshop and tested a series of product quality specifications in a private or university laboratory. Subsequently, CbagCo prioritised investment on assets for regular use. PRESDIR-S-0211 mentioned that the essential asset for the product development was the human resources who were highly experienced in several industries, having good networking or access to specific material and other resources and expert in the material engineering field. Nevertheless, these resources showed crucial resources for the development of bioplastic packaging but could not represent joint resources as all were from CbagCo.

> *"Some of which we don't want to buy or are too expensive to buy, rarely use, we send it to external, to be outsourced. The simple ones or regularly used, those are the ones we invest in." (PRESDIR-S-0211)*

Interestingly, PRESDIR-S-0211 stated that the CbagCo's bioplastic has specific characters that could not work directly on the standard conversion processes; thus, CbagCo provided the conversion machine for the customers to buy then allowed to copy or modify and multiply CbagCo's version of converting machine or using the customers' machinery whenever possible. PRESDIR-S-0211 added that many of the licensing customers successfully created better and more productive conversion equipment than the initial CbagCo's version because the licencing customers were experienced packaging manufacturers who mastered the conversion process and machinery. Therefore, after mastering the bioplastic conversion manufacturing taught by CbagCo, they were able to advance the conversion process themselves. However, PRESDIR-S-0211 recalled that these customers did not share back the improved bioplastic conversion to CbagCo concerning confidentiality and business competition. In this case, joint resources occurred between CbagCo and the licensing customers in a unique mechanism.

2.3. Relationship management

Although CbagCo did not involve customers in product development, CbagCo had a unique way to manage relationships with business customers and introduce bioplastic packaging. CbagCo educated their existing and new customers to be more receptive to bioplastic packaging and to prepare the bioplastic packaging market going forward. First, CbagCo sold carrier bags to retailers, served small orders even though normally CbagCo sold for large industrial scales. PRESDIR-S-0211 explained that CbagCo sold the carrier bags to the retailer for even only for smaller orders of 10,000 pieces, which value for IDR one to ten million (approximately £ 50 to £ 500), to introduce the environmentally friendly carrier bag and educate the market.

> *"First, we introduce this bag to people. We sell the bags, even if the order is only 10,000 bags with only a million Rupiahs... for market education." (PRESDIR-S-0211)*

Secondly, after having the market developed, CbagCo would approach converters to produce bioplastic packaging by showing demand or growing market. CbagCo then supported the converter by supplying the pellets, production machinery, and even handing over CbagCo retail customers to the packaging manufacturer.

> *"Some consumers want to use it. After that, we'll get more customers. Then we offered the plastic manufacturer to buy the machines. They bought pellets from us, made bags, then we shifted the customers to them (the plastic manufacturer)." (PRESDIR-S-0211)*

CbagCo supplied the conversion and printing machine that work for bioplastic packaging to the converter. These machines were slightly different from conventional plastic equipment. However, CbagCo allowed the converters to copy and reproduce the CbagCo's machines, modify, or create better machines themselves because CbagCo main objective was to introduce the biopolymer pellets instead of the machines. In the long term, CbagCo will have more converters as the customer; thus, it could focus on the production of biopolymer pellets for the converters on a larger scale.

> *"Regarding the machine, they also endeavoured to copy, and some have managed to copy even better. I said, go ahead. Our aim is not to sell the machine or the bag, but to introduce the pellets…" (PRESDIR-S-0211)*

PRESDIR-S-0211 explained that the customers, either converters or retailers, were not involved in product development. CbagCo got many requests for customisation or different specification from the customers, many of which could not be provided by CbagCo. Therefore, the customer only accepted what was available, did some trials and bought when satisfied with the result.

> *"Indeed, there are all sorts of requests, but many of which we are not able to fulfil. So, we only offer what we can. So, it is limited. In the meantime, they accept it as it is." (PRESDIR-S-0211)*

> *"So far, the customer is not involved in anything. They accept the product, try it and when satisfied, they buy it." (PRESDIR-S-0211)*

The relationship with the customer was limited, as CbagCo developed the bioplastic material and packaging exclusively. CbagCo found that convincing the packaging manufacturer to produce bioplastic packaging was quite challenging because the price of the final product was three to four times higher than the conventional plastic. PRESDIR-S-0211 convinced the customer to consider the future of their business when the government regulation to ban single-use plastic would be implemented, also passed some of CbagCo retailer customers to the packaging manufacturer. On the other side, the packaging manufacturers, who were also the licensing customers, successfully improved the conversion process and machinery after learning from CbagCo but were quite selfish as they were reluctant to share back their knowledge with CbagCo.

2.4. Absorptive capacity

PRESDIR-S-0211 explained the information and external knowledge needed for product development, including a combination of physics, chemistry, and mechanics. In addition, PRESDIR-S-0211 followed developments in the field of bioplastics and searched for the similarity of existing products to CbagCo products and sought further technologies, which were useful for product development, for example, additives.

> *"We go to the exhibition and see what's there... Are there similarities between us or not? ...In terms of additives, we learn from suppliers who are specialists in making the additives." (PRESDIR-S-0211)*

PRESDIR-S-0211 shared the activities and routines to acquire that knowledge barely involved the customers. For example, PRESDIR-S-0211 learned from literature study, joining, or visiting packaging exhibitions and even learned from the additive suppliers about using specific material in the formulation. These activities helped CbagCo to improve the material as well as the conversion process. PRESDIR-S-0211 illustrated that CbagCo once had a problem with heat being too high in the conversion process; hence CbagCo added a particular additive in the formulation to reduce the temperature and improve the conversion process.

When seen from the packaging manufacturers who were also CbagCo licencing customers, they learned about the bioplastic conversion process from CbagCo through a series of training programmes at the CbagCo facility. The packaging manufacturers learned how to process the bioplastic material, operate the machinery, and perform regular maintenance, also dealing with bioplastic unique characteristics that were new to them. The packaging manufacturers were able to combine the new knowledge about the bioplastic conversion process with their expertise in conventional plastic manufacturing; thus, they were able to modify the machine or create an entirely new machine that performed better than the CbagCo's version. However, the packaging manufacturers were reluctant to share this new knowledge and instead kept the advantage themselves as they were concerned that CbagCo would share this knowledge with other customers, creating competition.

> *"They tend not to tell us because they don't want us to tell other customers that can cause competition for them." (PRESDIR-S-0211)*

3. The outcomes of co-innovation

PRESDIR-S-0211 explained in detail the bioplastic packaging features developed by CbagCo. Based on this information, it can be seen that CbagCo's product performance, in general, has many disadvantages compared to conventional plastic. PRESDIR-S-0211 also stated that the limitation of the current product was due to the characteristic of the starch-based bioplastic.

> *"It can't perform as good as the plastic bag because of the nature of the plastic itself ...what we develop is the type that also uses natural starch." (PRESDIR-S-0211)*

Some weaknesses in performance are related to technical properties such as non-transparent film and lack of strength for holding heavier products, as well as not meeting the requirements for food packaging because there is still a migration of certain substances into food. PRESDIR-S-0211 explained that the bioplastic transparency is currently not as good as PP, but it looks more like HDPE. However, the bioplastic strength was not even half of HDPE strength, which could hold more than 10 kilos. PRESDIR-S-0211 added that the current bioplastic carrier bag could not hold over 5 kilos and was not waterproof. Thus, the application of CbagCo products is still limited to shopping bags, carrier bags or flexible film packaging for non-food products.

Although CbagCo bioplastic packaging has many shortcomings in performance, this product has several advantages from the environmental aspects. PRESDIR-S-0211 explained that the current bioplastic packaging is biodegradable, compostable, and recyclable. However, this product has not passed the EN13432 biodegradability standard due to its disintegration rate being slightly below the requirements. This packaging is also recyclable but needs to be sorted with wastepaper instead of other plastic waste.

> *"It has not met the compostable requirements set by EN Norm ... But actually, it is compostable and biodegradable." (PRESDIR-S-0211)*

PRESDIR-S-0211 added that CbagCo's bioplastic packaging is compostable within six months when buried in rich soil and does not need industrial composting. This is one of the advantages compared to PLA, which is often non-biodegradable or needs industrial composting. Therefore, PRESDIR-S-0211 stated that PLA is unlikely environmentally friendly nor works for Indonesia. CbagCo bioplastic was designed differently from PLA, and it was more suitable for conditions in Indonesia, in which natural soil was generally fertile with microorganisms, but the industrial composting facility was not available. PRESDIR-S-0211 further explained that during degradation, the product did not compromise soil fertility as it tended to retain water and was harmless for plants or when eaten by animals such as chicken, worms, fish, and others. Degradation is also dependent on microorganisms in the soil, but CbagCo has not further tested how long the product degrades in dry soil with a minimum of microorganisms. After degradation, this product was harmless to the environment and has passed the toxicity lab test following the Indonesian standard.

> *"Like PLA ...it cannot compost in the natural environment, only in industrial composting ...it does not work in Indonesia." (PRESDIR-S-0211)*

PRESDIR-S-0211 finally added that despite having some performance disadvantages, CbagCo bioplastic packaging was very environmentally friendly. However, PRESDIR-S-0211 was concerned about bioplastic high production cost that eventually led to higher selling price, up to four times the conventional plastic packaging.

> *"The price is even quadrupled compared to plastic ...many disadvantages still. However, it is far more environmentally friendly." (PRESDIR-S-0211)*

4. The drivers and success factors

From the interview with PRESDIR-S-0211, it can be concluded that bioplastic packaging is processed like conventional packaging. However, PRESDIR-S-0211 added that the production machine needed modification to follow the material characteristics that were different from conventional polymers.

> *"The process is blown just like the ordinary plastic bag." (PRESDIR-S-0211)*
>
> *The machinery must be modified because it is different from the plastic… Our products have thermoplastic properties but are more thermosetting." (PRESDIR-S-0211)*

The key to successfully getting the customers to adopt bioplastic packaging is by teaching the customers to produce the packaging themselves instead of buying from CbagCo. In this way, CbagCo would create more business customers and shift the focus to supply biopolymer to them.

> *"Our goal is not to produce the bag. So, we teach them more to produce their own bags... The customers to whom we offer the product are mostly plastic packaging manufacturers." (PRESDIR-S-0211)*

Furthermore, PRESDIR-S-0211 explained that the bioplastic showed positive development; the market started to grow influenced by the growing awareness of the negative impact of plastic on the environment in Indonesia. Likewise, government regulations have begun to address plastic pollution, urged a reduction and banned the use of single-use plastic packaging, for example, the ban on using the single-use plastic bag in Jakarta in July 2020, as well as in other regions.

> *"The recent condition is leading to a positive one because the government involvement has started… Some of the plastic factories are now more actively looking for opportunities to make CbagCo bags." (PRESDIR-S-0211)*

This condition, especially government regulation, is considered a positive driver to bioplastic development in Indonesia. As a result, packaging manufacturers noticed the changing market. They were concerned about losing business in the future when plastic packaging is banned while they do not have an environmentally friendly packaging solution yet. PRESDIR-S-0211 emphasised the importance of government regulation to drive demand because more packaging manufacturers were actively searching for environmentally friendly packaging to comply with the regulation. All these conditions become a positive development for CbagCo.

> *"Now they are facing a changing market; government regulations start to push towards being environmentally friendly. They are forced to think about the future because if plastic is banned, they will lose business." (PRESDIR-S-0211)*

4.1. The dynamic roles of customer and supplier

Based on interviews with PRESDIR-S-0211, it was explained that CbagCo customers only accepted products and services that were already available, and CbagCo has not served customisation requested by customers because of the limitations of their bioplastic technology.

> *"Indeed, there are all sorts of requests, but there are just a lot of us that we cannot afford... In the meantime, they accept what they are." (PRESDIR-S-0211)*

Therefore, it can be concluded that in the case of CbagCo, customers act as the adopters who use the bioplastic packaging and adjust to its limitation, adopting the new conversion process by learning from CbagCo to modify their existing machines. On the other hand, CbagCo drives the technology, pioneers the development of bioplastics in Indonesia, introduces bioplastic packaging to the Indonesian market and teaches them to adopt bioplastic packaging.

Appendix F-4: Converter case: FilmpackCo

FilmpackCo is a packaging converter located in the UK. The company processes raw materials in the form of polymer into packaging, which is then transferred to the product manufacturer for further processing into the final product. There are many packaging products made by this company, such as furniture bags, waste bags, mailing bags and types of film, using polythene and bioplastics material.

As awareness of plastic waste increases, FilmpackCo is also concerned about sustainability. Therefore FilmpackCo is developing green alternatives by offering bioplastic packaging from renewable materials, e.g. sugar cane, which is biodegradable and recyclable. In addition, FilmpackCo also developed a new generation of plastic film that uses up to 100% post-consumer waste (PCW) material and recyclable, and this is done to accommodate the application of tax for plastic packaging that uses PCW below the standards set by the UK Government.

1. The process of co-innovation

On the converter's side, the co-innovation was initiated by a significant number of customer demands received by FilmpackCo. TECHDIR-SC-001 explained in the interview that different fields of customers enquired about compostable solutions from the company.

> *"…people have been coming to us from lots of different fields and saying, Can we have a compostable solution for our process." (TECHDIR-SC-001)*

Responding to this request, FilmpackCo then conducted an initial assessment by visiting the customer's site. This visit is crucial to gather information on the critical features of the process, and the potential for implementing a particular specification into the customer's manufacturing process. TECHDIR-SC-001 explained that during the visit, a discussion with the technical people was essential to understand the compatibility of the new bioplastic film with the existing process and the specification of material used by the customer, as well as the critical features of the process that would impact the application of the new bioplastic packaging.

> *"...first of all, go to visit them. And we'll have a discussion with their technical people..... Look at their process to see what the critical features..." (TECHDIR-SC-001)*

> *"we have that initial meeting, and then say, well, we think the potential, will select some grades." (TECHDIR-SC-001)*

After the initial assessment, a decision on the continuation was made and followed with a product trial. In this process, the FilmpackCo used its expertise to suggest the best technical options, such as thickness, and additive chemicals to make the new packaging work better for the customer's process without compromising the biodegradability or compostability.

> *"We will maybe make that product as a trial, using our expertise to tell them... without destroying the compostability and so on." (TECHDIR-SC-001)*

The trials were undertaken at the customer's production machine, and often problems arose. TECHDIR-SC-001 implied that FilmpackCo would try to solve the problem whenever possible but if these issues could not be resolved, FilmpackCo would involve its supplier, the biopolymer producer, for solutions to the problem. Based on TECHDIR-SC-001's experience, the biopolymer producer provided support and worked together with FilmpackCo, so that most of the time they were able to find alternatives to resolve those issues.

> *"So we will conduct machine trials with the customer… And I go back to the producer and say, these are the issues we encountered." (TECHDIR-SC-001)*

In this process, FilmpackCo does not add any technical aspect to the polymer but focuses on making the bioplastic packaging work for the customer, especially the customer's process.

> *"We don't really add much to them, technically." (TECHDIR-SC-001)*

As a consequence, significant adjustments are sometimes required to be made at either FilmpackCo or the biopolymer producer. If required, FilmpackCo will modify the production machine by collaborating with the machine supplier.

2. The mechanisms of co-innovation

Business motives facilitate co-innovation, which is undertaken in three ways, i.e. among biopolymer producer, converter and product manufacturer.

> *"It's a three-way collaboration in you like... downstream and upstream. And yeah, that's quite successful." (TECHDIR-SC-001)*

The following describes the mechanism based on the prominent themes in the initial framework.

2.1. Joint activities

The activities in the product development are interactively undertaken among FilmpackCo, its supplier and customer, mainly these are trials, feedback and adjustment.

> *"We supply our customer we have trials we have feedback and we feed that back to our supplier…" (TECHDIR-SC-001)*

> *"We go back to the polymer producer saying these are the issues. Can you engineer a way around and come back, try again…" (TECHDIR-SC-001)*

FilmpackCo gives solutions to the customer, and is involved in trials both at the customer's site and at its production site, to ensure the polymer grade requested by the customer works on the machine, tweaks its process to create the packaging that works for the customer's process, and intensively communicates with the customer and biopolymer producer.

> *"…our expertise to tell them, what thickness they should be using… more additives to make it a little bit easier…" (TECHDIR-SC-001)*

> *"…we'll put the new material onto our machines because they've got to run for us as well…" (TECHDIR-SC-001)*

The biopolymer producer will act based on the request and feedback from both FilmpackCo and its customer (the product manufacturer), then give solutions for the processing condition and, if required, adjust the polymer or even make a new grade of polymer.

> *"…my supplier will come up with a change of modification or even a new modified grade of polymer." (TECHDIR-SC-001)*

> *"If it's on a very fast machine, and it needs to have certain properties… you can actually do that with the assistance of the polymer producer." (TECHDIR-SC-001)*

> "They will sit with us and say, try this different processing condition." (TECHDIR-SC-001)

FilmpackCo's customer usually accommodates new film characteristics, has many trials with the real production process, and makes the adjustments to their process based on FilmpackCo's suggestions, e.g., changing the machine settings.

> *"…that has to be a nice, shiny glossy film… it becomes very milky, and you can't see through it. Again it doesn't matter at all." (TECHDIR-SC-001)*

> *"They will change some settings, so maybe accommodate the different seal characteristics of the compostable versus a standard film." (TECHDIR-SC-001)*

2.2. Joint resources

The resources in the co-innovation are from each partner and include tangible and intangible assets. On the converter's side, the resources put into the co-innovation are expertise, production facilities, and machine hours. The converter's expertise is important for giving advice to the customer on using the packaging in the customer's production machine.

> *"…using our expertise to tell them, what thickness they should be using, whether there's anything we can use, more additives to make it a little bit easier…" (TECHDIR-SC-001)*

By using the feedback loop from the customer or biopolymer producer, the converter must ensure that the new polymer works in its own production facilities before trying it in the customer's facilities. To that extent, the converter dedicates trials at the production facilities, using real production scale, thus sacrificing its machine time for many trials.

> *"…use of our machines and our processing machines to make the film…" (TECHDIR-SC-001)*

> *"We'll put the new material onto our machines because they've got to run for us as well." (TECHDIR-SC-001)*

At the biopolymer producer's side, the resources dedicated to the co-innovation include the expertise to give solutions for the converter and the product manufacturer, and if required, R&D resources are allocated to create a new blend of polymer.

> *"…engineer another grade or do perhaps a blend of formulations to enable that to work." (TECHDIR-SC-001)*

At the customer's side, the resources contributed to the co-innovation include the use of production facilities and personnel who work for the development and trial stage. Accordingly, cost is incurred on these activities, such as machine time or the loss of production due to the trials.

> *"…their main investment is in the machine time the loss of production…" (TECHDIR-SC-001)*

> *"…the allocation of personnel. To develop a development and trial situation…" (TECHDIR-SC-001)*

These resources consume large capital expenditures due to the complexity of the application and the many trials required for the real production scale. Thus, they become expenses for each converter, biopolymer producer and product manufacturer.

2.3. Relationship management

From the converter's perspective, the dynamics in the relationship with the biopolymer producer tend to work in a closer relationship, compared to the one with the product manufacturer. This relationship develops over a long period as the converter becomes a significant proponent and the biopolymer producer is committed to giving a solution to the converter.

> *"…FilmpackCo has probably been one of the biggest proponents of that over the last several years; we've got a very good relationship with Supplier BK." (TECHDIR-SC-001)*

In a different perspective between the converter and product manufacturer, the relationship tends to be transactional, as the product manufacturer looks for a green packaging solution for suppliers in the market.

> *"…people have been coming to us from lots of different fields and saying, Can we have a compostable solution for our process." (TECHDIR-SC-001)*

TECHDIR-SC-001 found that the product manufacturer that is also an industry leader could be more demanding, especially regarding both environmental and cost saving. However, FilmpackCo found it is quite difficult to suggest the appropriate approach to this customer as there may be a mismatch with the customer's rigour standards and understanding of the environmental concept, sustainable supply chain or product design.

> *"Yeah, more demanding and I think less and less common-sensical. If that's the word. So they let procedures and the rigours of their internal strictures within that macro organisation delay or deprive them of an opportunity to achieve…" (TECHDIR-SC-001)*

Surprisingly, close collaboration is not yet the foundation of co-innovation in bioplastic packaging.

> *"It's not a close collaboration." (TECHDIR-SC-001)*

Based on FilmpackCo, business and transactional relationships are more dominant with either the biopolymer producer or the product manufacturer. The converter took the opportunity to market bioplastic packaging to the customers, while the customer was looking for an environmental solution.

> *"…make the decision as a business decision to become involved, such as the relationship with the Supplier… will you give us the grades, you give us the information, we will try and use that to market a renewable solution, a compostable solution within our sphere of influence with our customers." (TECHDIR-SC-001)*

> *"…they become aware of a need for them as a business to be seen to supply an environmental solution for their particular product." (TECHDIR-SC-001)*

Accordingly, the opportunity to build a close collaboration between a customer and a supplier, is when the supplier already has the credentials to supply the particular innovative product that customer now needs.

2.4. Absorptive Capacity

TECHDIR-SC-001 explained that the information that encourages consumers to innovate with suppliers is bad press on the negative impact of plastic packaging, which ultimately encourages product manufacturers to look for environmentally-friendly solutions for their products. Similarly, the increasing global concern regarding plastic pollution has driven packaging manufacturers to the need to be able to offer a packaging solution; this would be an advantage in the future, and enhance both their business and position in the market.

"…because they're, like, got a lot of very bad press and so, the newspapers. and so on." (TECHDIR-SC-001)

"What's driven the owners of the business, of doing, probably it's to enhance their business..." (TECHDIR-SC-001)

The information acquired for the product development was implicitly detected as TECHDIR-SC-001 explained the process of co-innovation. The information gives an overview for FilmpackCo and biopolymer producers about what kind of packaging would work in the existing manufacturing processes. These include the specifications requested, specifications previously used, certain film properties such as slip and stiffness, manufacturing processes, machine speed, and other critical features that had direct implications for the new bioplastic packaging application.

"We will, as you say, look at the specification and the film that that we use..." (TECHDIR-SC-001)

"You know, if it's on a very fast machine, and it needs to have certain properties of slip and stiffness." (TECHDIR-SC-001)

Furthermore, TECHDIR-SC-001 explained that the crucial information was as much feedback as possible from the product manufacturer in order to enable FilmpackCo to provide the best solution.

Activities and routines involving direct interactions during co-innovation, such as visiting the customer's factory and having discussions with the technical staff who operate the production facility, contribute to the learning between partners. Another interaction was through regular meetings where all parties shared updates, discussed alternatives, for example, material selection and then made important decisions together. For FilmpackCo, critical information and new learning were obtained when conducting real scale product trials at the customer's plants. This is because their expert personnel can see directly how bioplastic packaging fails when applied to the production machines, then learn and create solutions.

"First of all, go to visit them. And we'll have a discussion with their technical people..." (TECHDIR-SC-001)

"…if we have that initial meeting... will select some grades" (TECHDIR-SC-001)

“...put the thing on the machine, and it might be able to be a disaster or ... it's just not sealing well enough.” (TECHDIR-SC-001)

The learning activities create new understanding about how to make the new materials work on the customer's machine. This is a critical point for the suppliers because they had to put in joint efforts and resources to provide a solution. It was apparent that suppliers using their expertise to provide solutions, advice and education to the customers related to the use of the new material in their processes. The suppliers, in this case, were the biopolymer producers as the FilmpackCo's supplier and FilmpackCo as the product manufacturer's supplier. Moreover, the customers, in this case, FilmpackCo and the product manufacturers, learn how to use the new material.

“But generally speaking most processes you can find a way around it with the polymer produces assistance away around those issues.”

By learning from lots of feedback and trials in the consumer production process, FilmpackCo found a solution and how to implement a type of product from one customer, then used the concept more broadly to other customers who use similar products. This makes FilmpackCo a step ahead of its competitors, becoming a market leader and having a successful customer relationship. TECHDIR-SC-001 also added that after working with the customers and seeing the market developments, the essence of developing bioplastic packaging is business motive and margins. However, there is an urgency to use bioplastic packaging in 10 years, and the current situation is such a "tangled web".

“And well, the basic thing is that with all this feedback... we ended up with a product which we know will work for those processes, which at that time, probably nobody else had.

“The bottom line is still about business development in margins and the future really... in 10 years’ time you may not have a business, you know, well, or a very restricted business.”

3. The outcomes of co-innovation

At this point, the outcome of co-innovation is the packaging at an acceptable price to the customer. This is achieved through managing the grade of biopolymer used that, even though it is more expensive than the conventional polymer, when applied to the packaging with a thinner or very small spread could be cost-neutral or increase the price to a reasonable degree for the customer's product.

> *"There is a cost savings because the films are thinner. It can be more expensive per kilo, but much less expensive per square metre of film or per pack." (TECHDIR-SC-001)*

> *"They gave us an additional restriction that it should also be cost-neutral."*

> *"…also trying to make it a lot thinner at the same time to offset some of the additional costs due to the density." (TECHDIR-SC-001)*

On the performance, the biopolymer must be able to work on the converter and customer's existing manufacturing machine and process. However, adjustment is possible to a certain degree of the feasible cost that could be applied to the final product.

> *"You have to try and compensate for that bag, not just making a compostable bag that will suit their process, satisfy their customer." (TECHDIR-SC-001)*

The essential environmental aspects are not only the biodegradability and compostability, but bioplastic packaging ideally should be recyclable as well. This is due to the inability of the waste sorting mechanism to separate bioplastic packaging that got mixed with the normal recycled plastic waste; therefore, bioplastic packaging contaminates the recycling system. Thus, developing a recyclable bioplastic packaging could resolve this issue.

> *"…renewable, degradable can always be a dry, proper, responsible post-consumer waste recycling." (TECHDIR-SC-001)*

Another environmental performance expected from bioplastic packaging is being carbon neutral, which supports the customer's environmental responsibility.

> *"They wanted the shrink film that they have around the bottles, forget the bottles themselves, they wanted that to be carbon neutral." (TECHDIR-SC-001)*

The expected long-term outcome from co-innovation is building unique expertise in working with new plastic that works for many applications and for many customers. Thus there will be a successful customer relationship and ensure FilmpackCo is a market leader.

> *"We've got a solution for many good uses of mailing film carrier, bags or refuse sacks. So basically, we ended up with a product which we know will work for those processes, which at that time, probably nobody else had. So we have a market leader as well as successful customer relationship." (TECHDIR-SC-001)*

4. The drivers and success factors

Based on FilmpackCo's experience, business motives become an essential factor for bioplastic packaging product development, adoption and co-innovation. The motives of retaining brand and protecting the market share due to the pressure of having an environmental responsibility are apparent to drive the high demand for bioplastic packaging.

> *"…not because of a real concern for environmental issues, because they've got to protect their brand." (TECHDIR-SC-001)*

> *"And protect their market share. All the business and economic considerations." (TECHDIR-SC-001)*

> *"Every day now almost we're getting, erm, requests; this is my film that you supply. Yeah. Can you make it biofilm?" (TECHDIR-SC-001)*

Business motives facilitate co-innovation, of which the key success is through three-way collaboration among biopolymer producer, converter and product manufacturer.

> *"It's a three-way collaboration in you like... downstream and upstream. And yeah, that's quite successful." (TECHDIR-SC-001)*

This mechanism enabled all partners to overcome the critical issue of making the new material work predominantly in the converter and product manufacturer's existing machine and process.

> *"We go to the machine, we find out what the issues are. We go back to the polymer producer saying these are the issues. Can you engineer a way around." (TECHDIR-SC-001)*

“To make it, to make it work to that process was, it was very, very demanding.” (TECHDIR-SC-001)

“We'll put the new material onto our machines because they've got to run for us as well…” (TECHDIR-SC-001)

The other factors are the contribution of the supplier to give environmentally-friendly solutions, promote the customer's innovation using an innovative, environmentally-friendly packaging that also enhances the customer's brand. This contribution was derived from the converter and product manufacturer’s view as the customer.

"A certain customer and they become aware of a need for them as a business to be seen to supply a, an environmental solution for their particular product." (TECHDIR-SC-001)

"Some innovation from the film producer in utilising those new grades, to make film structures to gee…, to give us a commercial advantage." (TECHDIR-SC-001)

Adoption of bioplastic packaging at the product manufacturer would only happen if there is a willingness to adjust the process, accept a lower performance than that of the conventional plastic and accept a higher cost to a certain degree, all of which are compensated by allowing the addition of a printed logo, such as "compostable".

"And people are prepared to pay extra money." (TECHDIR-SC-001)

"We might even print a little logo on it that says, all compostable. So the appearance doesn't matter, if it smells or any, it doesn't matter, because they can say that's a compostable film. So kudos is involved and brand protection and brand enhancements." (TECHDIR-SC-001)

This logo gives brand enhancement and recognition as being environmentally-friendly, sustainable or innovative for the product manufacturer.

5. The dynamics roles of customer and supplier

The dynamics of customer and supplier co-innovation is shown by the role of each co-innovation partner from the converter's perspective. The converter's roles are the connector between biopolymer producer and product manufacturer, and influencer in the adoption of bioplastic packaging by the product manufacturer in the converter's network.

"We don't really bring much to that, other than to use these particular polymer solutions and promote them to our customers." (TECHDIR-SC-001)

The biopolymer producer is the driver of innovation, which is similar to the innovation of oil-based polymer decades ago. This role is exemplified by the invention of biopolymer and formulation of grades that work for the customers.

"On the on renewability side, there was only one big player I knew who actually started this, quite some time ago..." (TECHDIR-SC-001)

The biopolymer producer is the technical expert, who gives solutions to any problems on the implementation that take place at the converter and product manufacturer's process.

"Most processes, you can find a way around it with the polymer producer assistance, a way around those issues." (TECHDIR-SC-001)

Interestingly, the interaction of co-innovation partners is likely to show the product manufacturer role as the adopter, which is expected to be more cooperative, understanding of the complexity of bioplastic packaging value chain, open for adjustment, and more accepting of the current bioplastic performance, which has not yet matched the conventional plastic's. However, the product manufacturer is sometimes very demanding and does not have a congruent understanding regarding the bioplastic or even the sustainability concept.

Appendix F-5: Converter case: BarrierCo

BarrierCo is a packaging manufacturer located in the UK. This company does not produce plastics, instead it adds barrier laminates to the packaging to enhance the barrier properties and improve the functionality of the plastic packaging. The company product range includes conventional plastic packaging and sustainable packaging that uses polylactic acid (PLA), is compostable and biodegradable. The sustainable packaging range is available for liquid packaging, processed food, fresh food, and film packaging for customer's specific use.

BarrierCo has been developing sustainable packaging sporadically for several years, and experienced a number of failures in the product development. Eventually, as there is more interest in greener packaging, BarrierCo started a new project by forming a new team and collaborating with new suppliers, and has finally been able to develop a breakthrough product range that is also well accepted by its customers.

1. The process of co-innovation

TECHMAN-SC-0226 explained that the co-innovation was initiated by an approach from the PLA supplier, whose intention it is to market BarrierCo's product. Moreover, there was also an approach from a customer who is looking for a sustainable film packaging.

> *"The PLA supplier approached BarrierCo, again... the sales team are now approaching their customer base. And so they're actively promoting these products." (TECHMAN-SC-0226)*

> *"So, we have two PLA suppliers. So, we, we did a trial. So, we were approached by a prospective customer; he wanted a compostable lidding film." (TECHMAN-SC-0226)*

BarrierCo then started a product development project with the supplier, after having a number of dialogues, setting the right parameters, and conducting many trials, which were first conducted internally then the product was taken to the customer's plants.

> *"We had put together a... tried a new development, which was a laminated of PLA with cellophane. Okay." (TECHMAN-SC-0226)*

“We laminated it and trialled it. So I would say to try a reel out. So we laminated this product. And then we had interest so we sent a trial to a consumer. And it works really well.” (TECHMAN-SC-0226)

After trials at the customer's plants, both BarrierCo and the customer reviewed the results to decide whether to transfer to a real production trial. If the trial succeeded in meeting the customer's requirement, the next stage would be the "handover" to the customer.

"...So we then got a scale-up inquiry from the customer." (TECHMAN-SC-0226)

“So we can get sign off from the customer, that it meets their specifications. But more importantly, we need to take that it from being a development product into a commercial product; at some a… certain point in that process, responsibility for the product is handed over to production.” (TECHMAN-SC-0226)

In the handover stage, BarrierCo presented the whole operation for using the new packaging. Detailed explanations of the technical aspects, machine settings and other aspects were provided for the customer’s production operator to ensure the customer understands them, is able to work on their own and is satisfied with the result. Accordingly, both BarrierCo and the customer decided to sign over the project with additional key reviews if necessary.

“And then it's so, so that's what we call the handover. So they have to sign, so production will be presenting… the technical lead in developing the product would present it to the internal customer.” (TECHMAN-SC-0226)

“They would say, okay, yes, yes, we understand that, we know that. We're happy. It will be signed over, but more importantly it will be signed over but with a key review.” (TECHMAN-SC-0226)

The next stage is the review, which is done annually or frequently to check if the product runs well in the customer's manufacturing system, still meets all the parameters, and whether any changes are needed at the technical and operational aspects. Similar reviews are also conducted between Company2 and the sales manager of the supplier.

“Actually on this date, let's review all of them. ... Okay, so let's do three production runs. And we sit down and review this year, all of the parameters are still great. That makes sense. Or have we had to change anything to get it resolved. But that also keeps everybody on track.” (TECHMAN-SC-0226)

"So we have then, the sales manager will be tasked with having a review. So we would have the internal review that a sales manager would also have to have a similar review with the customer. To make sure that okay." (TECHMAN-SC-0226)

In the review, BarrierCo would also reflect on to what extent the project had met the challenges, and any adjustments and resolutions made to deliver the product in order to meet the customer's expectations.

"We've done something. We've produced a product, it works to meet a challenge, we did something slightly different… and then deliver on their expectation really." (TECHMAN-SC-0226)

The product development process took several years. The progress is time-consuming and somewhat slow due to many trials and errors, the learning process and adaptations.

"Very, very slow basis and times." (TECHMAN-SC-0226)

"So we have a development process that we were building, so when we actually been building over our space the last 12 months…" (TECHMAN-SC-0226)

"So we sort of went on for probably a couple of years doing, doing this sporadically, so, very real here and there. And then obviously, the interest grew…" (TECHMAN-SC-0226)

"It may not work the first time and so we will have to learn and adapt as it's going. Because it's also a great deal of the time." (TECHMAN-SC-0226)

2. The mechanisms of co-innovation

2.1. Joint activities

The activities involving supplier and customer during product development were referred to in TECHMAN-SC-0226's explanation of the co-innovation process, resources and relationship. Joint activities mainly were the involvement in many trials and creating a feedback loop for improvement, in order to meet the customer's expectations.

"I think that the crucial, I would suggest the crucial part of it, is the trialling of the material." (TECHMAN-SC-0226)

"And then the next critical stage is production of the material… the trial and the feedback from the trial suggest in two instances the feedback initially for the customer in engaging what they want, but the feedback and from the trial itself is absolutely key." (TECHMAN-SC-0226)

Interactions with the supplier were with the technical people, for example visiting BarrierCo during the trials, giving close support and advice on material handling and troubleshooting with the BarrierCo team.

> *“So he was in our factory in two weeks watching and then trying to assist with and advise us on how to handle the materials, troubleshooting and looking at what we should be doing..." (TECHMAN-SC-0226)*

> *"I think that's probably the most interaction and the largest amount of input we've had from a supplier in terms of trying to resolve something." (TECHMAN-SC-0226)*

The feedback is highly essential in terms of understanding the scope of the project and listening to what customers actually want and setting the direction for the next step of product development. Accordingly, communication with the customer should not only focus on making sales.

> *"...that initial scoping out and understanding what I need is critical." (TECHMAN-SC-0226)*

> *"Where do you go to visit the customer already know what he want to sell them. But actually, the crucial bit it's listening to the customer, understanding what they actually want…" (TECHMAN-SC-0226)*

> *"Because without that crucial part, a piece of information, the next stages are very difficult to identify." (TECHMAN-SC-0226)*

2.2. Joint resources

The resources put into collaboration from each partner were mainly related to trial activities. At the supplier side, the resources were the technical people who visited BarrierCo during trials. The expertise of the supplier’s personnel was crucial to resolve problems during the trials at BarrierCo.

> *“One of the PLA suppliers... They sent a guy over from the US who was there, present for the trialling, for nearly two weeks.” (TECHMAN-SC-0226)*

At the BarrierCo side, the resources dedicated to the product development were a small team of five people dedicated to handling the project and committed to all development activities, detailed recording of the progress, problems and solutions, and commercialisation of the new product. Other resources were the machinery and machine time.

> *“…resource-wise we have. So we have technical lead on a project who would be really present at any production or trials. They would write what we call a, we have a DTI*

development, trial instruction… they would write that document… Then we'd also include operators, process managers…" (TECHMAN-SC-0226)

"We looked at it… Right, what do we need on this project tonight, We need a technical lead, we need a commercial lead." (TECHMAN-SC-0226)

From the customer side, the resources dedicated to the collaboration were the personnel, at least to run the trial at the customer's production facility and the machine time.

"But they'd be at least there be a technical involvement from their side. And then if it was something that's been trial on the machine, a bit, at least one or two to sort of operators or operatives or operations people…" (TECHMAN-SC-0226)

TECHMAN-SC-0226 reflected on the experience and highlighted that the critical resources in co-innovation are the technology, production facility and the machine time for the trials. Furthermore, the essence of resource sharing is a commitment from each partner.

"So, so I think from both sides from supplier onwards… technology and machinery resource, but also for the customer as well as their resource and their machine time." (TECHMAN-SC-0226)

"The best way of really, something that is really resource sharing means everyone can, so everyone commits..." (TECHMAN-SC-0226)

2.3. Relationship Management

The relationship with the supplier and customer was started as a business motive, to market the product, then followed with closer interaction in the form of technical involvement. The approach could be either from the supplier wanting to sell the product to BarrierCo, or the customer looking for sustainable packaging.

"So, we would have to think, Initially it'd be very much a commercial-led conversation and more sales, and then there would be technical involvement." (TECHMAN-SC-0226)

"Then customer side, it would be really like a, so the customers come to us they want this product. We've identified the product and we're going to sell them or supply to them." (TECHMAN-SC-0226)

TECHMAN-SC-0226 added the efforts made to maintain the relationship with the customer and supplier are to keep regular communication to ensure the timescales of the deliverables and meet the customer's requirements.

> *"…keeping close collaboration, a close contact, to ensure that there are no timescales and, and progress is communicated regularly." (TECHMAN-SC-0226)*

TECHMAN-SC-0226 indicated the importance of feedback from the customer, in which the relationship between partners should be underlined with honesty.

> *"Because without that crucial part, a piece of information… But also with that feedback, part of the feedback is being honest at both parties." (TECHMAN-SC-0226)*

2.4. Absorptive Capacity

Data about the absorptive capacity were embedded in participant TECHMAN-SC-0226's explanation about joint activities. Therefore, the data are either explicit or implicitly extracted based on the understanding of each element of the absorptive capacity. The information needed by BarrierCo to develop the product while also managing the collaboration includes: the objectives of the project, specifications, set of requirements such as the targeted barrier performance for different applications, working parameters, the tracked progress of the product development, problems and solutions, and changes needing to be made.

> *"We were given a set of not so much, sort of specifications, where they have a set of requirements that they would like to achieve. So some objectives, and they were barrier ranges for different products." (TECHMAN-SC-0226)*

> *"So actually, they've got all the parameters that they need to follow. So too, so for lamination you need to whether this be this coat plate, with these tension… on these mix." (TECHMAN-SC-0226)*

At the review stage of the product, BarrierCo also required the following information from the customer: whether the product is still used, any changes to the operation, and the following steps with the product This information was acquired throughout all the stages of co-innovation and carefully recorded, for example in a data sheet.

"To make sure that, okay, I was still as surprised as to you. Is it still working on your lines? Yeah. Has anything changed within your process? What, what are your next steps with it?" (TECHMAN-SC-0226)

The most crucial information is feedback from the customers, to understand what they want, develop and improve the product and ensure the delivery meets the customer's expectations.

"A standard procedure is this the trial and the feedback from the trial suggests in two instances the feedback initially for the customer in engaging what they want, but the feedback and from the trial itself is absolutely key." (TECHMAN-SC-0226)

Secondly, the activities and routines to obtain information and learn were acquired throughout all the stages of co-innovation and carefully recorded, for example in a data sheet, which aimed to keep each person involved in the project having the same understanding and working on track. The following quotes were from TECHMAN-SC-0226.

"That makes sense. Or have we had to change anything to get it resolved? But that also keeps everybody on track."

The important activities for learning are through a numbers of trials, internally and at the customer's plants. Through these activities both BarrierCo and the customer learn from different situations and outcomes, overcome errors and failures, then record them.

"…and they supplied so we then produce the laminates of the PLA 2 with the compostable adhesive and this and cellophane send it into the customer and it didn't work it failed. But the... say that the application was to be heat sealed to tray that had a lining on it." (TECHMAN-SC-0226)

"So we ran some trials within our process. So, and I think that the tray is lined with a polyester liner. And then we started heat sealing and…we heat sealed." (TECHMAN-SC-0226)

"So we took a number of different film options and I've carried out sort of compatibility testing, with the various rate films to the various trays to build up a greater knowledge." (TECHMAN-SC-0226)

During the trials at the customer's plant, BarrierCo gave advice on how to work with the product, and this is where BarrierCo and the customer also learned.

But more learning was from the customer's side because the applications of bioplastic packaging were very new to them.

> *"We go either into the customer and go into their facilities and take the trial films and run them on their machines. Yeah, look at how it's performing. Advise them if they're running outside of the parameters that we should be. So what we would do, because some of these films are very, very new, and we would also be learning about them." (TECHMAN-SC-0226)*

Another activity that promotes learning is a thorough recording of the project development that includes a highly rigid set of criteria and steps to be implemented. Recording is also implemented when sharing information with the customer, and having meetings internally or with the customers. These recording mechanisms were refined over time to improve the usefulness in capturing key learning and improvement, and then used to produce reports and handover documents. These recordings also helped to ensure BarrierCo had met the customer's specifications.

> *"So we have a development process that we were building... We have a very, very rigid set of criteria and steps that we follow. And to, to progress to the next stage, you have to ensure that you've completed some specific steps within that. And that keeps us on track, enables, ensures that we've captured information." (TECHMAN-SC-0226)*

> *"Some key points, we also share information with the customer…. we're capturing everything." (TECHMAN-SC-0226)*

> *"We actually had an internal meeting. We, because we were trying to build and refine our reporting mechanism, so actually capturing our key learnings or key, key learnings and areas that we… How we improved within that. So we're building that reports and that builds into what we call handover documents. So we can get sign off from the customer that it meets their specifications." (TECHMAN-SC-0226)*

Other than that, doing regular reviews and giving feedback were important to the product development. Feedback was obtained from the customer during trials, implementation, meetings and the review after the handover of the product.

> *"And we sit down and review this year, all of the parameters are still great." (TECHMAN-SC-0226)*

> *"This is critical for the success of any sound customer feedback received, then we have an internal review meeting…where we're going to review the customer feedback." (TECHMAN-SC-0226)*

The information obtained through activities was useful to build greater knowledge and understanding that facilitates product development and improvement actions. This information was made into parameters for different applications and challenges, and solutions for troubleshooting. The information was accumulated to produce data sheets that were useful for enhancing the product dimensions and would enable sales to different customers,

> *"From this information, the BarrierCo develops parameters based on the field experiences that can be used for different situations, solutions for different troubleshooting…" (TECHMAN-SC-0226)*

> *"And then we sort of tone and then from that point, we were then produce data sheets, which would enable us to sell the product or service other customers but with more dimensions. What we aren't clear on when we get, get into these situations with new customers, is that this is very much a development piece." (TECHMAN-SC-0226)*

Both BarrierCo and the customer significantly implemented the understanding and learning into actions and the product. Adaptation from the BarrierCo side is on the efforts made to improve the product to meet the customer requirements and from the customer side is a willingness to change the production process and follow the suggestions from BarrierCo in order to make the new packaging work. Therefore, the product is improved but the acceptance of the product is due to adaptation.

> *"It may not work the first time and so we will have to learn and adapt as it's going." (TECHMAN-SC-0226)*

> *"The technical lead in developing the product would present it to the internal customer… all the steps we've been through, all of the areas that we struggled with, but what we did took to understand to improve, to get the result. Within half the conversations with production, they would say, okay, yes, yes, we understand that, we know that, we're happy." (TECHMAN-SC-0226)*

> *"So they want, they want a new product that's, that is outside of their normal… they want to innovate they want to change." (TECHMAN-SC-0226)*

3. The outcomes of co-innovation

The outcome of co-innovation at BarrierCo is an advanced bioplastic packaging product range, such as clear film and metallised cellulose acetate film. These products have high barrier performance, anti fog, clarity and some other performances of conventional plastics. On the other hand, these products are bio based and/or biodegradable, widely recyclable, and some have home compostable options. Certification of the products was also an important addition to generate sales. All of these products were showcased in a packaging exhibition in the category of packaging innovation.

> *"…got a product…, our innovation, the result of innovation, is selling the… range of products we produce, which is bio based, is metallized cellulose acetate." (TECHMAN-SC-0226)*

> *"We've got some really… it's a certified product to sell." (TECHMAN-SC-0226)*

> *"So today, we have the product has been showcased on the packaging innovation stand, that's there right at the front. So that's a very, very good at, but we've also had lots of interest today because of that..." (TECHMAN-SC-0226)*

By using their successful experiences working with the previous customer, BarrierCo was quite confident in responding to a request for new applications, such as for fresh fish packaging. BarrierCo would expect the product could become a standard product and be widely used for the new industry.

> *"They want to use that product for smoked salmon, so we've got some trials that were as a result to them, I mean set up to, to test it out. And hopefully that will then become a standard product widely used in the wet salmon industry." (TECHMAN-SC-0226)*

4. The drivers and success factors

TECHMAN-SC-0226 explained the factor that leads to success is the capability to create a transformational product portfolio that then creates sales. The products were successfully accepted by customers, not only in specific industries but were also applicable to different industries.

> *"Actually have we, have we done something transformational, or have we added to our product portfolio... we've now got another product in our portfolio that we could sell." (TECHMAN-SC-0226)*

> *"Yes we, that can be added to and can be used in different productions. Okay, so in another industry or another area we can use these, that I said next challenges some of our products, how can we use them differently." (TECHMAN-SC-0226)*

In the plastic manufacturing industry, the market is the main driver and all actions head towards meeting the market demand. However, TECHMAN-SC-

0226 explained that the bioplastic packaging market is very immature, which means there is reluctance to change, and uncertainties were becoming a barrier at the moment.

> *"Yes... is driving. Yeah, the market it's not mature enough yet. Yeah, it's a very immature market and very young market." (TECHMAN-SC-0226)*

> *"Yeah, I think so... Yeah. And then that, and then I'll say it makes it difficult for its reluctance to, to really jump on board with it. But then that's where having a very, very good product that makes the brief... So, so breaks those barriers down, as I always suggest." (TECHMAN-SC-0226)*

5. The dynamics roles of customer and supplier

The dynamics of the co-innovation could be seen from the daily ups and downs explained by TECHMAN-SC-0226. The frustration when running the project was to meet the delivery date, because any delay would slow down the remaining steps. Accordingly, communication with the persons in charge at the customer's side is crucial to handle this situation.

> *"So we're certainly so as the plan slips, you know, do because that can cause some frustration. If we missed our delivery date today… they're expecting the film to come to arrive for a certain set of trials. And actually, we're going to slow that down." (TECHMAN-SC-0226)*

> *"It looked like they were going to miss their delivery. So actually we set up a conference call, spoke with it." (TECHMAN-SC-0226)*

Other challenges were related to openness from the customer's side, in terms of sharing information and willingness to change. These were exemplified by TECHMAN-SC-0226's experiences when running the trial at the customer's plant. TECHMAN-SC-0226 found that the customer did not want the BarrierCo personnel to be present when running production. Because of this, BarrierCo could not directly observe the real conditions of the trial and became dependent on the report from the customer team. As a result, this constrained BarrierCo from being directly engaged with the problem and potentially limited the understanding of any problems during the trial operation. This situation also raised concern on the BarrierCo side, regarding whether there were real problems in the operation or if it was merely the customer's operator being reluctant to change.

“Some people, some customers don't want us to be present when they're converting the film... They're very secretive about what doing.” (TECHMAN-SC-0226)

“If the operators or there's some reluctance they don't really want to change. We're not visible, we're not present to watch, observe how it's perform, you know, we have if we get a report back is not workede don't know if it's the product or reluctance from their side or something they're doing that stopped it working." (TECHMAN-SC-0226)

In the co-innovation, contributions from each partner that were significant to the product development were clearly noted by TECHMAN-SC-0226. First, on the supplier side, their contribution is the biopolymer used as the raw material.

"...from the supplier side, they've already developed the product and they want to sell...” (TECHMAN-SC-0226)

"…their product that you've already got." (TECHMAN-SC-0226)

The contribution of BarrierCo in the co-innovation is their technology and expertise that improves the functionality of the bioplastics, as BarrierCo does not actually produce the plastic.

"So we don't produce the plastic itself but what we do is, we add enhancements to the bioplastics to improve their functionality." (TECHMAN-SC-0226)

“So we need you to, so our contribution would be our technology and their expertise." (TECHMAN-SC-0226)

In order to do that, the customer plays an important role to share the relevant information about their requirements that enables BarrierCo to develop the product that works for the customer.

“Involvement would be really getting all of the relevant information about the product or the film that they want to send in. All of the… so which would enable us to raise coats internally and then enable us to get the film in.” (TECHMAN-SC-0226)

The contributions noted explicitly by TECHMAN-SC-0226, from the biopolymer producer and BarrierCo were the technology and machinery, and at the customer were the machine time and operational resources. However, the essential contribution from the customer is a willingness to change in order to be able to use the new product.

“So, so I think from both sides from supplier onwards, so, happy contributions, we said technology and machinery resources, but also for the customer as well as their resources and their, their machine time.” (TECHMAN-SC-0226)

“And really the customer, as far as the customer’s contribution to that, and this is a willingness to change. So they want, they want a new product that's, that is outside of

their normal scope... so this is a massive sort of step change. So there's got to be a big appetite for them to want to change.” (TECHMAN-SC-0226)

Appendix F-6: Converter case: FoodpackCo

FoodpackCo is a packaging manufacturer, established in 1993 in the UK. FoodpackCo is a specialist in flexible packaging and printed tapes, it manufactures shrink sleeves, self adhesive labels, die cut lids for applications in various industries. Its main the main markets are the food and beverage industry, supplement and nutritional products, cosmetics and beauty products. Besides producing packaging, FoodpackCo also supplies machinery to customers for shrink sleeve applications on packaging bottles, labeling, taping, packaging and several others.

Currently, FoodpackCo does not offer bioplastic packaging product range. But about three years ago FoodpackCo had developed bioplastic packaging by collaborating with suppliers. Although in the end FoodpackCo did not continue the bioplastic packaging development, the FoodpackCo case showed the mechanism of co-innovation between FoodpackCo as a converter with biopolymer producer and several other suppliers. In addition, FoodpackCo case showed important issues that lead to discontinuation of the development project.

1. The process of co-innovation

FoodpackCo developed bioplastic packaging about three to four years ago driven by positive press releases and reviews about the potential future of saw information about bioplastics, particularly PLA in the market. Therefore the company was interested in developing bioplastic shrink sleeves, the plastic label attached to a beverage bottle or packaging, to keep up with the competition. Subsequently, FoodpackCo approached biopolymer producer to enquire and test the material.

> *"Because the press release was saying the competition is launching. So we tested, we tested the material. And when you're making the test, then we meet the supplier." (ACCMAN-SC-0304)*

There were many problems during trials with the supplier, and the end product did not meet expectations. The main problem was the difficulty of applying bioplastic material to the existing manufacturing process. ACCMAN-SC-0304 explained that the nature of PLA material was different from the conventional plastics; this made printing the label became more difficult and seaming using adhesive solvent took longer. Therefore, FoodpackCo further observed the market for potential demand. However, after FoodpackCo had participated in several packaging exhibitions, there was no sign of interest from the customers. Therefore, FoodpackCo did not continue the project.

> *"We waited to see if there was a demand. And there was there was no… we did several exhibitions. Nobody was really asking." (ACCMAN-SC-0304)*

Interestingly, FoodpackCo did not involve the product manufacturers in co-innovation. FoodpackCo collaborated with the suppliers to develop viable products and would later show the product manufacturer if they got something interesting or a good result. To test whether the product worked at the customer, FoodpackCo either did an in-house trial because FoodpackCo had similar equipment as the customer or tested the material at the machine supplier that sells similar equipment. Thus FoodpackCo did not involve the customer for testing the material at the early development.

> *"We tested to see if we have something interesting to show the product manufacturer …the company I worked for, had had a Shrink Tunnel. So we could test …we didn't have to go to the customer." (ACCMAN-SC-0304)*

2. The mechanisms of co-innovation

2.1. Joint activities

The joint activities were mainly related to the prototype trial on the existing production machine. The trials aimed to find out the extent to which the bioplastic material could be rolled out on the customer's production machine and were done at FoodpackCo facilities because the company had machines like those of the customer. However, when FoodpackCo did not have the necessary facilities, FoodpackCo would trial at a machine supplier who sells machines like those of the customer, instead of involving the customer.

> *"We sold the equipment; the equipment was made in Italy. So we could send the test to Italy to test rather than the product manufacturer." (ACCMAN-SC-0304)*

During the trial, FoodpackCo and the suppliers discussed the required adjustments, such as ink or other material adjustments. During the trial, suppliers also provided support by sending a technician to FoodpackCo's site or providing solutions for the material to work at the existing conversion process. ACCMAN-SC-0304 saw that bioplastic material at that time, about three years ago, had not yet developed enough to suit the requirement of more complex packaging.

> *"Generally, you have the discussion before if you need to change something if you need to change the ink." (ACCMAN-SC-0304)*

2.2. Joint resources:

ACCMAN-SC-0304 emphasised that the essence of bioplastic development projects was doing the same process using new materials. This reflects the importance of bioplastic material to be processed using the customer's existing manufacturing system; hence it is also important that co-innovation enables the bioplastic to work in the same process as the conventional plastic packaging.

> *"You don't need any new. So, all the development work is to do the same process with a different material." (ACCMAN-SC-0304)*

All partners were contributing resources for trial by using the existing resources. Supplier provided raw material without charge, technical support and sent a technician to give the required assistance during the trial at FoodpackCo's site. On the other hand, FoodpackCo contributed the machine time that included the production overhead cost as they sacrifice the normal production hours. Moreover, ACCMAN-SC-0304 considered these costs were more substantial than the raw material at the supplier's expense.

"But the big cost is here. The printing the printing cost is more than the is more than the material cost." (ACCMAN-SC-0304)

2.3. Relationship management

Co-innovation in FoodpackCo was carried out with several suppliers, PLA suppliers, printers, ink and machine suppliers. FoodpackCo conducted a series of tests, for example, with the machine suppliers that sell machines like those of customers. FoodpackCo did not involve the customer in the product development and would show the product manufacturer after having developed an interesting offering.

"We don't involve the product we didn't involve the product manufacturer. We tested to see if we have something interesting to show the product manufacturer." (ACCMAN-SC-0304)

ACCMAN-SC-0304 added that there was contact between suppliers to find out to what extent new packaging materials would work in existing systems. For example, the film suppliers contacted the converter or printing company and independent the ink suppliers to discuss the suitable ink to ensure the bioplastic films could be printed.

"The film supplier is talking to the ink company. Because they know, they know the material has to be printed. So they independently talking to the ink company." (ACCMAN-SC-0304)

2.4. Absorptive capacity

ACCMAN-SC-0304 explained the information acquired in the co-innovation. First, the market information and positive press about bioplastic raised the interest and encouraged FoodpackCo to further enquiry with the supplier. The media and news from the external present a potential future of bioplastics had led FoodpackCo to develop packaging using the new material to stay competitive.

"We saw market information about the PLA for shrink sleeves. And we thought we should look at look at this material to keep up with the competition." (ACCMAN-SC-0304)

During co-innovation, FoodpackCo and the supplier learned from trials about the new bioplastic material and its application on the existing production machine. The FoodpackCo as the customer gave feedback to the biopolymer producer about problems during the trial and the product outcome, which was not as expected, then asked the biopolymer producer to improve the material.

> *"We give the feedback to the producer. One, the clarity is not so good, the printing is not as good. And the shrink was not as good… we said to them, we need a better, better material." (ACCMAN-SC-0304)*

Co-innovation with the supplier had facilitated a further understanding of bioplastic packaging. ACCMAN-SC-0304 explained that at that time, bioplastic packaging was being developed but not enough to cope with FoodpackCo complex packaging conversion process nor deliver the expected outcome. Problems like longer processing time, printing result, seaming and clarity of the shrink sleeves, including the price had been added to the list of consideration for not to continue the development.

> *"We think (the bioplastic) was being developed but not enough for our product." (ACCMAN-SC-0304)*

In addition, ACCMAN-SC-0304 stated that bioplastic packaging was not commercially acceptable, although it was suitable for marketing. ACCMAN-SC-0304 exemplified that even though bioplastic packaging was used for the 2012 London Summer Olympics and was well-reviewed, it was not followed by a substantial commercial demand. ACCMAN-SC-0304 added an example at another company that also developed bioplastic packaging around two or three years ago and had to stopped the development as there was no demand for bioplastic packaging.

> *"They developed a product …ready to to sell it to the customer. But no demand no demand. So, three years ago, two to three years ago, they they stopped." (ACCMAN-SC-0304)*

Based on the interview with ACCMAN-SC-0304, it can be seen that FoodpackCo learned about the development state of bioplastic material and to what extent it worked to meet the company's expectation and most importantly, the bioplastic packaging did not get desired response from the market. These facts were implemented to the decision for continuation or setting up the priority of the product development, which will strongly consider the existing of market demand.

3. The outcomes of co-innovation

FoodpackCo co-innovation with suppliers was carried out about three years ago and was not successful due to lack of market interest and technical obstacles. At that time, bioplastics were new and not yet developed as today. ACCMAN-SC-0304 saw the bioplastics worked for simple packaging, but the technology was not enough to work with complex packagings, such as shrink sleeves or layered packaging.

> *"We thought that the product was very new and not developed. So it's okay for simple packaging, but not for complicated packaging." (ACCMAN-SC-0304)*

ACCMAN-SC-0304 briefly explained the complexities and constraints of bioplastic applications for complex packagings, such as shrink sleeves and food containers with a sealable lid. For shrink sleeves, bioplastic labels must be printed and attached to the bottle, and at that time the bioplastic could not print easily using the same process for conventional plastics. Next, the printed shrink sleeves must be attached to the bottle or primary packaging. In this process, the shrink sleeve moved and shrank when applied with heat. Unfortunately, the bioplastic took longer to process, and the results were not as expected. Also, when developing a lidding film for bioplastic containers, ideally, all of the packaging components were biodegradable; hence the lid needs to be layered with also biodegradable coatings to make it stick to the container. However, FoodpackCo had not used a biodegradable coating on the product.

> *"There is a material available in PLA but the shrink characteristic was not so good." (ACCMAN-SC-0304)*

At that time, FoodpackCo had not yet succeeded in developing bioplastic packaging, but based on that experience, ACCMAN-SC-0304 shared some crucial points in developing bioplastic packaging. First, the development of bioplastic materials must pay attention to the variety of packaging features needed, the complexity of the processing and application in existing systems in different industries. For example, flexible film for beverage packaging shrink sleeves is more complicated to process as it has to shrink in the application, while flexible film for sandwich packaging is simpler to process and easier to attach to the sandwich box. In addition, packagings with high barrier property are crucial for managing the fresh produce or food product shelf-life, but this property is not relevant for shrink sleeves, which indirectly contacting the product or known as secondary packaging.

> *"In the beverage industry…the shrink sleeve is not primary packaging …so the barrier property is not relevant. But in the food industry, primary, you need the barrier properties." (ACCMAN-SC-0304)*

ACCMAN-SC-0304 added the need to improve biodegradability of bioplastic packagings, which not only work in industrial compostable but also home compostable. Another option is to improve biodegradability at landfill, for example, when trapped without oxygen, moisture or facing different conditions at landfill.

4. The drivers and success factors

ACCMAN-SC-0304 emphasised the essence of bioplastic development projects is doing the same process using new materials. Again, this reflects the importance of bioplastic to be processed using the customer's existing manufacturing system; hence, co-innovation should enable the bioplastic to work in the same process or system.

> *"All the development work is is to do the same process with a different material. The new material/packaing works in the customer's existing system." (ACCMAN-SC-0304)*

Based on FoodpackCo's experience, the price factor is a driver for customers to use bioplastic. ACCMAN-SC-0304 explained that if bioplastics do not work and the price is high, the development will be slow. The price of bioplastic packaging was double that of conventional plastics, and this is a concern for the customers, product manufacturers, retailers and end-users, to adopt or use bioplastic packaging. ACCMAN-SC-0304 believed that an acceptable price is a driver to push the demand, which eventually push product development.

> *"If it doesn't work and the price is high… the development is slow. But if it doesn't work, but the price is low, yeah. People keep pushing the demand, pushing the development." (ACCMAN-SC-0304)*

5. The dynamic roles of customer and supplier

ACCMAN-SC-0304 explained the position of FoodpackCo, which lies in between the product manufacturer as the customer and the suppliers that included biopolymer producer, machine and ink suppliers. In this position, FoodpackCo, as a converter became the supplier and customer at the same time.

> *"We are the converter but we are also the consumer." (ACCMAN-SC-0304)*

One of the dynamics with the supplier in co-innovation was shown when dealing with complexity in packaging manufacturing. Bioplastic was considered a new material, of which the characteristics were unable to work directly on existing production systems, as problems occurred at different processing points such as printing and machine-ability after printing. Faced with these problems, the PLA producer explained that their material worked in other markets and will work to resolve this issue. However, as the project was finally stopped, ACCMAN-SC-0304 did not explain to what extent these issues were resolved.

> *"They said for in other markets is is working but maybe every printer is different, different process, but they will they will work on it." (ACCMAN-SC-0304)*

Appendix F-7: Converter case: BiopackCo

This company manufactures biodegradable, compostable & water-soluble plastics bioplastic packaging, and it has operated in the UK since 2007. This company focuses on manufacturing various bioplastics and does not manufacture conventional plastic. This company also provides technical assistance and consultancy related to product design, convertion processes, running trials and regulation and testing advice.

BiopackCo products are made from several types of bioplastic such as PVOH, PLA, cellulose-based and green PE from sugarcane. Water-soluble is one of the advanced features of BiopackCo products. Water-soluble packaging is made from PVOH and can be used for non-food bags and sachets, for example, laundry bags, liquid detergent sachets, horticultural products, and others. In addition, compostable products have been developed to conform to EN13432, and some products can be home compostable. This compostable product is used for various purposes, including for fresh food and produce, such as transparent wrapping film, fruit net, rigid tray and bubble wrap. Some compostable products have an excellent performance like conventional packagings, such as high gloss and transparency, and high stretch; for example, the padded envelope is made with an FSC paper outer and bubble wrap inner, which is more durable than most similar products made from conventional plastics.

1. The process of co-innovation

Before establishing a co-innovation agreement, the customer approached to BiopackCo to inquire and explore the possibility of using the available bioplastic packaging product range or developing new bioplastic packaging with BiopackCo. Then all parties conducted an initial assessment, in which the customer explained the list of requested product specifications, which were usually made based on conventional plastic standards. BiopackCo considered how far BiopackCo could fulfil the request based on a list of requests.

BiopackCo also used questionnaires in the assessment to get customers' detailed specifications of existing production machines, requested packaging specifications, and other technical aspects of packaging.

The development of new products at BiopackCo always started with a trial on a small scale and then gradually scaled up to s.d. to full-scale production.

> *"Some A4 sheet to roll of film to 10 rolls of film to a pallet, and then you work your way up." (DIR-SC-0515)*

Trials were conducted following the trial plan agreed at the beginning with the customer. In developing a prototype, or called the "sampling stage" by DIR-SC-0515, BiopackCo sent some samples or data to the customer to provide the initial idea of the product to be developed.

> *"We proceed with the trial according to the plan... you only sending out samples and data to the customer, if they're not there so they can assess the result." (DIR-SC-0515)*

Instead, the customer gave feedback to BiopackCo about the converting process, material that worked well on the machine and determined the area of further development. Thus, BiopackCo was able to find out the needs and expectations of customers. DIR-SC-0515 explained that the trial at the customer's production facility tends to take place at a later stage.

An essential stage of co-innovation is the initial assessment, where BiopackCo and the customer assess the availability of converting equipment, communicate the expectations of each party and estimate the packaging price before starting the development project. For BiopackCo, the crucial part of this stage was to assess the availability of the existing converting equipment converter and product manufacturer that would suit the unique character of bioplastic material. DIR-SC-0515 explained that Bioplastics could not be processed on all machines; therefore, the assessment of existing equipment determines the success of bioplastic converted to finished goods, which also determines the success of the product development project with the customer.

> *"How the material is going to be converted, it depends on the bioplastic. Some are easier than others, but you always have to be aware of the equipment that's going to take the bioplastic from raw material form through to the finish goods." (DIR-SC-0515)*

On the other hand, the customer gave feedback to BiopackCo about the converting process, material that worked well on the machine and determined further development areas. Thus, BiopackCo was able to find out the needs and expectations of customers. DIR-SC-0515 explained that the trial at the customer's production facility tended to take place at a later stage.

Co-innovation for bioplastic packaging with customers is a long process; DIR-SC-0515 gave an example of one project that has been running for more than five years. During co-innovation, many problems were discovered, and the processes were never straightforward. Therefore, BiopackCo had to resolve these issues, make continuous improvements to deliver what the customers wanted.

2. The mechanisms of co-innovation

2.1. Joint activities

Joint activities with suppliers and customers at BiopackCo were mostly trial products. The trial process was carried out many times, and many problems occurred during trials. The involvement of suppliers and customers during the trial includes testing on a small scale and full production scale at the customer's plant on the later stage agreed in the trial plan.

During the trial, there were many feedback loops. In the sampling stage, BiopackCo sends product samples and data to the customer for review. Customers must provide feedback to resolve issues and improvements to BiopackCo products, and if necessary, BiopackCo submitted this feedback to biopolymer producers. The feedback was usually related to an assessment of the material which can be appropriately processed and whether it has or has not performed as expected, and at which the production process the bioplastic packaging cannot be appropriately processed.

> *"It doesn't quite go how you expect or how you plan or something that's slightly different than what you started… The materials aren't quite doing what they should do, or they're*

not performing the way you want, or the process conditions aren't quite right." (DIR-SC-0515)

A trial was usually conducted at full production at the customer's production facility at the later product development stage. On this occasion, the customer and sometimes the supplier were present during the trial. The presence of all parties was a good thing compared to communication via email and reviewing the results of the trial because the customer could see directly how bioplastic packaging worked on their machines and when problems occurred, the converter and biopolymer producers could give advice and solutions according to the conditions they find immediately.

"You can go and do trials at the customer's premises. Yeah, that's quite often a good thing to do. So they could have seen themselves how it works." (DIR-SC-0515)

"If you're making the product and for some reason, you say that the material is behaving properly or it's not doing what it wanted to do, the supplier can come in and, you know, advise, that is also a good thing because actually, they can see what's happening." (DIR-SC-0515)

In the co-innovation, biopolymer producer, converter and product manufacturer were active in problem-solving and improvement. Problems were usually related to how the material could work at the existing production facility. Faced with this, the converter and biopolymer producer as the suppliers provided solutions to resolve these issues by adjusting existing production processes in the converter and product manufacturer or adjusting the material at the biopolymer producer. As the customers product manufacturers have shown mutual adaptations, such as to some extent willing to accept the price of bioplastic packaging, which is more expensive and the performance, which is not as good as conventional plastic.

2.2. Joint resources

In the BiopackCo case, joint resources with partners in co-innovation predominantly are the resources contributed to the trial at the converter and product manufacturer's plant, such as raw materials, people, equipment. Biopolymer producer provided the raw material and did not charge the raw material for sample trials and full-scale trials. While the resources from the customer were quite limited, most customers tend to demand the desired product to be delivered. However, other customers contribute access to their analysis equipment for testing.

> *"Supply of supplies and material… you try and get them to supply it as a sample without charge." (DIR-SC-0515)*

> *"Resources from the customer? Hmm. Quite often not. They'll go into results." (DIR-SC-0515)*

The trial used the existing facilities as the bioplastic packaging must be able to run in the existing production equipment. The trial in the production facility was conducted at the BiopackCo and product manufacturer's site; therefore, both bear the costs of machine time for this operation, including operators who work during the trial.

> *"You can joint resources, but people won't move equipment from one place to another. So you will have to use the resources that are in each people… that's kind of critical." (DIR-SC-0515)*

The availability of equipment that can work with bioplastic is critical in co-innovation, but the situation could get complicated because many equipment specifications were needed and varies depending on the type of bioplastic packaging being developed. Different types of packaging require different converting processes and equipment, for example, multilayer extruders for flexible films and injection moulding for others. Therefore, small scale trials for different packaging require different equipment. Sometimes the availability of equipment from partners was limited; hence BiopackCo also worked with third parties, such as universities that have the required set of pilot line equipment.

> *"We basically outsource theirs (equipment) to run trials there. We have done it elsewhere in the past… It's very expensive to invest in small equipment yourself… It's such a huge variation. Difficult to have everything." (DIR-SC-0515)*

Based on the DIR-SC-0515 experience, the converter does not want to invest in a new prime machine, for example, extruder, moulder or new press, because it requires significant financial capital. The DIR-SC-0515 emphasised that the converter does not want to change an existing prime machine. However, the converter is willing to modify existing equipment by investing in new toolings, such as a dye bowl or stamp that can work better for bioplastic materials.

> *"They may have to invest in new tooling. So a different dye bowl… the main machine the prime machine is important that they don't have to change that." (DIR-SC-0515)*

DIR-SC-0515 explained that at the moment, there was no share investment to build shared facilities. Significant financial capital is needed to build new facilities, and players with large financial capital in large-scale development projects would be involved. However, the DIR-SC-0515 added that partners share non-financial resources in the form of expertise in bioplastic technology and share information that is important for product development.

2.3. Relationship management

DIR-SC-0515 considered the relationship between partners in co-innovation was quite close because there was much discussion in product development, and each partner shared confidential information. The relationship among partners in the co-innovation showed interdependencies, which linked to their role as suppliers and customers in the supply chain.

> *"There is always there always is always quite a lot of discussion that goes. So it's quite a close relationship." (DIR-SC-0515)*

According to DIR-SC-0515, some customers are willing to work together to face problems during product development, but several others are quite demanding.

Relationship management conducted by BiopackCo can be seen from the efforts to build cooperative commitment and agreements with suppliers and customers at the beginning of the project. DIR-SC-0515 explained a pleasant climate of cooperation could be built if everybody was committed to the project, developed the same understanding, had collective objective goals together, had confidence in the project and was willing to follow the standard development process. During the project, each partner must understand the conditions and problems in the project, follow the project's development, and be supportive.

> *"If you can get people to work together and fully buy into the project, to begin with, and be supportive rather than destructive." (DIR-SC-0515)*

At the beginning of the project, excellent communication with customers was needed to educate users and manage expectations. Customers needed to know the bioplastic packaging in the market and which one is available to meet the customer's production capacity, specific characteristics of bioplastic packaging and the extent to which bioplastic packaging can be developed as conventional plastic. DIR-SC-0515 exemplifies the product seaweed packaging found in the media, but unfortunately, the product is not yet commercially available.

> *"Making sure people understand what they can get... Managing what, what's available, what they can expect." (DIR-SC-0515)*

According to DIR-SC-0515, a confidentiality agreement is needed in a new product development project because each partner must share specific and not widely available information. This agreement also regulates the use of information and intellectual properties generated from the project.

2.4. Absorptive capacity

During the interview, DIR-SC-0515 explained how BiopackCo retrieved information and knowledge from the externals, especially suppliers and customers, then processed and exploited that knowledge. Information from the customers needed for product development was the detailed packaging specifications requested by the customer. Furthermore, BiopackCo connected this information with detailed material specification information from suppliers such as technical properties, food contact approval, biodegradability, degradation process, and degradation time.

> *"From the supplier, what you need is the data on the raw material… By acquiring all that information, then you can put the two together and see what's suitable and what isn't." (DIR-SC-0515)*

Further information from the customer was the critical features of the customer's manufacturing process and equipment. These information were acquired through a standard questionnaire, which helps systematically gather information to assess whether the existing equipment is suitable for converting the targeted bioplastics material and collect the detailed packaging specifications, such as transparency or other technical details. Furthermore, feedback from the customer was also crucial to guide further improvement.

> *"We use a questionnaire when we're assessing equipment quite often … whether a bioplastic will run on a particular piece of equipment.... We've done it for specifications as well before." (DIR-SC-0515)*

BiopackCo also considered information about the existing product or development project from the internet, media and other sources. The information about the previous similar products or projects facilitated knowledge acquisition and learning for BiopackCo.

DIR-SC-0515 explained that the bioplastic developed was not considered an invention. BiopackCo learned, modified and improved new products from the previous projects or products, for example, learned how the similar product was processed, what the materials are and how to use it, then modified and improve it.

> *"So you don't want to go around and reinvent the wheel, you just want to know if it's been done before, but they need to be done in a slightly different way." (DIR-SC-0515)*

Based on the DIR-SC-0515 explanation, BiopackCo continuously learns from many trials and implementations. BiopackCo learned how to process bioplastic material in the converting equipment and applying bioplastic packaging to the main product. DIR-SC-0515 also mentioned the importance of the customer and supplier being present during the trial because all those present could see firsthand, learn and understand what was happening. Each partner communicated directly about the problems and trial results and then worked through them. This mechanism was much better than evaluating the trial results based on the samples sent and communicating indirectly via email.

BiopackCo developed a new understanding from interaction with the supplier and customer during co-innovation. Most importantly, BiopackCo acquired accumulated experience and learning to meet the customer requirement, detailed specifications, as agreed at the beginning of the project. For example, BiopackCo learned how to create a bin bag that meets a very high specification requested by the customer, which was considered quite hard for other compostable packagings to achieve.

> *"This company has acquired the Rolls Royce of bin bags… And trying to get a compostable material to perform those standards can be quite difficult." (DIR-SC-0515)*

In addition, BiopackCo accumulated further understanding of various parameters that includes suitable equipment for each bioplastic material and various material characteristics, such as limits of the bioplastic material, the extent to which the bioplastic material and the packaging would perform or which materials were more manageable to process. BiopackCo also learned steps of the product development, target to be achieved, and how to proceed to further development.

The knowledge developed from co-innovation was implemented for the next product development to improve the existing BiopackCo product and serve a broader customer. DIR-SC-0515 explained that the bioplastic developed was a novel invention but more of an improvement from the previous projects.

3. The outcomes of co-innovation

Through co-innovation, BiopackCo is able to make a variety of packaging, ranging from simple films, bubble wrap to complex, layered bioplastic packaging with superior performance. BiopackCo products are claimed to have excellent features depending on the type of product, such as high gloss and transparency bioplastic films that are also suitable for use with constant heat or impulse sealing, high stretch fruit netting with good welding properties, mechanical properties similar to conventional plastics. Co-innovation not only spurs BiopackCo to develop bioplastic performance similar to conventional plastic but also is easily processed by the customer's existing standard equipment.

DIR-SC-0515 explained that ideal bioplastic packaging could not be generalised because the application varies depending on its biodegradability and compostability. DIR-SC-0515 explained that biodegradable or compostable bioplastic packaging should be focused on single-use packaging applications, which cannot be reused or recycled because of contamination. For example, food service items, such as food trays, cutlery, and coffee cups, cannot be recycled because they are contaminated with food scraps and will most likely end up in landfills. Furthermore, bioplastic packagings from renewable materials that are not biodegradable should be appropriate for a durable and recyclable application.

> *"…the biodegradable or compostable ones. Then you need to concentrate on single-use plastics and also plastics which can't be reused or recycled. So basically contaminated ones." (DIR-SC-0515)*

However, the final price is still a concern as the price of bioplastic packaging was around three times the regular packaging. On top of that, DIR-SC-0515 explained that bioplastic packaging needs to be developed in a reasonable price range because the market can not simply accept the current price.

> *"you need to come in within a reasonable price range, you don't want to be fastly expensive is going to be 10 times the price of the normal material, then you won't stand the chance to acceptable." (DIR-SC-0515)*

4. The drivers and success factors

Based on the experience of DIR-SC-0515, bioplastic materials must work well with the existing converting system in co-innovation. Although bioplastic packaging has different characteristics from conventional plastics, it is impossible to design new prime equipment, especially for bioplastics, because it requires substantial capital to build new full-scale production equipment. Furthermore, most customers can accept the minimum change in the existing system, for example, buying dye stamps, printing plates or other supporting tools, but the customer does not want any change in the existing prime equipment.

> *"The main focus is to try and get a bioplastic to run on existing equipment rather than having to design a new piece of equipment. That really doesn't work." (DIR-SC-0515)*

Accordingly, bioplastic material must also be developed for easy use in the customer production process.

> *"The key to success is producing something that the consumer can easily use it and easily understand. So you don't want to make anything that's too difficult to deal with at the end of the day." (DIR-SC-0515)*

DIR-SC-0515 added the importance of willingness from the customer to collaborate during co-innovation, which meant being understanding of the limitations of bioplastic problems during co-innovation and working towards resolutions. However, sometimes customers want to develop bioplastic packaging just because they want to show their contribution to the environment.

> *"It ticks their environmental box. Really, they're not that keen about doing it, rather not have it at all." (DIR-SC-0515)*

DIR-SC-0515 also added that at the moment general public appreciates and is interested in using bioplastic packaging, hence becoming a driver for further development. However, supermarkets and retailers are less interested in bioplastic packaging because the price is higher than conventional packaging and some limitation makes it more challenging to work with.

> *"the general public… willingly accept bioplastic… The supermarket, they won't because it costs them more and it's more difficult… They just don't fit into what they want to do." (DIR-SC-0515)*

5. The dynamic roles of customer and supplier

The role of each partner in co-innovation is related to the position in the supply chain. BiopackCo is a converter positioned in the middle between biopolymer producer and product manufacturer. DIR-SC-0515 emphasised that BiopackCo role as a connecter was to fit in between the available biopolymer material from the supplier with the product manufacturer wants, which might be pretty challenging. DIR-SC-0515 explained that often a mismatch as a biopolymer producer did not know the converter and product manufacturer wants. On the other side, the product manufacturer did not know what commercially available bioplastics would meet their needs, expectations and production capacity.

> *"The resin manufacturers don't always know what converters want or what the customer wants. From the customer, they don't know what's available and how to get that. So really we try to fit in between." (DIR-SC-0515)*

DIR-SC-0515 explained the role of biopolymer producer as the supplier was to provide a sample of material for conversion trials, advise to resolve problems and adjust the material as required. The product manufacturer's role was to provide feedback, willing to cooperate throughout the co-innovation process to facilitate suppliers learning what would work for the customer and make improvements to deliver the result.

> *"The customer has to give you reasonable feedback on what, what what you sent and we can work in between." (DIR-SC-0515)*

Finally, DIR-SC-0515 mentioned that all partners should take a cooperative and supportive approach to resolve issues together.

Appendix F-8: Product manufacturer case: DrinkCo

DrinkCo is a multinational producer of food and beverage products. The company operates in various countries in Europe, America, Africa and Asia Pacific, one of which is in Indonesia. DrinkCo is one of the market leaders for food and beverage products in Indonesia, with superior products such as bottled drinking water, fresh milk and essential nutrition. DrinkCo is a company that has a commitment to sustainable development and a circular economy, which is shown in its vision of realising human health, protecting the environment for business sustainability, as well as sustainability of the surrounding community and future generation.

DrinkCo sets a roadmap as a form of commitment to use packaging that is more environmentally friendly, including setting a target in 2025 to have 100% recycled packaging, using 50% recycled PET (rPET). Another commitment is to be able to recover more than they produce and, in the long run, to move towards a zero net carbon, which is aligned with the 2050 Europe climate ambition. And currently, DrinkCo also has the initiative to develop bioplastics in collaboration with several start-ups in the Netherlands and the US.

As a product manufacturer, DrinkCo's position is as a customer, and ongoing co-innovation is with a biopolymer producer. The ongoing bioplastic development project is the development of PEF, or Polyethylene Furanoate, a biopolymer derived from non-fossil-based materials, such as plant-based, non-food biomass, and agri-waste. The PEF developed is expected to have equal quality with virgin polymer and will be used as a raw material for packaging to replace PET-based packaging such as bottled water. Later, the packaging made from PEF is not only degradable but also recyclable so that it does not contaminate the existing recycling streams. Apart from PEF, DrinkCo is also developing bioplastic packaging from PLA, but it will not be used for products in Indonesia.

1. The process of co-innovation

SUSDIR-C-1106 explained the objective of the development was to acquire 100% access to bioplastic technology; therefore, a dedicated team, which consisted of research and innovation, as well as sourcing, was first established to handle the development project. This team worked to search for and understand the bioplastic technology available in the market, then made the collaborative approach to several potential partners.

> *"... the team tries to understand the available technology ... what's available in the market ... our target is to have 100 per cent access to the material ..." (SUSDIR-C-1106.Quo1)*

Furthermore, DrinkCo conducted an initial assessment of the potential development of bioplastic materials with several partners, namely start-up companies in the US and Europe. SUSDIR-C-1106 explained that partner selection is a crucial stage where DrinkCo will determine collaboration partners based on assessment criteria for scalability, readiness, cost, investment in the project, the right to access and use the material, compliance to various regulations and market potential of this material in the future. In discussing access rights and use of materials, DrinkCo must see the extent to which the bioplastic material can be used in certain geographies or products, the potential for the material being developed will be widely accessed by other companies, including competitors and ensure compliance with applicable regulations such as anti-monopoly regulations.

> *"There are several start-up options, which are mostly in the US, there are several Europeans." (SUSDIR-C-1106.Quo2)*

> *"We have assessment criteria, especially in terms of what it is called the scalability, from the readiness, from the material, the cost." (SUSDIR-C-1106.Quo2)*

> *"Discussion related to ...the term of usage of the material once it can be scaled-up ...in certain geographies or certain products, of course, everyone must also ensure that we later have to comply with competition, anti-monopoly law and so on." (SUSDIR-C-1106.Quo3)*

The next stage was to develop an initial product prototype, which involves a lot of trials with partners. Products are developed on a lab-scale and trial plans made from the smallest scale, for example, 10 to 100 kg. If achieving the agreed deliverables were successful, the development would be gradually increased to a larger scale, for example, 5,000 tons to be processed at the pilot plant. SUSDIR-C-1106 added that the development process was currently still on a lab scale. The development of this material was quite long, approximately between 3 and 5 years, which were broken down into shorter stages. The targeted deliverables milestones must be achieved within each stage; for example, material development at a scale of up to 10 kilos or a lab scale was carried out for up to two years.

> *"The lab-scale ... maybe ten of kilos or 100 kilos ... if it's proven successful, then the next step is to build at the bigger scale." (SUSDIR-C-1106.Quo4)*

> *"It took stages to reach the three to five-year collaboration. So the first stage, for example, if we make a partnership within two years, what do we have in the deliverables?" (SUSDIR-C-1106.Quo5)*

If successfully produced in the pilot plant, SUSDIR-C-1106 explained that the bioplastic material being developed was in the form of resin, which would be used as material for producing packaging, such as plastic bottles. DrinkCo would manufacture the packaging, and the external or independent converter would not be involved in the co-innovation. Later, the external converters, which were in partnership with DrinkCo, would be able to access the biopolymer only when asked by DrinkCo as an external converter to produce packaging to cover DrinkCo's lack of internal capacity.

> *"Because the output will be in the form of resin. The option for us is to produce ourselves... if we don't have the capacity, enough capacity, we will be partnering with other companies; therefore, they can also access the raw materials." (SUSDIR-C-1106.Quo6)*

2. Mechanisms of co-innovation

2.1. Joint activities

DrinkCo and the biopolymer producer worked together to create breakthrough material through a project. In this case, the biopolymer producer provided the technology to make a specific polymer grade for Drinkco. SUSDIR-C-1106 explained that the two companies were involved in many trials ranging from lab-scale, which were then gradually increased to industrial scale. SUSDIR-C-1106 added that before entering the trial phase, DrinkCo and partners worked together to prepare the facilities needed, for example, enlarging the lab, then the trial process was carried out starting on a lab scale.

> *"From our partners, OK, I have this technology... perhaps just a few grams of it... Then OK, we will develop it, right. They need investment in many kinds, such as increasing the lab capacity to reach kilos ..." (SUSDIR- C-1106.Quo7)*

SUSDIR-C-1106 explained that during the trial process, DrinkCo provided information and feedback regarding the application of the material to meet DrinkCo's industrial standards, which included technical aspects of DrinkCo's manufacturing such as material properties and commercial aspects, logistics and supply chain.

> *"How the materials that they developed when applied for industrial ... Does it meet the specifications defined by DrinkCo as an industry" (SUSDIR-C-1106.Quo8)*

The mutual adaptation from DrinkCo could be seen in the tolerance given towards lower performance of biopolymer compared to the initial expectations or compared to conventional plastics. SUSDIR-C-1106 explained that tolerances were given when the overall impact was minor but to a certain extent offset with other benefits, such as reduced carbon emissions, but there were non-tolerable areas where materials were not allowed to affect DrinkCo's product quality.

> *"We're not letting the new material after being developed then affecting the product quality. We can say that that is a failure..." (SUSDIR-C-1106.Quo9)*

> *"We will assess what the impacts are? Is it major that affecting the product quality, or maybe a minor one, which is acceptable, but will be offset by something later?" (SUSDIR-C-1106.Quo10)*

2.2. Joint resources

Co-innovation between DrinkCo and the biopolymer producer involved investment from both parties. SUSDIR-C-1106 explained that DrinkCo's partner was a biotechnology provider, a start-up company; therefore, their resources were technology and expertise in biopolymer development. In addition, both DrinkCo and partners had a dedicated team that specifically managed projects. A dedicated team from DrinkCo consisted of a research and innovation team and representatives from logistics, supply chain and commercials.

> *"So they also have a team for research, they have a team for commercial, logistics or a team for other relevant topics" (SUSDIR-C-1106.Quo11)*

Given the limited resources of these partners, who were start-ups companies, SUSDIR-C-1106 stated that DrinkCo provided a large enough amount of financial capital to fund research, to build lab and trial facilities specifically for the development of this material. Another resource from DrinkCo was to provide a pilot plant for testing the conversion of small-scale biopolymers into plastic bottles and a man-hour for trials. However, DrinkCo did not build a bio-based plant to produce biopolymers.

> *"We provide a fund, a support fund, to develop this technology ... even at the lab scale, it also requires quite a significant investment." (SUSDIR-C-1106.Quo12)*
>
> *"Suppose we have to produce ... blow it into bottles or other packaging, of course, we also need our pilot plant ... man-hour too ..." (SUSDIR-C-1106.Quo12)*
>
> *"The facilities are specially built, ya, definitely, to develop at the lab scale, there must be dedicated facility built for that." (SUSDIR-C-1106.Quo13)*

The number of resources invested by DrinkCo was quite significant and sufficient to bind each party to maintain cooperation. SUSDIR-C-1106 provided an example when there was a development of new technology, DrinkCo did not all agree to break off collaboration and moved to another technology provider, but together with partners it would improve the technology they have.

> *"Will need investment, need resources, which are quite significant..." (SUSDIR-C-1106.Quo14)*
>
> *If the technology that we are engaging now is not quite compatible, for example, we would immediately move to a different provider, no, it's not like that either." (SUSDIR-C-1106.Quo14)*

2.3. Relationship management

In co-innovation, the relationship between DrinkCo and partners was tied into a framework agreement that was established at the beginning of the collaboration, and SUSDIR-C-1106 emphasised this as the key factor. The agreement made included how DrinkCo engaged partners in a fair manner, compliance to regulation, such as anti-monopoly, anti-competition, then intellectual property properties of the jointly developed material, scaling up plans including terms related to the possibility of partners engaging with other companies.

> *"We are definitely not allowed to engage with partners; then as we feel that we are co-developing, then we take all of the material..." (SUSDIR-C-1106.Quo15)*

> *"If there is a partner ...another company, even that's DrinkCo' competitor is engaged with our partner, we must agree on the term and conditions ..." (SUSDIR-C-1106.Quo15)*

In addition, partners also interviewed DrinkCo representatives and assessed the seriousness and commitment of DrinkCo in jointly developing materials, especially how in the future after the materials are successfully developed and would be scaled up.

> *"They will also interview us, how DrinkCo sees the future of this material, how DrinkCo will commit to access this material." (SUSDIR-C-1106.Quo16)*

2.4. Absorptive capacity

Product manufacturers explored and collected information about the available bioplastic technology in the market in accordance with DrinkCo's target, namely to get full access to bioplastic materials. Furthermore, DrickCo explored several options of potential tech providers/partners globally.

> *"If we look at the process, how do we access this technology, we have a team that tries to understand the available technology ... Indeed our target is to access 100 per cent..." (SUSDIR-C-1106.Quo1)*

> *"There are several start-ups options, which are mostly in the US, there are several other in the Europe. ... we have an assessment of the criteria... the scalability, readiness, material, cost." (SUSDIR-C-1106.Quo2)*

DrinkCo also looked for the partner's capabilities and assessed several criteria such as readiness to engage in co-innovation, materials in terms of technology, cost, and environmental impact. In addition, DrinkCo also explored the potential for scaling up and implementation at DrinkCo, such as a potential plant that would access and manufacture the material. DrinkCo also reviewed regulations related to material control and recycling to ensure compliance when implemented in the future.

> *"The possibility for scaling-up is therefore very important. So, we have to understand the mapping, for example where the pit stops are, ...the potential plants that will access this product, then the CO_2 impact, the cost impact..." (SUSDIR -C-1106.Quo17)*

> *"Are we beyond certain, for example in particular geographies or products, which of course, must ensure that we comply with anti-competition, anti-monopoly law and so on." (SUSDIR-C-1106.Quo3)*

Learning between partners occurred through discussion and trial. DrinkCo learned a lot from partners to understand options of new materials, new technology, material characteristics that included machinability, properties, comparison to existing material. However, DrinkCo did not access knowledge on creating the material, the area exclusively belonged to DrinkCo's partner. SUSDIR-C-1106 added that DrinkCo always compared the new biopolymer with the existing polymer related to various technical parameters such as material properties, machinability when applied in DrinkCo's conversion process into packaging.

> *"Then from our side, of course, we learn this is a new technology, new material, which we will always compare with the existing." (SUSDIR-C-1106.Quo8)*

> *"At the end we don't go that far to understand know-how, or how the material is created ..." (SUSDIR-C-1106.Quo8)*

SUSDIR-C-1106 exemplified that DrinkCo learned new cellulose-based material derived from old corrugated cartons, different ways to use the material as bioplastic and converted it into packaging instead of the old way of recycling used cardboard to make new cardboard. DrinkCo also needed to learn the market or cardboard, which would be used as the raw material.

> *"I have to learn that cardboard is not used for the raw materials of new cartons, but how the cardboard market is… what it looks like when we convert it into bio-plastic…" (SUSDIR-C-1106. Quo18)*

On the other side, the biopolymer producer learned about the industry, such as to apply the material at DrinkCo industrial manufacturing, production of the material at a bigger scale, commercialising the material, logistics, supply chain. SUSDIR-C-1106 explained that the biopolymer producer learned a great deal about applying the bioplastic material at the real industrial manufacturing process, the results, and whether it would meet DrinkCo's specifications scale-up potential for the industry that would use the material.

> *"... they will learn more about ... industrial related topics ... what would it be at the industrial application ...Does it meet the specifications defined by DrinkCo as an industry ..." (SUSDIR-C-1106. Quo8)*

> *"How the materials produced at the bigger scale, then how to commercialise these materials, related to scaling up, related to commercial, logistics." (SUSDIR-C-1106.Quo19)*

SUSDIR-C-1106 emphasised that both DrinkCo and partner equally learned different and new lessons from each other, and the new knowledge was used as a reference to explore new technology: the potential for DrinkCo to have access to such technology and to improve the material being developed. SUSDIR-C-1106 acknowledged that development in this area was growing, and there was a possibility that the bioplastic material being developed was not compatible with the latest technology. SUSDIR-C-1106 believed that bioplastics as new material would have many opportunities. Therefore, considering the amount of investment as been made, DrinkCo would rather try to understand the market situations then catch up by improving technically and commercially.

> *"New knowledge, of course, we will continue to use it as a reference for what it is called to explore technology ...Then explore the potential to access new materials." (SUSDIR-C-1106.Quo14)*

> *"How we can understand what is happening to the market then how we, apart from our partnership, develop this event because this is a new material, there must be plenty of opportunities to make it better, technically and commercially." (SUSDIR-C-1106.Quo14)*

3. The outcomes of co-innovation

Co-innovation is currently underway at DrinkCo and at a small-scale material development stage. SUSDIR-C-1106 emphasised that DrinkCo targeted the performance would be technically as good as conventional plastic, and the material must meet several other DrinkCo's specifications, but most importantly, the new bioplastic packaging must not affect the product quality.

> *"We always say that at least equal to the existing then this will be a success. This is successful." (SUSDIR-C-1106.Quo20)" (SUSDIR-C-1106.Quo20)*

Apart from the technical side, DrinkCo expected the cost of material to produce a cost model that could compete with conventional plastics. SUSDIR-C-1106 added that later bioplastics would have a different cost model that no longer followed the oil price but followed the commodity market. In addition, the cost model of bioplastics must be able to compete with fossil-based plastics if it was applied in large volumes, provided that oil prices were at a certain level and did not fall, as happened even before the pandemic.

> *"We can make what is called a separate cost model, but at a large volume must be able to compete with fossils." (SUSDIR-C-1106.Quo21)*

> *"This bio-plastic can be competitive at a certain level of actual oil price." (SUSDIR-C-1106.Quo22)*

SUSDIR-C-1106 emphasised that the cost was crucial and was a key indicator of the success of co-innovation. However, this became a challenge, for example, when the project was unsuccessful in using less material for conversion into packaging so that it did not produce savings and reached the expected target cost. If the target cost was not achieved, then there must be an offset with other benefits that could be commercially equalised, such as reducing carbon emissions. From the explanation of SUSDIR-C-1106, it could be concluded that the cost must be in a tolerable range so that it remains commercially competitive.

> *"Suppose we can also ...align it on the commercial cost aspect, and I have often said that it is the key success." (SUSDIR-C-1106.Quo23)*

> *"It has to bring the advantage that we can convert to commercial, to be honest ... convert via carbon trade or something ...but at the end, it has to be competitive." (SUSDIR-C-1106.Quo24)*

From the environmental side, SUSDIR-C-1106 explained DrinkCo's commitment to packaging using recyclable, reusable or compostable in 2025. In line with this, SUSDIR-C-1106 explained that co-innovation in developing bioplastic packaging would explore plant-based or non-fossil-based materials, which would later have similar technical properties to PET, recyclable, but not compostable or biodegradable. According to SUSDIR-C-1106, one of the materials used was derived from used paperboard and from biogas, molasse.

> *"Not compostable or degradable bio-plastic, well, this is actually plant-based bioplastic, but the properties works like virgin, such as PET ...goes to existing recycling streams..." (SUSDIR-C-1106.Quo25)*

SUSDIR-C-1106 also stated that DrinkCo used PLA for yoghurt packaging, but the product was not distributed to the Indonesian market. In addition, SUSDIR-C-1106 explained that the use of biodegradable bioplastics must be ensured that they can degrade into nature; therefore, they should take into account the infrastructure in a country. Therefore, products such as PLA, which were biodegradable under special conditions in industrial composting were not suitable for Indonesia, which did not have adequate facilities.

> *"We have to make sure that it can degrade to nature... considering the available infrastructure in a country ... for example, PLA in Europe is still possible because it can enter the technical landfill." (SUSDIR-C-1106.Quo26)*

SUSDIR-C-1106 explained that a significant reduction in CO2 emissions was one of the achievements pursued by most companies. Therefore, when viewed from the LCA, the use of plant-based materials whose performance was at least equal to the existing ones has resulted in a positive impact in reducing CO2, thus would be beneficial to DrinkCo.

> *"Bioplastics by default to my knowledge, have brought a significant impact to CO2, it shows from the LCA... Now that's what actually pursued by the company..." (SUSDIR-C-1106.Quo20)*

4. The drivers and success factors

SUSDIR-C-1106 emphasised that the first key to success was partner selection and officially agreeing to the terms and conditions as well as the target deliverable in the co-innovation. In addition, SUSDIR-C-1106 explained the importance of delivering the expected technology as well as aligning the cost of the product as the key to the success of co-innovation. SUSDIR-C-1106 stated that in terms of technology, it must be at least equal to PET, and enter a recycling system, so that it appeared that the material was expected to work in the existing system, both in manufacturing and end-of-life. Beyond technology, SUSDIR-C-1106 several times conveyed the importance of co-innovation in producing materials that were costly and commercially competitive.

> *"When we agree on the terms and conditions, we agree on the terms, the deliverables that we put in the partnership agreement are already full success." (SUSDIR-C-1106.Quo23)*

> *"When we succeed ... together we develop from a technology perspective ... according to what we expect then ... align in the commercial cost aspect and I have said many times that it is the key success." (SUSDIR-C-1106.Quo23)*

From the interview with SUSDIR-C-1106, it could be concluded that regulation was the driver for the development of bioplastic packaging. According to SUSDIR-C-1106, the required regulations included targets to encourage the use of bioplastics materials as packaging materials, for example, as a mandatory requirement or recommended as a contribution to carbon reduction commitment in Indonesia. In addition, SUSDIR-C-1106 added the need to develop end-of-life packaging standards that suit a country's infrastructure, hence the bioplastic packaging will be developed to meet the standard since design phase.

> *"The regulator also put a specific target on bio-plastics... not mandatory, not compulsory, maybe as one way to achieve what is called carbon authorities, it could be." (SUSDIR-C-1106.Quo27)*

> *"So how did this government start to think about end-of-life standards. ...I think end-to-end is starting from upstream to downstream." (SUSDIR-C-1106.Quo28)*

> *"We have to make sure that it can degrade to nature by what it's called, considering the existing infrastructure in a country...for example, the PLA in Europe is still possible because it can enter the technical landfill..." (SUSDIR-C-1106.Quo26)*

SUSDIR-C-1106 explained the bioplastic material potentials, including commercial advantages from the product manufacturer's stand point as a business user. According to SUSDIR-C-1106, the material must be competitive in the market, not only for three to five years but longer, for example, ten years. Additionally, the material must have a commercial advantage in the sense that it was not only in the form of cost but could be in the form of other environmental contributions, such as reduction of the carbon emission, which the company would then analyse the impact commercially and must be a competitive advantage.

> *"The most important thing is that we have to look at the horizon in the future what this material will look like... it could be ten years, for example..." (SUSDIR-C-1106.Quo29)*

> *"… that the market for these materials must bring an advantage that we can convert to commercial, to be honest... convert via carbon trade or what offset..." (SUSDIR-C-1106.Quo24)*

5. The dynamic roles of customer and supplier

From the interview with SUSDIR-C-1106, it could be concluded that the biopolymer producer as a DrinkCo partner acted as the technical expert, who also drives the innovation for DrinkCo. On the other hand, as indirectly inferred from SUSDIR-C-1106's statement, DrinkCo as a product manufacturer who is also the industry leader has set expectations and specifications, which must be met, then together with the biopolymer producer, developed the material.

> *"Because the biotechnology provider, they've got the prospect, have got the expertise to develop this technology." (SUSDIR-C-1106.Quo30)*

> *"The second is when we succeed jointly develop from the technology side according to what we expect." (SUSDIR-C-1106.Quo23)*

Thus, it could be concluded indirectly that the product manufacturer guided the R&D development by considering the importance of materials that could be applied in industry, from the commercial, logistics and supply chain sides. It could be said that a strong business motive became the basis for co-innovation with DrinkCo so that many considerations must be met, measured from commercial benefits.

Appendix F-9: Product manufacturer case: NutriCo

NutriCo is one of the largest food and beverage producers running a global operation – one of which is in Indonesia. NutriCo's products, which are marketed using various brands, include infant formulas, cereals, dairy products, chocolate, coffee, ready-to-drink and bottled water, health nutrition, pet care and many more. NutriCo's business principles revolve around integrity, honesty, fairness and compliance to regulations. As a global market leader in the food and beverage industry, NutriCo is also committed to the UN's Sustainable Development Goals. Furthermore, the company has the ambition to create healthy lives for children and families, support communities, and create zero environmental impact, which includes tackling the plastic problem by 2030.

At the moment, NutriCo focuses on its commitment to achieve 100% recyclable or reusable packaging and zero waste by 2025. NutriCo is investing great resources for development projects in this area through the development of new materials and solutions. Some developments in bioplastic packaging include a mixture of plant-based materials for PET bottles, which will be launched as one of its premium products in Italy. Furthermore, NutriCo is collaborating in a major development project with a biotechnology start-up in the Netherlands to develop 100% plant-based PET materials. However, NutriCo is very cautious in taking steps for biodegradable packaging, and is now collaborating with a biopolymer manufacturer in the United States to develop biodegradable and recyclable packaging materials from PHA.

In Indonesia, NutriCo is a business unit that operates nationally throughout Indonesia. NutriCo has several factories and sales-and-distribution centres in many regions and has become the market leader in the industry. Several years ago, NutriCo Indonesia tested PLA's bioplastic packaging, which was intended to shrink sleeves, namely the plastic film label that was wrapped around the primary packaging. However, it was discontinued due to the many technical problems in its application. Moreover, NutriCo has not set a specific agenda for the implementation of bioplastic packaging in Indonesia.

1. The process of co-innovation

In general, the packaging development at NutriCo is carried out through various mechanisms. According to HOPACK-C-1207, the development at strategic level is driven by the Chief of Technology (COT), the top management on global level. The development was also assigned to a lower level, including NutriCo's research and innovation centre and the centre of packaging science. HOPACK-C-1207 explained that the centre of packaging science was established specifically to achieve the ambition of 100% recyclable or reusable packaging, and this centre also collaborated with external researchers and universities.

> *"It can start with all kinds of things ... if a project is considered strategic, it is then managed by our top management. They usually give direction to the global Chief of Technology." (HOPACK-C-1207.Quo1)*
>
> *"So normally, that team will collaborate with the external researchers." (HOPACK-C-1207.Quo2)*

HOPACK-C-1207 added that NutriCo was developing bioplastic packaging to replace conventional PET bottles with an external biotech start-up and two other product manufacturers. It was also estimated that the new packaging validation would be carried out in several countries where NutriCo drinking water units operate.

> *"Several types will be applied to our drinking water in several countries, whether it can be validated or not. That's what I suspect anyway." (HOPACK-C-1207.Quo3)*

Business units, such as NutriCo Indonesia, are not directly involved in the development of bioplastic packaging. HOPACK-C-1207 described the packaging development process that took place at Nutrico, starting from initial assessment and partner selection, technical development, lab scale, scale up to industrial scale, manufacturing materials, to manufacturing implementation. Validation and rigid quality check were included in each process.

"... The material manufacturing process will start after the technical development phase on both lab and industrial scales." (HOPACK-C-1207.Quo3)

NutriCo involves its stakeholders, such as resin manufacturers and converters, after the packaging concept is developed, or as early as possible. Their role is to conduct trials, which are aimed at finding out the suitability of the material properties running on their existing production, as well as any other adjustment needed to get the expected material quality. All partners involved in the development are bound by a non-disclosure agreement (NDA).

"...Generally, in a packaging development... At the concept phase, after it's clear, we invite stakeholders, including the converter ..." (HOPACK-C-1207.Quo4)

"The mechanical properties, in particular, must be reviewed for its fitness to see if we can use the equipment like in conventional plastics or if it should be adjusted ..." (HOPACK-C-1207.Quo5)

NutriCo Indonesia has explored partnerships with local start-ups to develop bioplastic packaging in Indonesia. NutriCo conducts internal research and an initial assessment of one of the start-ups that have achieved international recognition. The factors considered in the partner selection are the suitability of the product concept with Nutrico's vision and mission and the partner's capability to meet the required performance. After evaluating the potential, NutriCo found that the packaging that needed to be developed was difficult to convert and did not meet the protection requirement. Even though the packaging was edible and biodegradable, these features did not fit NutriCo's packaging roadmap, which prioritised recyclable or reusable packaging. As a result, NutriCo chose not to co-innovate with this local start-up because the company's capability and potential were not aligned with NutriCo's industrial needs.

"In Indonesia, there are people who try to convert seaweed into plastic, but it is still in a very early stage..." (HOPACK-C-1207.Quo5)

"When we cross-checked with our R&D, we discovered that it was difficult to pull off since it's extremely difficult to transform seaweed into plastic for packaging purposes. Another reason is that we are targeting recyclable or reusable materials, among others" (HOPACK-C-1207.Quo6)

2. Mechanisms of co-innovation

2.1. Joint activities

Based on his experience in the business unit, HOPACK-C-1207 explained that his involvement in the development of bioplastic packaging was in providing information about the material and machine specifications for the materials to be developed into many things, such as existing plastic films. The feedback was then submitted to the head office at the beginning of the development before being forwarded to the biopolymer producer. After reaching a certain stage, the business unit received instructions from the head office regarding a trial.

> *"Shrink the ratio and determine how many per cent will be reduced from the direction machine for the machine to perform according to the existing film. That is the feedback we give them..." (HOPACK-C-1207.Quo7)*

HOPACK-C-1207 described the adaptations made by NutriCo in regard to the new packaging trial, which included adjusting engine settings, operating parameters, and replacing spare parts. These efforts were made in the hope that the bioplastic material would be compatible with the new machine.HOPACK-C-1207 also said that the head office supported the business unit's need for additional investment so that the bioplastic materials could be utilised in the business unit. NutriCo was not reluctant to make adjustments, including accepting a much more expensive material in order to achieve the ambition of zero environmental impact. HOPACK-C-1207 added that this was not only for bioplastics, but also for other packaging. An example was when NutriCo Indonesia continued to use paper straws which cost up to five times more than plastic straws.

> *"We have to replace the sealing equipment to ensure good sealing integrity using the new materials. It shows NutriCo's commitment, as well as the centre's support." (HOPACK-C-1207.Quo8)*

> *"The price of plastic straw compared to paper straw is almost five times as much... It is an enormous amount when converted into Rupiah." (HOPACK-C-1207.Quo9)*

2.2. Joint resources

NutriCo owns in-house and packaging science centres. As a result, NutriCo has the capability to develop bioplastic materials and a broad understanding of material science, sustainability, environmental impact and other related aspects. To that extent, co-innovation is carried out with partners who can complement NutriCo's capability, and thus, closing the knowledge and technology gap.

> *"A partner who can close the gap on the knowledge and technology that we've got because we also have an in-house knowledge. We want our external partners to complement our capabilities." (HOPACK-C-1207.Quo10)*

Currently, NutriCo co-innovates with a biotech start-up to develop plant-based PET materials from scratch. HOPACK-C-1207 explained that a new material development project which was carried out from concept to materialisation required a huge fund. Consequently, NutriCo and several other product manufacturers provide significant financial capital for the project.

> *"We start from scratch. It means we will need a lot of money to develop and materialise the product. Therefore, we need partners who can provide the necessary fund." (HOPACK-C-1207.Quo11)*

2.3. Relationship management

As HOPACK-C-1207 was involved in the trial of PLA shrink for NutriCo Indonesia, following the direction from HQ, and was not directly involved with the partner in co-innovation, he was not able to share further information on the relationship management. HOPACK-C-1207 added that NutriCo was taking careful steps regarding bioplastic, particularly biodegradable packaging. Because of this, bioplastic packaging development was centralised on a global level.

> *"Our latest guideline states that we always need to consult with the centre. The market may not take the development initiative. Rather, the centre will help them with the access…" (HOPACK-C-1207.Quo10)*

2.4. Absorptive capacity

At the beginning of the PLA shrink development several years ago, HOPACK-C-1207 explained that the business unit level provided information and feedback in the form of material properties and performance, which referred to the existing conventional plastic and machine specifications in the hope that new bioplastic materials could be applied to the existing machines. The feedback was submitted to HQ and communicated to partners after.

> *"We usually refer to what is called a polyolefin-based material when it comes to the material's performance. As for shrink film, we usually look at the shrink ratio..." (HOPACK-C-1207.Quo7)*

HOPACK-C-1207 was involved in the PLA shrink trial phase at the business unit level, and from his experience of executing the bioplastic packaging test, HOPACK-C-1207 learned that the process of developing bioplastic packaging was not easy, and that it required very intensive and time-consuming efforts. HOPACK-C-1207 recalled several constraints, such as the procurement of material samples, which took a long time because the material was still under development. When the sample was finished and tested, the bioplastic material did not perform well even though NutriCo had made adjustments to the machinery to suit the new material's characteristics.

> *"When it comes to the execution, clearly the first lesson is the procurement of the sample materials took a long time. Since it was still under development, it had not become a standardised stock from the manufacturer ..." (HOPACK-C-1207.Quo12)*

> *"The lesson I learned was that the development required a long time to really meet the criteria or the expected quality or performance ...it really needed intensive efforts" (HOPACK-C-1207.Quo12)*

According to HOPACK-C-1207, the biopolymer producer did not have a standard material ready for trial and was simultaneously learning to produce the sample by following the requirements and specifications from NutriCo. Therefore, at the time, it took the biopolymer producer quite a long time to develop materials and send samples for trials at the business unit.

> *"... They were still learning to produce a sample that was in line with the expected performance" (HOPACK-C-1207.Quo12)*

3. The outcomes of co-innovation

The development of bioplastic packaging at NutriCo is aimed at producing packaging that is in line with the ambition of zero environmental impact, and focused on producing recyclable and reusable packaging. The development of bio-based packaging in Indonesia has not become a priority because NutriCo Indonesia mobilises its resources to achieve the ambitions set by the headquarter.

> *"We're not going for biobased just yet, but we are focusing on recyclable and reusable materials because that is the target for 2025." (HOPACK-C-1207.Quo13)*

From a technical point of view, HOPACK-C-1207 repeatedly emphasised the importance of barrier properties which was also a key requirement for any packaging developed for NutriCo. Barrier properties such as moisture, light, and oxygen on the packaging are very vital to protect the quality of food and beverage products.

> *"For food and beverage, as I mentioned earlier, barrier properties are one of the key requirements." (HOPACK-C-1207.Quo14)*

To achieve the corporation's ambition, NutriCo prioritises recyclable, reusable, or plant-based materials that do not create a conflict of interest with the land use for food. An example of bioplastic packaging that has been used by NutriCo is bio-PE lids from recyclable sugar canes to cover infant formula cans.

> *"The second generation with sugar cane, which has reached industrialisation, is this lid... it's from BIO-PE." (HOPACK-C-1207.Quo15)*

HOPACK-C-1207 added that NutriCo took careful considerations in developing bioplastic packaging, especially biodegradable ones, and always compared LCA with the previous plastic packaging. Furthermore, NutriCo and DrinkCo partnered with biotech start-ups to develop biobased materials from scratch. This bioplastic material is similar to recyclable PET and is used for the water bottle.

"NutriCo is very cautious in developing biodegradable materials, including bioplastics. We should always consult with the centre." (HOPACK-C-1207.Quo10)

4. The drivers and success factors

Inferred from the interview with HOPACK-C-1207, several factors contributed to the failure of co-innovation. First, from a technical point of view, the bioplastic material failed to reach key performance requirements due to technology limitations. At the time, the product did not produce barrier properties, which were vital to protect the product. This was non-negotiable for NutriCo because the failure to protect the product might affect their product quality and their reputation as the market leader. Second, reflecting from co-innovation in developing the PLA shrink, the bioplastic material was hard to process on the existing machines even after NutriCo made adjustments to the settings and replaced the engine's spare parts. Furthermore, the raw material procurement had to be imported, and therefore, cost a lot.

".. In terms of economic value, it's not any better or cheaper. The import requirement and high cost were the handicaps at the time." (HOPACK-C-1207.Quo16)

HOPACK-C-1207 also explained that the industry in Indonesia was not ready for bioplastic packaging due to several challenges, such as price, market, collection infrastructure, waste sorting, and packaging regulations which were still combined with waste regulations. According to HOPACK-C-1207, the cost was somewhat acceptable for NutriCo as the new packaging contributed to the corporate's agenda. However, for most businesses in Indonesia, it was difficult to accept higher costs because the consumers were price-sensitive and would rather buy the cheap product in small packaging, such as instant coffee in sachets, which was priced at IDR 1,000, or approximately less than GBP 0.50. Therefore, a high increase in the bioplastic packaging cost would have a significant impact on the consumers, and eventually, other product manufacturers. Still on this matter, HOPACK-C-1207 also added that the FMCG in Indonesia was reluctant to switch to recycled materials due to higher material costs.

"In Indonesia, people expect to buy products that cost a thousand Rupiah... so when they buy coffee or whatever, they are willing to spend around Rp. 1,000,-. Therefore, it's impossible for the products to use bioplastic" (HOPACK-C-1207.Quo17)

"The other FMCGs, especially the local ones, are not ready. They still perceive it as expensive and believe there is no need for it presently." (HOPACK-C-1207.Quo18)

The other challenges in Indonesia are the regulations and limited infrastructure. HOPACK-C-1207 described that Indonesia prioritised waste and recycling issues, and there was no specific agenda for bioplastic packaging. The existing regulation was a waste regulation, and there was no specific regulation about packaging and packaging waste. In the prevailing regulation, producers were responsible for reclaiming their packaging waste, one of which was by recycling. However, the implementation revealed that business players, FMCG, and the waste industry were not ready to switch to recycling and the infrastructure for waste collection and sorting was inadequate. For example, even though NutriCo used a recyclable label on their plastic bottle, whilst many other manufacturers still used PVC despite the ban stated in the regulations. Furthermore, the waste picker, who manually sorted plastic waste, generalised all plastic labels to go to landfill or burner. HOPACK-C-1207 believed that it would be a shame for NutriCo's recyclable label to be thrown along with the others.

"In Indonesia, there are no regulations about packaging and packaging waste. Everything is included in the waste regulation. However, it is clear that the producer is responsible for taking back the packaging waste." (HOPACK-C-1207.Quo19)

"Currently, in terms of recycling, not everyone in Indonesia is ready ... As for bioplastic, it will have to wait." (HOPACK-C-1207.Quo18)

"Waste pickers generalise that all PET labels are made from PVC ... Therefore, they are either landfilled or incinerated." (HOPACK-C-1207.Quo20)

5. The dynamic roles of customers and suppliers

The biopolymer producer's role is as an expert who drives innovation at the early stages of material development, such as concept development and lab-scale trial. In this case, NutriCo as an industry leader, indirectly drives the bioplastic material development by setting expectations, such as quality and performance specifications, as well as partners who can serve their needs on an industrial scale. HOPACK-C-1207 added that in general packaging development, new stakeholders were involved after the project was materialised.

> *"We involve all the stakeholders as early as possible. We'd like to engage them in the early stage of the development, but obviously it is better when the concept is clear ..." (HOPACK-C-1207.Quo4)*

The dynamics at the business unit is closely related to the trials. For example, how it copes with the challenges of processing the bioplastic materials using the existing machines. HOPACK-C-1207 gave an example of obtaining a specified barrier property in which the PLA film must be made six times thicker than conventional film. HOPACK-C-1207 explained that when multi-layer flexible packaging was applied, each layer became thicker, less flexible, and increasingly difficult to process using the existing machine. In addition, the cost and environmental impacts were also less favourable due to higher material usage.

> *"To be able to obtain barrier properties such as multi-layer metalised film, the material needs to be six times as thick as the film." (HOPACK-C-1207.Quo21)*

Appendix F-10: Product manufacturer case: CoffeeCo

CoffeeCo is a UK-based start-up that sells compostable coffee pods of specially selected coffee beans that offer great taste, convenience and sustainability. The founders of CoffeeCo recognised how consumers love the convenience of brewing coffee from the coffee capsule machine; however, most of the coffee pods available in the market contain plastic and aluminium, which are highly intricate to recycle and generally end up in landfills, polluting the environment.

In the beginning, CoffeeCo purchased the product from a third party supplier and resold it to the customers. CoffeeCo then started to develop new home compostable materials made from the coffee husk, bamboo and rice husk. The CoffeeCo case presents a unique view, illustrating a product manufacturer as a business customer, expanding to bioplastic technology development through co-innovation with its suppliers.

1. The process of co-innovation

In the beginning, internal R&D processes were conducted for concept development and initial prototypes. CoffeeCo founders started to leverage knowledge about coffee, food packaging, compostable material alternatives, defined material specifications and building a network.

> *"What we started doing, leveraging on our knowledge and our network, and we started finding new materials…" (COFOUND-C-0107)*

At the concept development, CoffeeCo defined the material specifications that include home compostable, plant-based, and minimal processing. COFOUND-C-0107 explained that this process was challenging as there were limited materials available in the market that could tick all the required specifications, including technical, engineering, production, logistics and final product specifications. Therefore CoffeeCo viewed this as an opportunity to develop innovative bioplastic material to fill the gap.

> *"And not all of them have, for example, low oxygen permeability, water-resistance, or temperature resistance, all of which you need for food packaging product, and that*

includes coffee pods. And so what we started doing is working with blends of materials …and to try and address that." (COFOUND-C-0107).

According to COFOUND-C-0107, CoffeeCo started with a small scale initial product prototype, experimenting with single and blends of materials, including those from coffee husk, bamboo, rice husk, and combinations. Additive materials were also used in the blends to achieve desired material properties to make it work in the conversion process and at the consumer's coffee machine.

"…quite helpful if you're using a blend of materials, if you need to change the mechanical properties to make it more elastic, …when you have a coffee pod in the machine, and you closed the machine, you don't want the coffee pot to crack…" (COFOUND-C-0107).

COFOUND-C-0107 mentioned that CoffeeCo works with a machine supplier and biopolymer producer, who helped improve the material blends to achieve targeted performance and trials of the prototypes.

"And we have two reliable manufacturing partners that we're working with at the moment. And both of which have been really great and really, really helpful." (COFOUND-C-0107)

The material development was a lengthy process in which there were few prototypes had been developed, and only one succeeded. COFOUND-C-0107 considered a long process as normal and iterations were crucial to improve the material, ensure the prototype fully functioning before testing on a larger scale, and enable learning. COFOUND-C-0107 added that validation and quality check or the material should be processed as early as possible, and currently, CoffeeCo has got several patents, food safety and home compostability.

"We've had maybe five prototypes that didn't work very well, and only one that does work well. So even though that sounds like a long and monotonous process is actually quite normal." (COFOUND-C-0107)

It can be inferred from COFOUND-C-0107 that CoffeeCo has planned to scale up in the near future and has considered the scale-up requirements in the material design, manufacturing and partner selection. For example, CoffeeCo chose injection moulding to produce the pods because it can produce large quantities of packaging in a short time and will be cost-effective. Therefore, the materials were designed to have properties suitable for injection moulding processing.

2. Mechanisms of co-innovation

2.1. Joint activities

COFOUND-C-0107 explained that the current partnership with polymer producer and converter covered several activities related to trial, improvement and production, which were more transactional and agreed in the contract and non-disclosure agreement.

> *"And we've had to rely on a lot of third parties to help us with production so often like leasing machinery or outsourcing some production work." (COFOUND-C-0107)*

The polymer producer supplied the raw material for CoffeeCo and provided support during the material development process regarding the compatibility of the material with the packaging production machinery and consumer's coffee machine. COFOUND-C-0107 added that CoffeeCo consulted the design and material blends to the biopolymer producer, who also helped modify the material compound that improved the material properties. As a start-up company, CoffeeCo relied on third-party suppliers to manufacture the product and conducted trials with the machine supplier.

> *"When we want to make the product or tweak the material, we consult our manufacturing partners." (COFOUND-C-0107)*

> *"They do also provide or can or can slightly tweak the resin that you use for injection moulding if they need to change the properties as well." (COFOUND-C-0107)*

2.2. Joint resources

In this case, the material development is mainly from CoffeeCo, and there were helps from the supplier that included access to the production machine. COFOUND-C-0107 confirmed that CoffeeCo did not have any joint investment with the supplier. The partnership was transactional, where the machine supplier provided access to the machine for testing the prototype and produced the coffee pods as well; then CoffeeCo would pay as per contract and agreement. CoffeeCo opted to lease the equipment because the injection moulding machinery is costly.

> *"We lease their equipment, or we contract out some production work to them, and mostly for prototyping recently." (COFOUND-C-0107)*

COFOUND-C-0107 explained that CoffeeCo considered injection moulding for processing the material into coffee pods because it is the best option to achieve cost and time efficiency and the most feasible process for scaling up to mass production. In more detail, COFOUND-C-0107 added that injection moulding produces thousands to millions of coffee cups efficiently, thus enabling CoffeeCo to get low and competitive unit costs.

> *"The reason why we want one might want to use injection moulding is because it's the most cost-effective, most efficient, and most scalable manufacturing process that we found." (COFOUND-C-0107)*

CoffeeCo has been operating relatively lean with some investment in specific machine parts, such as the moulds that form the material into the coffee pods, R&D, material procurements. CoffeeCo would also consider more collaboration with one of their biopolymer producer by launching a joint venture, in which the supplier would provide expertise for refining the material and file a joint intellectual property.

> *"Since we're working on this product together, and they're also offering some of their material expertise as well to improve the material for the product." (COFOUND-C-0107)*

2.3. Relationship management

CoffeeCo partnership with the injection moulding supplier and the biopolymer producer started as transactional, where CoffeeCo paid the suppliers to do the work for trialling the prototype or manufacturing the product. COFOUND-C-0107 shared more details that when creating the prototype, CoffeeCo determined the material specifications and design to the supplier, who then processed the material on the supplier's conversion machine. Subsequently, CoffeeCo tested the prototype, modified and improved the prototype.

> *"We hand them over our material specification, we hand over our design, and then they would work with their injection moulding facilities, make us a prototype, it was just sort of that, and you know, we'd pay them for that." (COFOUND-C-0107)*

The partnership was made following a partnership agreement, such as a leasing agreement, which includes the production work, non-disclosure, non-solicitation, non-circumvent and non-competing agreement; all responsibilities from both sides were regulated. CoffeeCo acknowledged that the partnership had been growing closer over time, and CoffeeCo plans to build a joint venture to develop CoffeeCo new material and files for joint intellectual property rights.

> *"…So it's been quite important to make sure loads of non-disclosure agreements are in place, as well as non-solicitation and non circumvent non compete agreements…" (COFOUND-C-0107)*

> *"We don't have any joint investment with the suppliers, we do have manufacturing partnership contracts." (COFOUND-C-0107)*

COFOUND-C-0107 considered that CoffeeCo's growth rate is relatively high and, therefore, CoffeeCo will be more selective in choosing partners who can supply consistent quality of material and fulfil the quantity following an agreed forecast.

> *"Whenever we pick a manufacturing partner ... we've got to make sure that they're given a clear forecast and that they can agree to that to assure us that they can meet those…" (COFOUND-C-0107)*

2.4. Absorptive capacity

When the business started, the founders of CoffeeCo did not have a background in sustainable packaging and coffee, and they had a limited understanding of bioplastic technology. COFOUND-C-0107 explained that the founders immediately acquired knowledge about the material, such as the material available in the market, its performance and the compatibility for food packaging. It turned out that not all of the available material has the properties needed for coffee pods, such as low oxygen permeability, water-resistance, or temperature resistance. COFOUND-C-0107 recalled that there were limited scientific references that could help them understand home compostable material, especially regarding the product design and commercial aspects, all of which were needed for decision-making.

> *"We started finding new materials, and there are very few there's only a handful of home compostable materials that you can use." (COFOUND-C-0107)*

> *"There's no clear information that can help inform design decisions. And definitely, very little information that can help inform commercial product decisions." (COFOUND-C-0107)*

COFOUND-C-0107 mentioned that the best way to learn is from trials and iterations because the scientific references are limited. Even though failures were inevitable, each iteration and prototype enabled CoffeeCo to understand the design and material feature and then draw conclusions on the impact of changes and modifications of the design and other parameters.

COFOUND-C-0107 explained that co-innovation facilitated a better understanding of the home compostable material, what works technically, and commercially. CoffeeCo also understood the market situations better, in which only a few home compostable materials actually worked, but not all of them were suitable for food packaging. COFOUND-C-0107 added that it was difficult to find a material that ticked comprehensive specifications, especially in protecting the product, such as having low oxygen permeability, water or temperature resistance.

Each iteration process and failure in the prototype transformed into accumulated understanding about various working parameters and how to work with the new material. COFOUND-C-0107 described the importance of understanding what causes failure and problem solving, new features of the material, product and design, a particle characteristic of the material compatible to certain designs, product features, technical and engineering challenges, also impact of every change to the manufacturing, consumer's, coffee machine and final product quality. COFOUND-C-0107 explained that it is better to apply a limited change to design or material and control the other parameters to understand the impact. These new understanding and knowledge were implemented to improve the material, design, process and final product.

> *"Even if we failed, we got to make sure like, Okay, what new product feature? Or what design feature or material feature? Did we understand a little bit better?" (COFOUND-C-0107)*

> *"And then if that works, for example, we might tweak the material next. … it's being really careful, the conclusions not changing too much, and making sure that every iteration and every prototype has some lessons to teach us…." (COFOUND-C-0107)*

From the partnership with material suppliers, COFOUND-C-0107 added the importance of quality control to produce high quality and consistent final products, especially for consumable products. Therefore, CoffeeCo would improve quality control and zero tolerance in real production.

> *"How can the product be of poor luck or poor quality. And that was a good lesson to learn. But we can't have any of that there should be sort of zero tolerance for that kind of thing, if we were making the finished product ready to sell to a packaging company or to a supermarket…" (COFOUND-C-0107)*

In addition, PO0107 also conveyed the importance of conducting testing and obtaining certifications of important specifications, such as food safety, oxygen permeability, compostability, as early as possible.

> *"Basically testing the parameters for each of our most important specifications should be done as early as possible." (COFOUND-C-0107)*

3. The outcomes of co-innovation

Bioplastic packaging for compostable coffee pods must be able to meet various specifications. From the performance aspect, the material must have several key properties, such as mechanical properties, heat resistance, that enable efficient processing in the injection moulding machine and consumer's coffee machine. In addition, low oxygen permeability and other barrier properties for food packaging are essential to protect and maintain the product freshness.

> *"…it can't be too brittle. And it has to have a relatively high melting temperature to the order of 120 degrees Celsius. And it has to have low or zero oxygen permeability, because of course, it needs to keep the coffee fresh as well." (COFOUND-C-0107)*

Based on CoffeeCo's experience, cost efficiency was achieved through efficient processing, for example, by selecting materials that can be extracted from plants without a lengthy process, choosing the most efficient conversion process into packaging. COFOUND-C-0107 explained that injection moulding was chosen because it is considered the most feasible for efficient processing and mass-scale production; therefore, the material was developed to be compatible with this manufacturing process.

> *"And so we can get our unit costs really, really low. And we can make, you know, we can go from hundreds of 1000s of units to 10s of millions of units quite quickly and quite cost-effective as well." (COFOUND-C-0107)*

COFOUND-C-0107 explained that the product is currently using PLA and acknowledged the weakness as it needs to be processed in an industrial composting facility to biodegrade; otherwise, PLA would take years to degrade, just like the conventional plastic packaging. Therefore, CoffeeCo were developing plant-based material from either coffee husk, bamboo, rice husk or combined material, all of which were also home compostable and took up to 20 weeks to degrade completely. COFOUND-C-0107 also confirmed that CoffeeCo would carry out a life-cycle analysis (LCA) of the material, including the carbon footprint, any harmful residue after the bioplastic packaging biodegrades, heavy metal residue due to processing, degradation within its shelf life; thus would ensure safety for consumption and the environment.

> *"And we're actually going to start conducting that very soon. And part of that actually is analysing the byproducts or, the residue, after it's decomposed, and then also doing heavy metal analysis…" (COFOUND-C-0107).*

COFOUND-C-0107 mentioned that the collaboration with CoffeeCo's manufacturing partners was also intended for scaling up, which was planned to reach several million units within a couple of years.

4. The drivers and success factors

CoffeeCo case showed that the key success in material development is creating materials that, according to COFOUND-C-0107', would thick all the boxes'. In more detail, COFOUND-C-0107 explained that CoffeeCo is developing coffee pods that work on the existing manufacturing processes (injection moulding), are compatible with several coffee machine brands, protect the coffee and do not affect the quality when consumed, and home compostable within the targeted time. Based on the CoffeeCo's experiences, it can be seen that the development of new materials is carried out by CoffeeCo because new material in the market has not met CoffeeCo's expectations, then failures in the trials occurs due to limited references and understanding on the new material characteristics in processing.

> *"…finding a material that meets all of our specifications. And again, that list is quite comprehensive, and has different aspects like material production, logistical. And then, you know, final product specifications." (COFOUND-C-0107)*

> *"we want to do ones for Lavazza machines, or for Nescafe, Dolce gusto or for Keurig machines as well. And so that's, that's quite important. And because every time you tweak the dimensions, … you might have effects that you aren't aware of until you try it" (COFOUND-C-0107)*

COFOUND-C-0107 explained that in the end, the key to a successful business is to deliver what the consumers want; CoffeeCo's consumers want to enjoy an excellent coffee, and this is the key to selling the product. In addition, consumers want consistent quality and competitive prices, which encourages repeat purchases. In fact, according to COFOUND-C-0107, using sustainable packaging is not the main selling point, even though there is currently massive growth for sustainable products and packaging.

> *"We've found that sustainability isn't really a big selling point for a lot of customers… But I think ultimately, people act in their self-interest… what will really help you sell a product is a good quality, and things like consistency as well." (COFOUND-C-0107)*

COFOUND-C-0107 observed that the UK market in general, including the middle and high-income working class, is willing to pay a premium price for high quality or sustainable products is still limited, and some consumers only occasionally buy premium products as luxury treats.

> *"…most of the consumer market doesn't really have much patience for expensive products…" (COFOUND-C-0107)*

Market and growing demand are the main drivers for sustainable product development, including packaging. According to COFOUND-C-0107, sustainable products, including packaging, must prioritise quality and price as selling points to encourage market growth and generate more developments. Eventually, there is a need for more and more people to use sustainable products to gradually decrease pollution and create positive impacts on the environment.

> *“If you can attract them with those two selling points of like good quality and good price tag, then you’re almost directly having a positive impact on the environment as long as what you’re selling is a sustainable or eco-friendly product.” (COFOUND-C-0107)*

5. The dynamic roles of customer and supplier

This case presents CoffeeCo as a product manufacturer or business user who uses the bioplastic packaging for the product, has comprehensive requirements and specifications to be met. However, CoffeeCo expanded its operation to develop bioplastic material due to the limited material availability that fulfils their need, and therefore CoffeeCo also plays the role of biopolymer producer. The dynamics in the bioplastic packaging development were illustrated during the process, especially during iterations in developing bioplastic coffee pods. CoffeeCo has two partnerships with the supplier, both started as transactional, where the suppliers supply the material and lease the injection moulding machine. The collaboration with the biopolymer producer grew closer as the supplier intensively helped CoffeeCo during the material development process. Accordingly, CoffeeCo considered establishing a joint venture and arranged a joint intellectual property right for the new bioplastic material developed with the material supplier.

Appendix F-11: Product manufacturer case: ChocolateCo

ChocolateCo is a small business in the UK that produce and sell premium hand-made chocolate bar. ChocolateCo was founded in 2009 by an entrepreneur who has a strong interest in healthy food and the environment. Accordingly, ChocolateCo products use natural and healthy ingredients, one of which the raw cacao from an ethically grown source. These chocolate bars are vegan, and the packaging is plastic-free as ChocolateCo use plant-based compostable packaging. ChocolateCo products are sold online on the company websites and other websites, which mostly sell vegan, healthy food, plastic-free, eco-friendly or natural products.

ChocolateCo packaging consists of an inner packaging made of a flexible film bag to wrap the chocolate bare and the outer packaging made of cartons. ChocolateCo works with a converter, which supplies the film packaging, which is plant-based, 100% industrial and home compostable. The converter provides bespoke packaging and, together with ChocolateCo, work to apply a simple design to the packaging. ChocolateCo also plans to scale up the business and use a flow wrap machine for packing the product.

1. The process of co-innovation

The owner of ChocolateCo initiated not to use plastic packaging for the product and started to look for the appropriate packaging in the market. ChocolateCo started to use cellophane bags but did not continue because its price was quite expensive. Then ChocolateCo tried another biodegradable plastic bag, but it did not work well, and FOUND-C-21210 found that biodegradable plastic would still create a problem for the environment. ChocolateCo looked for alternatives of material in the market and contacted many suppliers to compare pricing and flexibility in service. Finally, FOUND-C-21210 found a film packaging supplier that suits ChocolateCo needs. This supplier provided a new plant-based and compostable film packaging called Natureflex.

> *"I found out about Natureflex; it was at least seven or eight years ago, a long time ago… I find as many suppliers as I can between three and 10. I'll contact them all." (FOUND-C-21210)*

ChocolateCo's supplier was a converter that produces bioplastic packaging and conventional packaging. FOUND-C-21210 explained that the converter provided bespoke packaging following ChocolateCo's request. In this case, ChocolateCo set the desired design, colour and size. Even though ChocolateCo ordered a flexible packaging bag with a pretty generic model, getting the packaging as expected was not easy and faced many obstacles; for example, letters printed on transparent packaging could not look sharp, and the printed colour was not precisely as requested. Nevertheless, FOUND-C-21210 considered that the supplier was very supportive of ChocolateCo and strived to provide the best service.

> *"Yeah, it's very difficult, but we got two different ones in the end, a clear one and one. And then we use the same process at the moment, we're manually putting the bars in." (FOUND-C-21210)*

FOUND-C-21210 considered cooperation with suppliers for the long term, especially after seeing the supplier's flexibility for minimum orders, commitment, and much effort had been given to meet FOUND-C-21210's requirements. In the future, FOUND-C-21210 planned to increase production volume and use a small scale flow wrap machine to pack chocolate bars, and for that, FOUND-C-21210 required a film roll with a printed design and a suitable size.

> *"The next step is to get a small scale flow wrap machine. And then the. I'd have to try and buy it by the roll the correct width …and with the design printed onto it…" (FOUND-C-21210)*

2. Mechanisms of co-innovation

2.1. Joint activities

ChocolateCo produced vegan chocolate bars on a small scale and mainly processed manually. FOUND-C-21210 explained that the packaging was designed after designing the chocolate bar. ChocolateCo wanted the packaging in a specific size to facilitate the packaging process and look good on the product. FOUND-C-21210 revealed that the converter provided support in the design process, such as suggesting more suitable materials and how to process them. The converter also provided feedback and advice to overcome obstacles and improve the packaging design. For example, when ChocolateCo designed a transparent plastic bag with the brand printed on it, the results were unsatisfactory when applied to bioplastic packaging. Hence, the converter tried to improve the printing and advised FOUND-C-21210 to change the design, and then both conducted several iterations. The converter produced several samples to be reviewed until FOUND-C-21210 decides the design and specifications to be used.

> *"It's not an amazing quality of print, so I'm going to make sure the writing is bigger next time… the big letters are sharp, but the small letters are a bit blurred..." (FOUND-C-21210)*

> *"They have any suggestions on better material, or perhaps how to work with the material well …So it's very important to get feedback from the converter. And if they have any advice for improving things." (FOUND-C-21210)*

From this example, it can be seen that the mutual adaptation between the converter and the brand owner. ChocolateCo adjusted the design and manual sealing process to accommodate new film characteristics.

2.2. Joint resources

The ChocolateCo case showed limited joint resources in the collaboration as ChocolateCo, and the converter does not engage in a shared investment of machinery or equipment. In the current co-innovation project, the converter provided ink, packaging samples for trials and their expertise to support the customer's packaging application. Furthermore, ChocolateCo planned to buy a new packaging machine to increase the production capacity and efficiency, but this asset is not shared with the converter.

2.3. Relationship management

FOUND-C-21210 described that the relationship with the converter is built for long-term collaboration. ChocolateCo noticed commitment and sincere support from the converter even though ChocolateCo is a relatively small business. FOUND-C-21210 complimented the converter, who tried to give the best support even though currently ChocolateCo bought only a limited quantity, and FOUND-C-21210 was quite demanding regarding the colour and sizing. FOUND-C-21210 added that despite the packaging having some limitations, the converter tried different colours, sizes and designs and wanted to get it right to sustain future orders from ChocolateCo. The converter considered the potential of future orders as ChocolateCo business would grow in the long term, and as FOUND-C-21210 said, ChocolateCo ordered 10 or 20,000 bags at the moment and might increase to hundreds of 1000s or millions of bags on each order.

> *"It's definitely not just transactional there's been some genuine support. They really for the small size board I put in, they went above and beyond…" (FOUND-C-21210)*

> *"I was never 100% happy, I think they did more than other people would think, to try different colours, different lengths different design I think they did well because it was only for them it's a very small order…" (FOUND-C-21210)*

A small business like ChocolateCo considered several factors, such as price, flexibility and service when selecting a supplier. FOUND-C-21210 explained that the supplier was reliable, offered a competitive price, and accepted small orders from 5,000 units, which was often impossible with other converters requiring more minimum order units, approximately 50 to 100 thousand per order.

> *"Sometimes my supplier they can be a bit slow, but they're reliable and good price as well, and they can do relatively small order, like 5000 or 10,000 packs…" (FOUND-C-21210)*

2.4. Absorptive capacity

ChocolateCo and its suppliers were jointly exploring how to meet ChocolateCo's requirements, especially the ones related to design. FOUND-C-21210 provided colour and font specifications but encountered difficulties applying to the bioplastic packaging; for example, FOUND-C-21210 asked for a cream colour, and the result tended to be orange. FOUND-C-21210 received a lot of feedback and advice from the converter, and from this experience, FOUND-C-21210 realised the limitations of the bioplastic material and got more understanding of working with bioplastic packaging. For example, in sealing the film, FOUND-C-21210 used an impulse sealer that needed to be repeatedly adjusted to get the appropriate temperature so that the packaging could stick, seal well and not burn. However, often the bioplastic films did not seal properly, thus needing rework.

> *"But you set it too low, and it doesn't seal properly. So we have to check every batch …And then, as they go into the outer packaging, we have to check again that it's sealed. And sometimes they're not very well sealed, so we have to reseal them." (FOUND-C-21210)*

Later, FOUND-C-21210 would adjust the packaging design to work better and more compatible with the bioplastic material, improving the text printed on the packaging to enhance the sharpness or aesthetic. FOUND-C-21210 planned to communicate more about compostable packaging to consumers, explaining more about the bioplastic material and disposal of the packaging.

ChocolateCo planned to scale up, and for that, FOUND-C-21210 researched some alternatives of flow wrap machines compatible with the current packaging and the possibility to use other types of compostable film. FOUND-C-21210 also mentioned the interest in learning about different bioplastic or compostable films available in the market and explored bioplastic films alternatives to anticipate any problems with the supply.

> *"…researching the correct machine, and maybe something that can work with different films in case there's a problem with the supply of one film, it's compatible with other films as well…" (FOUND-C-21210).*

3. The outcomes of co-innovation

ChocolateCo worked with a converter to apply bioplastic film to the product. The bioplastic packaging used by ChocolateCo was quite simple as the converter provides a flexible film bag with the ChocolateCo label printed on the film, then ChocolateC inserted the chocolate bar into the film bag, sealed the film with a manual heat sealer and wrapped the product with the outer packaging made of paper. For this reason, the bioplastic film requested by

ChocolateCo must give good protection and appropriate function for food contact. FOUND-C-21210 read the specification for the material and found out that it is appropriate for food contact and has good barrier properties. FOUND-C-21210 explained that chocolate products are sensitive and easily affected by the external environment; therefore, moisture and odour barriers were crucial to protect the product freshness.

> *"Chocolate picks up other smells odours, very easily, strong odours. So if you store it next to onion or garlic or something, it'll be going to the chocolate. So it's very important to have odour barrier, moisture barrier." (FOUND-C-21210)*

FOUND-C-21210 also described some problems due to the limitation of the bioplastic packaging performance. ChocolateCo used a manual impulse sealer typically used for conventional plastic packaging; however, when applied to bioplastic packaging, it often causes the bioplastic packaging to burn or does not stick properly, and needs rework. These problems slowed the processing, and ChocolateCo had to bear higher costs due to damaged packaging and rework.

Inferred from the discussion, ChocolateCo has a genuine concern for the environment, willing to pay for the higher bioplastic packaging price and adapt to its limitation. FOUND-C-21210 mentioned that the bioplastic packaging currently being used was plant-based derived from sustainably grown trees, FSC qualified and home compostable within 45 days, quicker than many others that also have to be processed in the industrial composting facilities. FOUND-C-21210 noted that the conventional plastic packaging used more energy, leaked to the environment, and created microplastics in soil and sea. Thus, ChocolateCo would continue using compostable packaging and expect the future bioplastic packaging to compost in the landfill or anywhere safely.

> *"I still want to go for compostable, and ideally would compost in the landfill, or anywhere safely, because I see nature as being the perfect recycling system." (FOUND-C-21210)*

> *"I see this is perfect, whereas oil-based plastic recycling that uses a lot of energy. And then, not everything gets recycled it ends up in the sea… microplastics in the soil and the sea, and it's a huge problem." (FOUND-C-21210)*

4. The drivers and success factors

FOUND-C-21210 described the factors needed for the development of bioplastic packaging. One of them is related to packaging capability, where bioplastic packaging must have the expected specifications, primarily to protect products and be easy to compost in a relatively short time.

> *"The film is the most important thing, the specifications so the how easy it is to compost …the barrier for different types of barriers, very important as well." (FOUND-C-21210)*

Customers were also an important factor, and FOUND-C-21210 appreciated the ChocolateCo customers' high awareness of sustainability and the environment. However, FOUND-C-21210 received feedback from customers regarding difficulty at the packaging disposal because some councils do not take the compostable products in the compost bin. At the same time, consumers could not dispose of the compostable packaging in the recycling bin either, and other customers were concerned if the packaging still ends up in the landfill as it might not compost.

> *"My customers who are very environmentally aware and retailers. They find compostable products is a problem because some councils won't take it." (FOUND-C-21210)*

FOUND-C-21210 noticed the limitations of handling waste and infrastructure at the end of life. Education is needed for wider consumers and councils about managing compostable packaging waste, followed by working with the local councils for disposal of the material properly. According to FOUND-C-21210, despite the effort to create the perfect material, it is also crucial to ensure the compostable packaging is disposed of correctly, and this is the missing link. FOUND-C-21210 hoped that the local council would consider a policy to allow compostable packaging and process it in an industrial composting facility.

> *"Education for the council's, as well as the end consumer as well. Very important. Because you could create the most perfect film, but unless it gets disposed of correctly, and people know it's safe to dispose of in a certain way. It's quite, something missing." (FOUND-C-21210)*

5. The dynamic roles of customer and supplier

ChocolateCo case demonstrated supplier-customer collaboration to apply bioplastic packaging in small businesses. ChocolateCo was the adopter, as this case shows the ChocolateCo owner wanted to use compostable packaging because of a genuine concern for the sustainability and environment. Nevertheless, this case unfolds the supplier-customer dynamics as the customer is quite demanding on the aesthetic appearance of the packaging whilst the converter provides flexibility to adapt to small business needs by providing bespoke packaging and setting a minimum order affordable for small businesses. Furthermore, the converter played a role in promoting and facilitating the adoption of bioplastic packaging by providing support and advice for the business customer to work with the bioplastic packaging easily. Albeit the converter and ChocolateCo put much effort to work with the bioplastic packaging, there was no evidence of any material improvement made for ChocolateCo.

Appendix F-12: Product manufacturer case: TeaCo

TeaCo is a UK based company founded over a decades ago; it manufactures and sells a leading premium tea brand. This company promises to deliver a great taste from whole tea leaves, and some other variants use the whole flower or fruit mix. TeaCo's distribution covers all over the UK, targeting food stores, café and pubs, restaurants, hotels, major retailers, and available online. TeaCo has expanded its operation in the USA and distributes its products worldwide. TeaCo has gained B Corp certification for its commitment and efforts to bring positive social and environmental impact.

TeaCo ethically sourced tea from many countries; its production includes tea filling, packaging, and distribution handled by a manufacturing partner who had been working in close collaboration for a long time. Instead of using teabags like most tea in the market, TeaCo uses a tea temple, a pyramid-shaped tea bag that works excellent for brewing whole leaves tea. This tea temple is made from corn starch and compostable in industrial composting. In addition, TeaCo uses a plant-based film bag to wrap the tea temples and mixed carton and plant-based film for the outer packaging. TeaCo current packaging is plastic-free and has obtained a plastic-free trust mark from an independent organisation in the UK.

1. The process of co-innovation

TeaCo started the initiative to use bioplastic packaging at the beginning of the product creation. P21211 explained that the founder of TeaCo chose to use bioplastic to avoid putting plastic in the teabag. The founders of TeaCo considered that tea is an ingestible product and felt a bit strange drinking tea that had been sat in plastic. Therefore the founders chose to use plant-based plastic that would return to nature when disposed of as it felt more like the right thing to do. After the decision was made, TeaCo contacted the converter to make the teabag and did not find any issues to proceed with producing tea in a plant-based tea temple.

> *“And at the time, it would it just was a decision that we made. And so our manufacturers just made it, they just they just said yes. …there were no real problems from that...” (P21211)*

Around three years ago, TeaCo updated the packaging to have more plant-based content by changing the inner bag made of conventional plastic to a transparent flexible plant-based bioplastic and using a carton combined with bioplastic for the outer packaging. P21211 shared that to proceed with this change, TeaCo researched new plant-based material in the market and found the material, the supplier. Subsequently, TeaCo reviewed the supplier sustainability credential, checked whether the bioplastic material would meet specifications and requirements, especially in protection and food safety, and asked the converter to check the material compatibility to the production machinery.

> *“… it’s up to us in the initial conversation …with the supplier of the material, to have a discussion with them about our requirements. So, especially in food and drink, there are certain requirements that the packaging has to meet.” (P21211)*

P21211 added that TeaCo brought the design to the converter and asked to use it for all TeaCo’s products onward. Next, the converter sent the initial packaging prototype to be validated by TeaCo and proceeded to full-scale implementation. Applying bioplastic packaging to TeaCo’s product was relatively straightforward. P21211 stated that the bioplastic material is not always fit for the product or compatible with the production machinery; however, that was not the case at TeaCo, because the bioplastic packaging was used for a simple application, and TeaCo’s product did not require very high protection from the external environment.

> *“It’s been easy enough. And the machines have been perfectly compatible with the material that we’ve wanted to use, which has been really good.” (P21211)*

2. Mechanisms of co-innovation

2.1. Joint activities

P21211 explained that the first activity with suppliers was to discuss TeaCo's requirements to the biopolymer producer, mainly to ensure that the material met the food and beverage packaging specifications. TeaCo conveyed the material sample, packaging design and asked about the material's compatibility with the converter's process. It turned out that the converter immediately complied with TeaCo's request and had no difficulty in production time.

> *"…we would then get a sample of the packaging that we would like to use going forward to get a sample, send it off to the to the manufacturer or the converter, and just see how it goes." (P21211)*

The converter was very supportive of accommodating TeaCo's demand for changing to bioplastic packaging because TeaCo had a close relationship with the converter for many years. For example, although it was not easy when changing to bioplastic packaging, the converter could solve problems during the trial or application of bioplastic packaging without burdening TeaCo. The converter was willing to work on TeaCo's request for sustainable packaging because they also strived to be more eco-friendly or sustainable, thus aligned nicely. P21211 also exemplified that the converter would share information on new sustainable packaging or alternatives that might work on TeaCo's packaging and send the packaging sample, and TeaCo would be happy to discuss this new opportunity further.

> *"So instead of coming to us with loads of problems, they would come to us with like, Oh, this happened, but we fixed it, don't worry." (P21211)*

> *"So if they come across a piece of packaging that we haven't seen before, or they get sent a sample that they think would work really well in our packaging..." (P21211)*

2.2. Joint resources

The TeaCo case showed limited joint resources between partners, and in accordance with the P21211 statement, TeaCo and its suppliers did not build joint facilities such as special machinery to produce TeaCo's packaging. One of the factors was that the packaging requested by TeaCo used a simple design and did not require a particular machine.

> *"The materials that we use, or the style of packaging that we use isn't overly complicated. So the machinery that they would need in order to manufacture our product …that is quite a normal…" (P21211)*

As inferred from the interview with P21211, the supplier's resources included sending samples to TeaCo, such as samples of material resources from the biopolymer producer, samples of packaging from the converter, and the use of existing machinery production lines. Converter expertise was also crucial in overcoming problems during the transition to bioplastic packaging.

> *"We would then get a sample of the packaging that we would like to use going forward to get a sample, send it off to the manufacturer or the converter, and just see how it goes." (P21211)*

2.3. Relationship management

TeaCo has had a long tracked relationship with the converter for over a decade, and both sides showed a strong engagement. The converter also showed commitment to support TeaCo's packaging needs by accommodating the transition to bioplastic packaging, suggesting sustainable packaging alternatives. P21211 shared that TeaCo also planned to extend plant-based packaging to its tertiary packaging as suggested by their converter. This solution would extent TeaCo's sustainability practice to its logistic operations.

> *"We want you to make all of our products in this material going forward …we were able to present them, and they were they were so confident in saying yes, comes from the fact that we've developed a really, really strong relationship with them over the last 15 years." (P21211)*

In response to the converter's support, TeaCo also showed commitment to continue working with the same converter because the relationship that has been built for years was going very well. P21211 gave an example if the selected bioplastic material at that time was not compatible with the converter's machinery, TeaCo would look for alternative materials suitable for converter's machines or might delay the application of bioplastic packaging until the converter can produce it.

> *"It's just such a nice relationship that we've built with them over the last 15 years, there would be no reason for us to go anywhere else." (P21211)*

> *"You know, if there's huge issues in the beginning, we'll either work really hard to try and rectify those issues, or just find another solution. So we'll find another material." (P21211)*

TeaCo case appeared that the close relationship with the converter was built on honesty and openness. P21211 added that TeaCo and the converter communicate regularly and exchange ideas about new packaging innovations that would suit TeaCo. TeaCo and the converter were learning together in the application of bioplastic packaging, building synchronised direction and value, all of which then promote a closer relationship.

> *"We've got this sort of relationship where it's very honest. And it's very open… Yeah, it's really nice." (P21211)*

2.4. Absorptive capacity

TeaCo always looks for updated information on new bioplastic material, available technology, and material supplier. P21211 explained that TeaCo would check for better technology or improved bioplastic material that work more efficiently. TeaCo would consider the material specification that includes durability, end of life recyclability or compostability, suitability for food and refreshment packaging. Regarding the material compatibility with the converter machine, TeaCo sent the material sample to the converter to get feedback and then decided on the material.

> *"And the kind of the process that we underwent is that we did the research we found, we found the product, we found the company and then we took it to our manufacturers…" (P21211)*

TeaCo and the converter were learning together, sharing information and getting feedback from each other. P21211 shared that when TeaCo decided to use bioplastic packaging more than 15 years ago, this type of packaging was very new to the converter as well; therefore, TeaCo and the converter learned together. The converter shared their learnings from a production point of view, and TeaCo also shared anything learned from a customer point of view. P21211 also noted that this process helped both sides have the same vision and direction and built the same understanding of packaging innovation.

> *"… it's kind of a constant learning for both of us really, because in the beginning, when we decided to go down the bioplastic route, that was very new to them, as well. So we were kind of learning together.*
>
> *"…in the kind of packaging innovation and we've definitely grown together and shared our learnings as one." (P21211)*

From the production aspects, TeaCo learned how to work with the material characteristics, limitations, compatible machines, production rate, and how this bioplastic material would meet food safety requirements. P21211 added that this understanding helped TeaCo understand what is possible when searching for new materials or new packaging solutions.

TeaCo also paid attention to the consumer's reaction and feedback. P21211 exemplified that TeaCo noticed the consumer found problems and confusion on the disposal of the compostable packaging. TeaCo became aware that their consumers found it confusing and frustrating not to know how to dispose of the packaging properly as most of TeaCo's consumers have good intentions to sustainability issues. Subsequently, TeaCo responded to this problem by adding more information regarding the material and disposing of the used tea temple and the outer packaging.

> *"… it's always important to see how our customer reacts to an innovation in material because ultimately, it's down to the customer to dispose of that piece of material." (P21211)*
>
> *"…with the best will in the world, you want to recycle properly, and you want to put everything in the right bin. But if you don't know what bin it goes in, it can be very frustrating and very confusing." (P21211)*

The co-innovation facilitated TeaCo to understand that the application of sustainable packaging was not limited to the product packaging but also the packaging used for the logistic or tertiary packaging. Teaco learned from the converter that pallet packaging used to send the product to the warehouses and retailers would also create waste and should be addressed even though the consumers did not use this packaging. P21211 added that now TeaCo had a better understanding of the machinery, compatible material for wrapping the pallet, and, as suggested by the converter, TeaCo planned to extend the application of bioplastic packaging to its tertiary packaging.

> *"We are hoping to come up with a solution on our pallet packaging … we're trying to fix that problem, I guess just pre-emptively, and so we have a better understanding of what machinery, what materials can go on and the machines that wrap the pallets." (P21211)*

3. The outcomes of co-innovation

Co-innovation between TeaCo and the converter aimed to apply bioplastic material for TeaCo's packaging and did not include improvements to the material or production process. Co-innovation went relatively smooth because the bioplastic material was used for the simple packaging format. One of the critical performances was that the packaging must have the capabilities to protect the product and would not compromise product quality. P21211 explained the importance of choosing packaging materials safe for food products and have good barrier properties. The new material must also be compatible with the converter's machinery because TeaCo's filling and packing processes were at the converter's site.

> *"So it has to be food safe. The material on the inside has to be airtight. Stop any sort any bugs and stuff getting in." (P21211)*

P21211 explained that TeaCo accepted that the cost of bioplastic material was more expensive than conventional plastics because TeaCo considered plant-based packaging to be more eco-friendly or sustainable for TeaCo products. Besides, this option was also suitable for TeaCo's customer base and reciprocated the customers' expectations. P21211 added that TeaCo received positive feedback from customers for using plastic-free packaging, which became a factor that made the customers choose TeaCo.

> *"We're more than happy to spend a little bit more on a packaging solution that is more eco friendly." (P21211)*

> *"They've chosen us because we are more eco friendly or because of our packaging solutions, and so I think that's reciprocated by our customers…." (P21211)*

TeaCo chose plant-based compostable packaging because the founders considered it the right thing, especially it did not use fossil fuel and returned to nature after being composted. TeaCo analysed the carbon footprint and LCA internally, and TeaCo realised their knowledge gap and planned to undertake a formal lifecycle analysis. P21211 recalled that as the converter strived to improve its sustainability credentials, it can be concluded that the success of co-innovation with TeaCo would increase the converter's sustainability credential, which benefits the converter commercially.

> *"They strived themselves to be a little bit more eco-friendly, a little bit more sustainable. So the two ideas kind of aligned really nicely." (P21211)*

4. The drivers and success factors

TeaCo had a genuine intention to create high-quality tea drinks for customers, strive to meet a high social and environmental performance standard, and obtain B Corp certification. TeaCo initially chose the plant-based tea temple because the founders felt it was the right thing to serve premium tea from quality tea leaves that work well with a pyramid-shaped plastic-free teabag. TeaCo also made sustainability a value passed on to employees and applied to its operational activities. This value underlies TeaCo choice of suppliers to prioritise those with good sustainability credentials to improve TeaCo's packaging using more eco-friendly materials and accept higher prices of bioplastic material.

> *"We just did it because it was the right thing to do …we had this choice from the very beginning, you go plastic, or you go plant plastic." (P21211)*

> *"…you choose a manufacturer that is going to support you on your journey, you choose packaging solutions that are more eco friendly. It kind of trickles down into every decision that you make and every aspect of the business...." (P21211)*

P21211 considered innovation and change to use more environmental-friendly packaging in the industry is customer-driven. P21211 recalled a TV programme that highlighted plastics in teabags, and customers were utterly outraged because they were not informed about this when buying a pack of tea. Subsequently, many companies tried to fix this issue with a new commitment to be plastic-free or change the teabag's plastic content with other materials. P21211 noticed that the customers would share their voice on social media, influencing customer purchase intention; therefore, TeaCo would consistently hear the customer reactions and expectations, for example, how TeaCo's customers reacted to innovation in material and shared their confusion over the packaging.

> *"It's mostly customer driven… customers are going to social media to voice their outrage, and if you seem not to be making any changes, people just aren't going to buy your product." (P21211)*

> *"It's always important to see how our customer reacts to an innovation in material because ultimately, it's down to the customer to dispose of that piece of material. …But if you don't know what bin it goes in, it can be very frustrating and very confusing." (P21211)*

Accordingly, P2121 shared that even though the customers had chosen eco-friendly products and had the intention to dispose of the waste properly, there are challenges in the waste stream. Some of the problems are the limited infrastructure at the end of life, some customers do not have access to recycling, or certain councils did not collect food waste. Therefore, more communication and lobbying to the government are needed in order to bridge this gap.

> *"…what the customer really wants to do and what the company is trying to do, and then there's a bit of a gap …The infrastructure is not there." (P21211)*

5. The dynamic roles of customer and supplier

TeaCo case showed that the brand owner initiated to adopt bioplastic packaging and use more eco-friendly material for the teabag. The founders felt that teabag put in the consumer's drink should be free of plastic and then initiate using plastic-free tea temple, a pyramid-shaped plant-based teabag, which worked well for putting tea leaves. TeaCo then researched and looked for the material, material supplier and converter to produce their desired packaging.

"…when we started, we made a choice to go down the plant plastic route, the bioplastic route. And because it just felt like a bit more of a bit more like the right thing to do." (P21211)

"…we would make all the decisions, we would have all the conversations with the with the product supplier, and then we would just present it to the converter." (P21211)

TeaCo and the converter built an excellent close relationship since the beginning, and there was a strong engagement between TeaCo and the converter to remain in the collaboration. TeaCo and the converter started learning together in applying plant-based tea temple, and when TeaCo wanted to improve the outer packaging using plant-based film, the converter was very supportive and managed to find solutions that satisfied TeaCo. Beyond giving support, the converter also influenced TeaCo by suggesting new material or extending the packaging application. TeaCo highly considered these suggestions, for example, when TeaCo planned to improve the tertiary packaging as suggested by the converter.

"…that kind of comes from having such a close relationship with them …otherwise we wouldn't be able to find these solutions to potential problems, because it wouldn't be in our control, it would just be something that they do." (P21211)

Appendix F-13: Product manufacturer case: ServpakCo

ServpakCo is a UK-based company that has been running for more than ten years. It is one of the pioneers in the compostable packaging market. ServpakCo's operation has expanded to the US, New Zealand, Australia, and Hong Kong, where they are selling a wide range of compostable packaging in the form of products made from bioplastics and compostable paperboard. All of ServpakCo products are made from plants rather than common plastic. ServpakCo provides packaging for the foodservice business such as cups, cutleries, plates, salad containers, straws, napkins, takeaway boxes, and bags. These products are sold to the UK and global customer base, including big distributors, contract caterers (who provide catering to offices), hospitals, schools, and other businesses (cafes, hotels, and restaurants, for example).

ServpakCo works with converters worldwide, who act as the manufacturing partners for their products. This collaboration has grown positively since the company started. ServpakCo's products are certified for industrial composting and safe for the environment. ServpakCo also provides services beyond packaging, such as marketing communications, waste consultation, and composting services to help customers maximise the advantages of compostable packaging. ServpakCo's hard work has been well recognised, as evident through the awards they received in innovation, environment, and sustainability over the years.

1. The process of co-innovation

ServpakCo initiated the co-innovation process by looking for plant-based materials and converters which transform those materials into packaging. ServPakCo selected its partners by prioritising collaboration with leading bioplastic material producers and converters experienced in producing bioplastic packaging. QA-C-21215 explained that ServpakCo bought the packaging from the converter and requested a special design for ServpakCo products. Accordingly, ServpakCo determined the design and requirements and, together with the converter, developed the design to be implemented in the actual production. At the development stage, the process frequently did not run smoothly, and multiple iterations were required because ServpakCo paid close attention to the product quality before they were sent to the customers, including functionality and visual appearance. According to QA-C-21215, the iteration process was usually lengthy, but working with an experienced converter helped the process run seamlessly. Subsequently, ServpakCo controlled the quality standard and gave the converter approval to continue to full-scale production. Furthermore, the converter would send the packaging to ServpakCo's warehouse to be distributed to the customers.

> *"We will maybe talk to the (bioplastic) material producers to understand what new materials they're working on, and what new functionality they've got to offer…" (QA-C-21215)*

> *"All of our products are designed by us… There are certain features …the branding is applied to the product well, and it's legible. So, there are functional quality aspects that we have to control, but there are also the visual." (QA-C-21215)*

Furthermore, ServpakCo sells products to customers and collaborates with customers in waste management. According to QA-C-21215, ServpakCo supplied foodservice products to several customer bases such as caterers, cafes, distributors, and the government. ServpakCo strives for the packaging to be composted at the end of its life cycle, following the circular economy principle. Therefore, ServpakCo works hard to build customers' trust in compostable packaging by certifying its products to assure quality and compostability, educating the customers about compostable products and waste management, and providing waste management services for business customers.

> *"We spend a lot of money to certify our products to make sure that they are certified as compostable and are accepted in the industrial composting facilities. …that goes hand in hand with the waste stream consultancy and advice that we give our customers." (QA-C-21215)*

2. Mechanisms of co-innovation

ServpakCo's co-innovation is not only limited to developing packaging and selling it to customers, but also managing proper disposal for the compostable packaging. ServpakCo is the middleman between the converter and the business user, and it separately manages co-innovation with suppliers and customers. Their co-innovation with the suppliers aims to develop a lineup of foodservice packaging such as cups, salad boxes, and food trays, in addition to supplementary products that use bioplastic packaging such as napkins and sugar wrapped in bioplastic packaging. Meanwhile, their co-innovation with the customers aims to manage packaging which reaches the end of its life cycle, routing the packaging to the industrial composting facility.

2.1. Joint activities

In the packaging development, ServpakCo had limited joint activities with the biopolymer producer and relied more on the converter to manufacture the packaging. Inferred from the conversation with QA-C-21215, ServpakCo communicated with biopolymer producers on a limited basis to explore new materials and technology. The joint activities carried out with the converter showed that ServpakCo first determined the overall design and packaging requirements to be produced, then iterated on the design and quality with the converter to align with both ServpakCo's and the converter's standards.

> *"You will have to make sure that you go through various iterations of the design process, and make sure that everything meets our standard and, and is approved by us. So, yeah, it's a long process, and sometimes it works seamlessly." (QA-C-21215)*

QA-C-21215 explained that ServpakCo supplies foodservice packaging and provides support services for customers, such as composting service, socialisation, and training to the customers to educate them about compostable packaging and its proper disposal. ServpakCo also provides marketing communication materials such as posters, flyers, signages for all trash bins. They also optimise visual and non-visual cues to direct the consumers to dispose of the waste to the food waste bin sent to the industrial composting facility. For customers operating in a closed environment which allows them to control their waste, such as a cafeteria in a big office or university, ServpakCo helps them to transform their food waste into a closed-loop as in the circular economy.

> *"We also offer lots of other services relating to our brand, and that's including composting service, and marketing materials, …Like a way to get rid of all the waste in an environmentally friendly and sustainable way." (QA-C-21215)*

> *"…provide talks to their staff, so that we can really drive home the importance of compostable packaging and make sure that everyone understands the concept...." (QA-C-21215)*

> *"Because it's a very closed environment you're able to control the waste side of things as well so that really helped with our with our waste disposal closed-loop system." (QA-C-21215)*

According to QA-C-21215, the most crucial activities for the continuity of ServpakCo's collaboration with suppliers and customers were managing and balancing the supply of raw material and fulfilling the customer's orders. ServpakCo must support the customer's sales and business growth target, ensuring continuous packaging supply while the supply of raw materials tends to fluctuate, and sometimes scarcity occurs.

> *"We need to make sure that we have enough stock to fulfil their orders. That's pretty crucial." (QA-C-21215)*

2.2. Joint resources

Since ServpakCo relies on the converters to produce their packaging, the converters' expertise and capability are essential in the co-innovation process. QA-C-21215 shared that converters were of excellent expertise, very well-informed about bioplastics, and highly capable of working with the material. The converters also shared their knowledge with ServpakCo to develop packaging using their new functionalities. Converters with excellent reputations and certifications would produce the packaging in a certain quality standard that would mostly fit ServpakCo's requirements.

> *"When it comes to bioplastics, the converter is usually a very very well informed as well so we would maybe share knowledge and try and develop products using new functionality if it's out there." (QA-C-21215)*

At the very beginning of the collaboration, ServpakCo purchased the standard product range from the converter. However, ServpakCo co-invested in the converter's toolings and specific machinery to develop specific products over the years. QA-C-21215 recalled that, at the moment, up to 60% of ServpakCo products were produced through co-investment with the converters.

> *"We've opened and invested in tooling with our converters and bought production machinery if if the converter didn't have it … I'd say that was probably about 50 to 60% of our products have got our investment in them in some way." (QA-C-21215)*

ServpakCo's sustainability agenda is also aimed to build the closed-loop cycle in accordance to the circular economy principles. Therefore, ServpakCo works with the customers to manage the packaging waste. ServpakCo shares its environmental knowledge with the customer's staff by providing socialisation or training on compostable packaging and its waste management. QA-C-21215 mentioned an example of a regular meeting and talk on the importance of compostable packaging and how to treat it; those talks were held for the local government staff. ServpakCo also provides marketing communication materials such as posters, banners, or signages to be placed in the customer's operational area to advertise compostable packaging and directs end-users to dispose of their compostable packaging to the right bin. Moreover, ServpakCo also provides a waste collection service to collect compostable packaging waste from customers and bring it to the industrial composting facility. This service was just launched in several locations in the UK.

> *"We also offer lots of other services relating to our brand, and that's including composting service, and marketing materials." (QA-C-21215)*

> *"We have also worked with them to provide co-branded materials such as posters, flyers, and even signage for all the bins, which shows you how to dispose of the products." (QA-C-21215)*

2.3. Relationship management

ServpakCo has a long relationship with the suppliers and has relied on the converter to produce the packaging. QA-C-21215 explained that ServpakCo was a pioneer in plant-based packaging, especially for the foodservice market, and had collaborated with many different partners since the establishment of the company. ServpakCo prioritises cooperation with converters capable of processing bioplastic materials and producing packaging that can meet their quality standards. In this regard, ServpakCo considers the converter's reputation, certifications, and experience because ServpakCo will need to ensure that the packaging that they produce will meet a certain quality standard. The material producers usually partner with converters that can produce these materials, and sometimes ServpakCo asks for converter recommendations from the material producers. However, QA-C-21215 added that it could also be the other way around; ServpakCo would introduce the converter, with whom they had previously worked, to the material producer.

> *"…really grown these relationships over the 12 years …we were quite pioneering in this in this market, and we've come to really work very closely with the partners who produce… the product." (QA-C-21215)*

> *"We might ask the material manufacturer for their recommendation for converter, if they've got a good relationship with a converter… Or we might already be working with a converter, and we would then introduce them to the material producer." (QA-C-21215)*

QA-C-21215 explained that ServpakCo strived to build a long-term relationship with the converter to keep releasing innovative products to the market. ServpakCo regularly communicates with the converter, primarily to align quality standards for the finished product. ServpakCo works very closely with the converter and regularly visits the converter or arranges video calls to maintain regular communication.

> *"We worked very closely with them... Lots of regular communication, just to make sure that they understand the standards that we expect." (QA-C-21215)*

In terms of the customer relationship, QA-C-21215 explained that ServpakCo approached the customers by presenting their whole range of compostable packaging for food services, such as cups or deli containers, and a comprehensive way to sustainably reduce waste. ServpakCo has complementary services to support the customers' functional activities, such as providing marketing communication materials and waste management services.

> *"We would pitch the whole range to the customer... and we would also pitch a way to get rid of all the waste in an environmentally friendly and sustainable way." (QA-C-21215)*

ServpakCo built a tight-knit, strategic relationship with key customers such as big distributors or caterers by giving reasonable pricing and continuous supply in accordance with the customer's sales target. QA-C-21215 added that one of ServpakCo's biggest customers performed weekly reviews on ServpakCo's performance. ServpakCo communicates regularly with its strategic customers to ensure their needs are managed.

> *"…we need to ensure that their account is managed in the best way possible, that we negotiate with pricing, and with stock availability, with forecasting." (QA-C-21215)*
>
> *"It's just to make sure that we are meeting their targets, and that we get reviewed every week. We have to make sure that we're constantly trying to meet their targets as well…" (QA-C-21215)*

ServpakCo's case shows how the relationship with the suppliers and the customers was managed when ServpakCo relied on the converter to produce their packaging, and there were varying degrees of communication with the biopolymer producer and customers. According to QA-C-21215, although ServpakCo communicated with the biopolymer producers and converters, the co-innovation was not carried out in a three-way system. Communication with biopolymer producers is important for ServpakCo to explore new materials or technology for new product development and to manage the bioplastic material supply, especially when the material stock fluctuates. Meanwhile, the converter usually does not like it if ServpakCo communicates directly with material producers. Similarly, QA-C-21215 added that when ServpakCo worked on bespoke packaging orders, they would manage the project by communicating directly with the customer, without directly connecting them to the converter. With these communication boundaries, ServpakCo manages co-innovation in two sets of relationships because the material producer, converters, ServpakCo and customers did not connect to each other at the same time.

> *"…there's varying degrees of communication. Sometimes converters don't really like you talking to the material manufacturer…" (QA-C-21215)*
>
> *"The customers would never speak to the converter, so we would need to manage the project, and make sure that the product was produced in the way that the customer wanted…" (QA-C-21215)*

2.4. Absorptive capacity

ServpakCo focuses on developing and distributing the packaging while the converter manages the production. Accordingly, QA-C-21215 shared that ServpakCo received updates on new materials, functionality, or development from the material producer. Furthermore, to produce a specific bioplastic material, ServpakCo asks for the material producer's recommendation for converter alternatives that can work with that particular material.

The assimilation between ServpakCo and the converter occurs through intensive communication with the converter and customer, such as regular discussions and meetings to share project updates or weekly reviews with the strategic customers. QA-C-21215 shared that ServpackCo considered the converters as experts in packaging manufacturing. Accordingly, ServpakCo asks a lot of questions about packaging manufacturing to the converter and learns about the packaging or design possibilities that can be tried next. ServpakCo and the converter also work together to match their packing quality standards, resulting in the converter becoming aware of the quality requirement from ServpakCo, which emphasises both functionality and visual appearance. Likewise, ServpakCo also learns about the converter's production standard quality. Through this assimilation, QA-C-21215 explained that ServpakCo communicated the expected quality standards in a more intensive manner to converters that were either accustomed to producing conventional plastic packaging or were not too experienced with bioplastic materials. It can be concluded that, after the converter finally fulfilled ServpakCo's request, they would have a better understanding of the customer's quality requirements and become more capable of working with bioplastic materials.

> *"The converter is usually the one with the most expertise. We're the ones with the awkward questions want to produce a product that might not be possible." (QA-C-21215)*
>
> *"…when working with a converter who is perhaps not so experienced …we'd worked very closely with them, …lots of regular communication, just to make sure that they understand the standards that we expect." (QA-C-21215)*

ServpakCo maintains good relationships with customers by making regular contacts with them. This also allows ServpakCo to receive valuable feedback to improve their product range or meet the customer's needs. QA-C-21215 shared an example in which ServpakCo became aware of the changing market and regulation, such as the EU single-use plastics directive that banned plastic cutlery. Since this new regulation also banned PLA, it impacted one of ServpakCo's product range even though it was made of bioplastic. ServpakCo worked together with several customers to manufacture a new range of wooden cutlery to replace the previous cutlery range made from PLA to fulfil the new regulation's requirements.

> "*…ensure that we are taking into consideration, their concerns about the changing market" (QA-C-21215)*
>
> *"…changing our product mix to suit their new requirements so I think the EU single-use plastics directive is going to be banning plastic cutlery. And so for us that's our PLA cutlery. Even though it's a bioplastic, it's still counted in this new regulation." (QA-C-21215)*

With their up-to-date knowledge about new materials, technology, new functionality, changing markets, and regulations, ServpakCo continuously improve their products, offering a new range to the market that adapts to the customers' requirements, changing markets, or regulations. Then, ServpakCo go back to the converter and material producer to develop and produce the packaging. By addressing the customers' concerns and striving to create the perfect products for them, ServpakCo is able to retain their customers while manufacturing innovative products in accordance with the regulations.

> *"So we're working with the supplier to make sure that the quality is right, …works for our customers and it works with the range as a whole ... We're doing quite a lot of that at the moment, trying to meet new regulations…" (QA-C-21215)*

3. The outcomes of co-innovation

ServpakCo serves the foodservice market, in which their products are used to serve hot and cold food and beverages for dine-in or takeaway. ServpakCo's co-innovation focuses on developing a complete range of packaging applications for the foodservice business and proper waste management for compostable packaging. From the interview with QA-C-21215, it can be inferred that ServpakCo explored the new bioplastic material or technology available from bioplastic material producers but did not co-innovate in the areas of material development or manufacturing process improvement.

ServpakCo emphasised the product quality aspects and established a very detailed quality control for functionality and visual aesthetic. QA-C-21215 described several aspects of functional qualities that ought to be met: the material should be durable and very secure; the lid should fit the cup nicely without sharp edges, and visible points to ensure that the packaging is usable for the customer. On the visual aesthetics side, ServpakCo requires certain shapes or sizes, and their brand logo is embossed very nicely on the packaging.

> *"…It shouldn't feel flimsy or like it's going to break. And we have to make sure that the product is usable for the customer." (QA-C-21215)*

In terms of cost, QA-C-21215 explained that co-innovation did not lower the costs, as it depended on the packaging features requested by the customer. The cost may increase when the customer asks for a specific type instead of the standard range. The packaging quality standards are crucial for customers, and ServpakCo also certifies the packaging with biodegradability and home composting certification as proof of quality to the customers. Nevertheless, ServpakCo manages to increase cost efficiency from the operations side. One way to do it is by minimising shipping costs by bringing the production closer to the market. QA-C-21215 gave an example that, to serve the European market, ServpakCo partnered with European converters to produce the packaging, while the bioplastic materials were imported from the USA.

> *"I think our costs are going up …I suppose, new requirements for customers they, they want to use the products in new and different ways…" (QA-C-21215)*

> *"…certified everything again to home compostable is going to double your costs …but yeah we'll be trying all the time to make sure that we have the option for customers." (QA-C-21215)*

> *"…we can we produce this product with a European converter rather than somewhere in the USA or in Taiwan or just tried to bring it closer to home." (QA-C-21215)*

From a sustainability standpoint, ServpakCo prioritises plant-based packaging that is also compostable or recyclable. Therefore, ServpakCo looks for suitable materials from material producers to be processed by converter partners. ServpakCo considers compostable packaging suitable for the foodservice business, but there are weaknesses in the waste disposal system. QA-C-21215 added that compostable packaging would be more eco-friendly than conventional packaging when properly disposed of in industrial composting. To help with that, ServpakCo works closely with customers to manage compostable packaging waste properly; thus, co-innovation with ServpakCo will improve customers' sustainability or circular economy practices.

> *"PLA item in compost is actually very it's very environmentally friendly, and it's very easy for the consumer as well because they can just put everything into one bin, and it will turn into compost." (QA-C-21215)*

> *"But we also make sure that we focus on the waste side of things, and try and put it on our own waste streams where possible…" (QA-C-21215)*

ServpakCo keeps up-to-date with developments in bioplastic materials, market changes, and regulations. They develop innovative packaging according to the customer's needs as a result of Servpakco's close relationship with the customer. Co-innovation with ServpakCo is also beneficial for the converters as they can continuously produce innovative sustainable packaging widely used in the foodservice business.

"Our relationships with converters are long-term enduring relationships. We work together to make sure that the products that we produce for them, are right for us and innovative and first to market." (QA-C-21215)

4. The drivers and success factors

QA-C-21215 explained that the key factor in co-innovation was the material's availability and the continuous supply following the customer demands. According to QA-C-21215, some bioplastic materials were experiencing limited supply, and in order to buy and secure the material allowance for the next year, the converters would need to purchase large quantities from the material producers. Consequently, ServpakCo must carefully and consistently manage fluctuations in the supply of bioplastic materials to produce and sell packaging made from this material. QA-C-21215 added that it was essential to avoid shortages and ensure the key customers' supply target was achieved.

"I think that a big driver for co-development is, as we said before, material availability, particularly now… we need to make sure that we are consistently producing products made from PLA. And because if we don't use it, then our PLA allowance will go to a different brand." (QA-C-21215)

Customer demand is also an important factor that encourages co-innovation. ServpakCo serves the global market, in which different countries have different regulations. Therefore, QA-C-21215 emphasised the importance of following the changing market and regulations. Since the customers must follow the regulations in their operational areas, ServpakCo is keen to listen to customer concerns and quickly adapt to the customer's needs. For example, due to the new EU single-use plastic directive, ServpakCo prepared a solution for the customers by providing new cutlery products from sustainable wood.

"…mainly in Europe. There are different types of single-use plastics directives, for example, the different types of regulations that are coming in. We are really just trying to be one step ahead of, of those things for our customers…" (QA-C-21215)

ServpakCo also considers the end-of-life and infrastructure at that point as key factors for the wide adoption of compostable packaging. QA-C-21215 added that they needed the government's support, one of which was by further developing the infrastructure for compostable packaging. However, according to QA-C-21215, the government was quite hesitant in supporting compostable packaging due to limited access to composting facilities despite this compostable packaging cannot be recycled. Furthermore, QA-C-21215 noticed that not all customers had access to industrial or home composting, which could hamper the sales of ServpakCo products.

> *"…for PLA products in particular. I can understand the hesitancy with by governments because if you don't have access to compost, you can't recycle the product." (QA-C-21215)*

For this reason, ServpakCo continuously researches end-of-life rather than beginning-of-life solutions to provide evidence that compostable packaging is very environmentally friendly and convenient for the consumer. ServpakCo saw an opportunity to address this challenge and managed to create innovative solutions on the waste stream by collaborating with food services that operate in closed environments (such as cafeterias) because those customers can collect packaging and food waste on-site.

> *"If there was, you know, a way for government to be able to increase the infrastructure for compostable packaging, then, that really would be the answer for a lot of these things. But it's just very hard to always get your voice heard." (QA-C-21215)*

5. The dynamic roles of customer and supplier

ServpakCo's case demonstrates the customer's role in defining the packaging specification, as exemplified by ServpakCo's attempt to determine the design and standard quality before carefully relaying the information to the converter. ServpakCo engages with a broader supply chain, as shown by the fact that they co-innovate with foodservice industries and local waste services to overcome challenges in compostable packaging waste streams. As an example, ServpakCo offers waste management consulting and works with the local commercial composting to collect food waste from business customers to be sent to industrial composting.

Converters play a vital role in this case, as they are the key manufacturing partner. ServpakCo considers the converters as technical experts in bioplastic packaging manufacturing. However, the converter might also indirectly inhibit co-innovation with a wider supply chain because there were times when the converters were not pleased with ServpakCo's direct contact with the biopolymer producer. Therefore, direct communications among ServpakCo, converters, and biopolymer producers never occurred.

ServpakCo's case also shows the dynamics when working with big-name customers, who are mainly distributors serving expansive offices. To build a tight-knit collaboration, ServpakCo needs to fully support its strategic customer's operation, particularly to guarantee a continuous supply. QA-C-21215 shared that the customer targeted the quantity to be delivered following their own sales forecast, and they also reviewed ServpakCo's performance regularly.

> *"…we get reviewed every week, …from one of our biggest customers on our performance. …constantly trying to meet their targets …depending on the time of year and what products they want." (QA-C-21215)*

Appendix F-14: Product manufacturer case: PharmaCo

PharmaCo is a pharmaceutical company that operates globally, including in the UK and Indonesia. This company is an industry leader in producing medicines, vaccines and other healthcare products. Like other companies, sustainability is also a concern of PharmaCo. There are several agendas to improve PharmaCo's sustainability throughout its operation, including improving health and safety for consumers and employees to striving for a net-zero impact on climate and a net positive impact on nature.

PharmaCo targets several special agendas for packaging and the supply chain, such as eliminating single-use packaging, reducing environmental impact and achieving zero waste, prioritising recyclable and reusable packaging, eliminating problematic and single-use packaging when possible. PharmaCo has an ongoing co-innovation with a biopolymer producer to develop bioplastic for applications on various products, such as medicines for allergies, pain, critical illness other health care products.

1. The process of co-innovation

ParmaCo looked for collaboration partners approximately a year earlier. PharmaCo did not collaborate to develop a new material development from the start but looked for a material supplier with a product prototype. The biopolymer producer on the other hand, approached PharmaCo to engage in co-innovation after having an initial product prototype, which had been tested and developed to reach a pilot-scale capacity. The biopolymer producer must be able to show the potential to scale up and supply the PharmaCo global operation as well.

An important phase before both partners engage in co-innovation is the Initial assessment, in which PharmaCo considered the compliance to laws and regulations, partner's capability, scale-up potential, feasibility, implementation to different countries. PharmaCo's team looked in more detail to understand what has been done or achieved by the biopolymer producer, and the potential application, how it supports PharmaCo's need to fit end-product application and marketing in the global market. PharmaCo looked for many opportunities with other providers, then filtered and selected a shortlist of potential partners.

The co-innovation between PharmaCo and the biopolymer producer aimed to develop the material further to meet PharmaCo specific needs. The biopolymer producer's current bioplastic material has a few gaps; for example, the biopolymer producer early development was for the product with a shorter shelf life; hence needed to be modified to fit PharmaCo's pharmacy products with long shelf life. And as concluded from the discussion, co-innovation covered a long development process.

2. Mechanisms of co-innovation

Co-innovation for developing bioplastic packaging involved PharmaCo, the biopolymer producer and additional third parties; it did not start from the beginning of new material development but aimed to address gaps of the existing packaging prototype and implement the bioplastic packaging to PharmaCo's product. Nonetheless, HOPR-C-21219 exemplified that on some occasions, PharmaCo helped research in material development by providing research funding or grant to universities or research institutions.

2.1. Joint activities

Inferred from the discussion, joint activities between PharmaCo and the biopolymer producer partner mostly covered exploration and shared information, which helped the biopolymer producer to carry out further material development. Concept exploration between PharmaCo and the partner addressed the gap of the current development and resolved crucial aspects, such as packaging compatibility, application in different countries, cost and supply chain sufficiency.

Even though PharmaCo highly prioritised packaging to meet protection, safe consumption and safety standards as it is crucial for medicines, mutual adaptation and certain tolerance were given by PharmaCo when possible. Several examples were summarised from the interview; first, as the new material is different to plastic, there was not enough information to check safety standards like conventional plastic; therefore, PharmaCo looked for a benchmark, alternative testing or new testing to ensure safety. In order to do these, PharmaCo would need to involve more partners, experts and consultants for testing. Secondly, PharmaCo also accepted higher costs after considering the price affordability for the consumer and the profit for the company. The discussion about what the approximate end cost would be and the feasibility happened just before PharmaCo put its investment in co-innovation.

2.2. Joint resources

The biopolymer producer approached and sent proposals to several companies, including PharmaCo, as the development needed significant capital. The biopolymer producer ran the project, and PharmaCo contributed through funding to cover the development cost and scale-up. Most contributions from PharmaCo were in financial capital for the biopolymer producer in exchange for agreed deliverable and exclusivity. The amount of investment depends on scale, considering the benefit of the exclusivity to leverage PharmaCo's brand. However, HOPR-C-21219 stated that there was no joint investment in building a plant or special equipment in the co-innovation.

2.3. Relationship management

Inferred from the interview with HOPR-C-21219, partner selection, achieving an agreement and commitment were crucial for co-innovation. PharmaCo looked for many opportunities with other providers, then filtered and selected a shortlist of potential partners. In this mechanism, PharmaCo considered the following points: the biopolymer producer's early investors in order to gauge the potential of the company, capability to meet the expectation and deliver the result, how far biopolymer producer research has been done, data transparency, knowledge sharing between partners, additional third parties to be involved in the co-innovation, ethics and compliance. HOPR-C-21219 implied that the size of the biopolymer producer could show their capability to meet PharmaCo's requirements. So far, PharmaCo has found it challenging to collaborate with some providers including early small startups, which sometimes has not yet considered ethics and compliance or has difficulties getting there.

Several points to be agreed are the investment and deliverable, cost, intellectual property. Summarised from the interview with HOPR-C-21219, the amount of financial investment depends on the scale of the project, the benefit of the exclusivity to leverage PharmaCo's brand. Another essential point to be agreed is cost, and HOPR-C-21219 also recalled that it took a long negotiation to have an agreement on the joint IP ownership. PharmaCo has to consider its existing patents, whether a new patent with the biopolymer producer will be joint or separate.

2.4. Absorptive capacity

PharmaCo started looking for available technology and solutions in the market a year earlier. PharmaCo looked for an innovative new material that suits its sustainability direction from some potential partners. Next, PharmaCo thoroughly reviewed the partners' background and capability to work with PharmaCo. For example, PharmaCo acquired information about the partner's early investors, the development that has been done, and its scale-up potential, supporting data, proof of ethics and compliance. PharmaCo also looked for information on how the new packaging can be applied for the PharmaCo market and meet regulations from local authorities. Furthermore, PharmaCo also asked the partner to inform the estimated packaging costs charged to the final product. And PharmaCo, together with biopolymer producers, explored the gap in existing bioplastic material that has been developed to fit PharmaCo's needs in further development.

Inferred from the discussion with HOPR-C-21219, the assimilation between PharmaCo and the co-innovation partner occurred through sharing information and expertise. The biopolymer producer learned how to reach commercialisation, generate revenue, learn the industrial aspects, how to create viable business propositions and understand precisely what brand owner's need from PharmaCo's feedback. On the other side, the brand owner also learned the new technology and the potential application to the product and understood the early development process without doing the R&D themselves. Eventually, this new understanding would be applied to improve the bioplastic material for specific packaging applications at PharmaCo.

3. The outcomes from co-innovation

The biopolymer producer had developed an innovative bioplastic material from renewable resources. The material is derived into a new class material, which is chemically different to conventional plastics or the former bioplastics. This material works similar to the conventional plastic PET, but it is biodegradable and recyclable and at the end of life. The co-innovation with PharmaCo aimed to develop further the bioplastic material for specific packaging applications at PharmaCo.

PharmaCo highly prioritised protection for the product, strict health and safety standard for medicines. For example, durability and quality are crucial for PharmaCo's products, which have a long shelf life of approximately 2-3 years. The biopolymer producer's early development of the material was intended for single-use packaging and product with short shelf life. Therefore, the packaging needed to be further developed to fit the PharmaCo packaging specification and must not affect the product quality.

Cost is essential and has to be aligned with commercial aspects as well as profit for the company. Pricing strategy for the more expensive or premium product must come with more value or specific benefit, which can be quite challenging for medical products. HOPR-C-21219 explained that there is a limit for higher price medicines the consumer is willing to pay, and this is different to luxury or hi tech products like the Apple computer.

HOPR-C-21219 stated that packaging is one area to be addressed in the PharmaCo sustainability agenda, as seen on the company website. Accordingly, PharmaCo selected a co-innovation partner who can provide a new packaging material that contributes to PharmaCo's sustainability goals, including net-zero impact on climate, minimises waste, increases circularity, and improves the product environmental performance throughout the whole life cycle.

4. The drivers and success factors

Inferred from the interview with HOPR-C-21219, the key factors to successful co-innovation are cost, consumers' expectations of sustainability, the commercial advantage of using the new material, and compliance to regulations at the regional market the packaging is used. HOPR-C-21219 explained that cost was one of the essential discussions prior to co-innovation; each partner must agree on the cost of the bioplastic material and the final packaging. And the brand owner would accept a higher price than the conventional plastic packaging but highly considered the impact of cost on the customer's purchase behaviour and the company's profit. Moreover, consumer expectations on sustainability vary depending on product types, such as health care and convenience products like toiletries. For health care products, the consumers prioritise health and safety, whilst sustainability has got their lower attention. However, sustainability also helps to leverage the brand and PharmaCo, just like any other company, want to improve and pay more attention to sustainability for wider aspects of its operation, from health and safety of their employees to packaging. Therefore, the brand owner's decision in changing the packaging material is driven by the consumers' expectations on sustainability, the bioplastic packaging potential in increasing the brand, sustainability credentials or other commercial benefits.

Another key success in developing bioplastic packaging is to ensure availability and continuous supply of the raw material and the packaging at an industrial scale. The biopolymer producer must consider the supply chain to cover PharmaCo's global operation,commercial needs and avoid shortages, like in the case of recycled material, as more recycled packaging is used globally. In terms of market and regulation, HOPR-C-21219 also added that different markets or regions have different regulations. Therefore, the material development must consider the market where the packaging will be used, and co-innovation partners must be able to address various regional requirements.

5. The dynamic roles of customer and supplier

As concluded from the interview with HOPR-C-21219, The biopolymer producer plays the role of the expert in bioplastic material development by creating new material claimed to be more innovative than the other bioplastic materials. While PharmaCo, as the brand owner, plays the role of the adopter as the brand owner main intention is to use the new bioplastic material for packaging applications. The brand owner also directs the development to meet their requirements and quite demanding as there are many selections criteria to be met, including the partner capability, compliance, and quality requirements. The brand owner also plays a role as a connector to a wider supply chain, such as involving more experts or testing labs to address gaps that cannot be resolved by either the brand owner or the biopolymer producer.

Appendix F-15: Product manufacturer case: ConveCo

ConveCo is a multinational company based in the UK and is a global industry leader in consumer goods, selling a fast range of beauty and personal care, food, beverages and household products. ConveCo sells and manufactures the products and operates in many countries, including Indonesia. In line with United Nations Sustainable Development Goals, ConveCo sets its agenda on sustainability in diverse areas, such as targeting net-zero emissions, zero waste operations, and improving nutrition, health, and well-being.

ConveCo has a specific target on packaging, focusing on using less plastic, optimising and increasing recycling rate,using recycled plastic, and developing a reuse & refill scheme. Specifically for bioplastic packaging, ConveCo prioritises materials that would not affect food stocks and contaminate the recycling stream. ConveCo has used bioplastic packaging in a few products, such as ice cream and tea, launched in a few different countries but not yet available globally.

1. The process of co-innovation

Co-innovation di ConveCo aimed to develop further the packaging for application for the brand owner’s products, involving collaboration with the material producer, converter and other partners in the value chain. SUSPAK-C-21305 explained that first, the brand owner undertook an initial assessment of several material alternatives. The brand owner reviewed the source material, how the material provided the functionality, met specific technical performance, the end of life and compatibility to the existing waste stream. The brand owner also considered how the new packaging would fit the consumers’ expectations on sustainability and experience using the packaging, such as squeezing the bottle or drinking tea.

Second, the brand owner reviewed a number of potential partners and considered the proposed solutions. SUSPAK-C-21305 mentioned that the concept development and exploration for packaging application happened during the initial assessment and partner selection, in which the brand owner had discussions with the potential partners about the alternatives and solutions. Based on these discussions, the brand owner narrowed down the choice, then selected the collaboration partner.

Next, the brand owner worked with the partners, including the converter and the material producer, to further develop the packaging to be applied to the intended product. In this development, SUSPAK-C-21305 added that the material would be first developed for conversion into packaging at the converter who supplied the brand owner's packaging. Afterwards, the work moved to the validation phase, where the new packaging was being trialled at the brand owner's actual production, and if successful, the packaging would be launched to market.

According to SUSPAK-C-21305, the brand owner did not co-innovate for material development, which started from a lab-scale because this project usually takes a long time and lengthy process. An example of the brand owner involvement in material development is when the brand owner gave a research grant to academia or university to develop a novel material.

2. Mechanisms of co-innovation

2.1. Joint activities

ConveCo case showed that joint activities in concept development with partners occur before engaging in the collaboration. At this stage, the brand owner and the supplier explored the use of bioplastic materials for certain packaging applications and developed the material's functionality. In addition, the brand owner also discussed the project's timelines of when and what would be delivered.

ConveCo showed mutual adaptation by the brand owner, who is an industry leader. The brand owner accepted a higher cost than conventional packaging by considering the offset against other benefits. The brand owner understood that the bioplastic material would not be instantly compatible with the existing infrastructure, and changes were needed to accommodate the new material. SUSPAK-C-21305 shared an example when converting an ice cream tube from plastic to bioplastic; the converter changed the mould to a new shape, and ConveCo also assessed the implication of using paper-based ice cream tube to the whole value chain. Another example was when changing to biodegradable teabags, ConveCo had to replace the machinery because the new packaging uses adhesive for sealing, where the process is different from the heat sealing processing of the previous teabag. The brand owner highly appreciated the converter's willingness to adapt and full support. For example, when the packaging did not meet the agreed-upon criteria, some converters were willing to go the extra mile to find the root cause and solve it.

Nevertheless, SUSPAK-C-21305 added several considerations that the brand owner could not tolerate, and the co-innovation could stop partway through. For example, a problem with the bioplastic packaging functionality or when the packaging does not meet the brand owner's expectations. ConveCo highly considered how the new material works with the brand. While running the project, the bioplastic material might not be interesting anymore for the brand, so Conveco stopped the co-innovation project and looked for other sustainable material alternatives.

2.2. Joint resources

In the co-innovation, joint resources were limited to using the existing resources for trialling the new bioplastic packaging at ConveCo's actual plant or changing machinery when necessary. SUSPAK-C-21305 shared an example of the bioplastic ice cream tube at the validation stage, in which the material producer supplied the bioplastic to the converter to be processed into packaging. Next, the converter sent the new bioplastic packaging to the brand owner factory to be filled with the product. SUSPAK-C-21305 added that some infrastructure changes were required to work with the new material, such as changing the mould or other equipment for the ice cream tube and changing the machinery to process the new teabag. SUSPAK-C-21305 added that joint investment in resources was possible in different scenarios.

2.3. Relationship management

Inferred from SUSPAK-C-21305, the relationship with the biopolymer producer was considered as a long-term collaboration. Furthermore, the brand owner opened for collaboration with the biopolymer producer and the converter as well as with broader partners in the value chain and potential startups. However, the brand owner has many requirements, and failing to meet the functionality requirements could cause project discontinuation. SUSPAK-C-21305 added that this situation could even happen after the project had been up and running

Partner selection is an important first step for ConveCo before engaging in co-innovation. According to SUSPAK-C-21305, the brand owner reviewed a number of potential biopolymer producers and considered the proposed solutions. A comprehensive business case was presented to the brand owner to demonstrate how the bioplastic packaging meets functionality specifications that included technical properties, end of life and source of the material; fit for brand purpose; brand and sustainable strategy. The business case must also consider the marketing campaign and communication of material sustainability to the consumer. The brand owner also checked the sustainability credential of the biopolymer producer's material, such as home composting certifications. SUSPAK-C-21305 also explained that the brand owner's collaboration with the converter depended on the supplier's capabilities, which could vary in each region.

SUSPAK-C-21305 emphasised that clarity, transparency and trust are the keys to successful collaboration. Inferred from the discussion with SUSPAK-C-21305, other points that preserve collaboration with ConveCo are the agreement on the project's timelines and deliverables and commitment to supporting the brand owner—for example, being involved in more discussion and working above and beyond to resolve problems during the development project, being more flexible and adaptive to the brand owner's requirements, such as accommodating changes at the later stage.

2.4. Absorptive capacity

As inferred from the SUSPAK-C-21305 explanation, before engaging with one of the partners, ConveCo sought information on the available technology and materials, then held discussions with several potential partners regarding the solutions offered for ConveCo. In this case, ConveCo also reviewed the partner's capability to support and fulfil ConveCo's requirements. ConveCo also reviewed material specifications, such as source, technical performance, end-of-life disposal, and verified the material's sustainability credential. From the commercial side, ConveCo reviewed the extent to which the material is in line with ConveCo's sustainability direction, consumers' expectations on sustainability; hence changing to sustainable packaging would enhance ConveCo's brand.

SUSPAK-C-21305 conveyed the importance of supplier assimilation with ConveCo through discussion and being more responsive to ConveCo's needs. SUSPAK-C-21305 explained that even though the supplier has produced packaging according to the agreed requirements, there could be problems when implemented in the value chain. From this process, it can be concluded that biopolymer producers and converters could better understand the brand owner's needs and how materials worked along ConveCo's value chain. Eventually, the biopolymer producer and converter supplier could have more capability to provide solutions to ConveCo, be more responsive and adaptive when collaborating with brand owners.

3. The outcomes of co-innovation

As the co-innovation was intended to apply the bioplastic packaging for one of the brand owner's product packaging, SUSPAK-C-21305 emphasised that the functionality requirement must be met. The packaging must have the desired technical properties that work not only at the production but also convenient when the end consumers use the packaging, such as opening the ice cream tube, squeezing a bottle, or drinking tea.

For changing to using bioplastic packaging, ConveCo considered many scenarios to ensure the bioplastic packaging fit for purpose. SUSPAK-C-21305 exemplified that biodegradable packaging was an excellent option for teabag application because tea ground cannot be separated from the used teabag; thus, recycling was impossible. In this scenario, the sustainable path was to shift from the conventional teabag containing plastic to biodegradable teabags. SUSPAK-C-21305 added another example, the sustainable solution for multi-layered packaging should first consider reducing the layers into a single layer that work with the recycling stream before considering the biodegradable format.

SUSPAK-C-21305 stated that innovation had to come at a cost, and bioplastic packaging was more expensive than plastic packaging. However, the brand owner managed to offset the higher cost with commercial benefits, such as enhancing the brand through sustainability. Accordingly, ConveCo also paid attention to how new packaging would support ConveCo's sustainability agenda, reducing carbon footprint, more recycling and creating less waste. SUSPAK-C-21305 explained that the source of material and end-of-life options were also important considerations in choosing the packaging solution. Bioplastic packaging from renewable sources such as plant-based biodegradable teabags was more likely to reduce carbon footprint; despite the paper-based ice cream tubes from renewable sources, it is also recyclable and has better recycling rates than plastics.

Last, SUSPAK-C-21305 noted that ConveCo was cautious about claiming exclusivity or intellectual properties from the co-innovation and considering it on a case-by-case basis. ConveCo would allow the innovation to be accessible to other industries and widespread the application of bioplastic packaging because innovation in sustainability should be widely available for the future.

4. The drivers and success factors

As said by SUSPAK-C-21305, the key factor for changing to sustainable packaging and using bioplastic material is communicating sustainability to the consumer. ConveCo created excellent marketing communication, explaining the story on sustainability and how the ConveCo new packaging would contribute to sustainability. Using effective marketing communication would eventually enhance ConveCo's brand positioning through sustainability. Accordingly, ConveCo accepted the new packaging's higher price as this cost would be compensated by commercial advantages and increasing the brand positioning was one.

Inferred from the interview with SUSPAK-C-21305, the bioplastic material must meet comprehensive specifications to be accepted by ConveCo, a brand owner who is also an industry leader. Moreover, the potential partners must present these in a business case to the brand owner. Despite meeting the technical requirements and consumers' expectations of sustainability, the bioplastic packaging must also work with the infrastructure at the end of life. SUSPAK-C-21305 exemplified that ConveCo would review whether using biodegradable or recyclable bioplastic packaging will work with the waste stream and infrastructure where the ConveCo's product is sold. However, developing a bioplastic material took a lengthy development, and there would be a risk where the material would not suit ConveCo's interest anymore. Hence, ConveCo would have to stop the collaboration and look for a new solution in this situation.

Last, SUSPAK-C-21305 emphasised the importance of co-innovation for developing bioplastic packaging to involve a wider supply chain, NGOs and government to facilitate understanding of a more comprehensive view representing the whole value chain.

5. The dynamic roles of customer and supplier

Based on the discussion with SUSPAK-C-21305, it can be seen that ConveCo as the brand owner, is the central part between the packaging supplier and the end-user. The brand owner would adopt the new bioplastic material, which was ready to be further developed for specific packaging, and might collaborate with the whole value chain, including the consumer. The brand owner played an important role in communicating sustainability and change of the packaging to the consumer. ConveCo aligned the changes in the packaging with the consumer expectation and solutions offered by the biopolymer producer.

The dynamic in the co-innovation that appeared from the discussion with SUSPAK-C-21305 showed that ConveCo set comprehensive requirements for the bioplastic packaging and has the power to stop the co-innovation project. Therefore the converter and biopolymer producer must have the capability to provide solutions and adapt to the changes required. SUSPAK-C-21305 shared an example when everyone had worked following ConveCo's requirement, but in the end, the packaging did not meet ConveCo's expectations or the material choice was not suitable anymore, so the brand owner had to stop the ongoing project. Furthermore, ConveCo's team would have to start again to look for a new solution, change to other sustainable material and start a new project.

Appendix G: Benchmark case reports

Appendix G-1: Benchmark case: BioRes

The BioRes (code: P0207) has worked as a university researcher in the area of the development of new bioplastic material for over a decade. P0207 has a profound understanding regarding the bioplastics industry situation, the bioplastics characteristics, material development and the adoption of bioplastics by the industry. Furthermore, P0207 has had the experience of doing a research collaboration with the industry. The research project was developing a new biodegradable plastic film to be used for agriculture. This experience has provided valuable information regarding the process of developing bioplastics by a company that was used to conventional plastic but wanted to have bioplastics products. Extracts from the interview with P0207 are presented in the following sections.

1. The process of co-innovation

The collaboration process was initiated through an approach by the company to the university, looking for a biodegradable solution through a collaborative research project.

> *"…so they actually approached us looking for a resolution because they want to export their products…." (P0207)*

After some introductions, the initial assessment was undertaken through meetings and a visit to the company's plants. The visit aimed to acquire information about the existing machines, existing products, and performance requirements.

> *"…after one or two meetings then after the visit to the company, we just started to do the work." (P0207)*

The visit to the customer's plants enabled the researcher to learn the actual conditions that could not be covered by discussions and descriptions from the company's representative, and hence would avoid misinterpreting the information.

> *"We always have a tour of their plants to see their existing lines…" (P0207)*

Afterwards, the researcher started the work, which included the exploration of previous research, academic literature and patents as references in designing the product, conducting trials and creating a product prototype. This stage tends to be explorative as the researcher needs to design a novel product that would not create patent issues. Therefore, it is essential to collecting as much information as possible that contributes to the formulation of ingredients that achieve the plastic properties, and a process design that accommodates the company's existing technology, because the exact formulation of materials and processes that work are unknown.

> *"…we just collect, collected as much information as we can and then try to design new products. But we don't know how that will work…" (P0207)*

The challenge in creating a product prototype is making it small scale that not only works in the lab but also in a real production scale. Problems often occur when the prototype is applied to the real production machinery, hence, trials were undertaken iteratively in the lab and at the company's site.

> *"We produce materials in very tiny amounts and yes, to check them…. But if you really want to industrialize, yes, you have to move this scale into a very massive scale... And that's really difficult…" (P0207)*

> *"There is also a problem when you have to pilot the prototype product made, but there's also problems with implementation at the mass scale…" (P0207)*

The overall duration for co-innovation was more than a year, which was considered quite quick as the company urgently required the new product.

> *"If the company wants to do that thing, they want to do it very quickly …" (P0207)*

2. The mechanisms of co-innovation

2.1. Joint activities

Joint activities, which are predominantly carried out with companies, are trials and feedback. In the product development process, the researcher received a lot of feedback from the company, including details of the product specifications requested, information on the needs of the company and the target market of the company. Usually companies do not want big changes to their existing production process. Therefore, they tend to require adjustments to the formulation so that the product can be applied to their existing production process. In fact, the company closely guides development and determines formulations that are considered appropriate for the company. Feedback from the company is used for design improvement which is then retried until the result is accepted by the company.

> *"You still have to be engaged with industry because the thing you developed may not be the thing they want. So, still you have to engage with them, send the material to them, ask them to check if it is okay or just produce that in their industrial line." (P0207)*

> *"…like 20 formulations, we don't know which one is the best. And we work on that, we show them the results, they will say okay, just take a look at those 10 or something like that…." (P0207)*

A crucial point in joint activities is the sharing of confidential information which includes the existing formulation and its performance, but occasionally the company retained information deliberately.

> *"…company has to show us the details, of course that is confidential, the existing formulation and what performance they already achieved." (P0207)*

> *"They already have their formulation. The materials formulation, right, that works very well. And they should tell this to us. But they just not tell more." (P0207)*

The above quotes exemplified that the company only informs part of the formulation of the material to the researcher. One of the reasons is to keep the company's secrets because the formulation has not been patented.

2.2. Joint resources

Resources from companies that are provided for co-innovation include the provision of funds for R&D, information, provision of production facilities and personnel for trials.

> *"Sometimes they also send people to the university. They want their people to work here and use our facilities in that way…" (P0207)*

> *"But for those specific purposes, they may come to us to saying some their test there." (P0207)*

Meanwhile, the university provides researchers with high expertise and industrial scale R&D facilities. With these resources, the researcher can provide a variety of alternative formulations for selected companies.

> *"My contribution is about the materials development, based on my expertise, doing the design of the materials… made many, many impossible formulations…" (P0207)*

R&D laboratory facilities, especially those on a semi-industrial scale, are very important in the product development to facilitate upscale prototyping from lab size to real production size. In addition, R&D facilities are important for companies that do not have their own laboratories, for example small and medium-sized enterprises (SMEs).

> *"Because in our lab, we already have industry scale machines producing product… that's already like a semi industry scale here. So, so that's easier to upscale to their factory production…" (P0207)*

> *"Small SMEs…. They don't have labs in their companies. So they want to work with the university." (P0207)*

2.3. Relationship management

Based on P0207 experiences, communication with the representative of the company were crucial to the success of product development. Both partners were learning to communicate to obtain the same understanding through regular meetings, visits and discussions.

> *"Instead of learning the product or something, it's learning how to communicate between the industry and research." (P0207)*

The communication tends to focus on solutions for the company, by providing the product the company needs.

> *"They actually approached us looking for a resolution because they want to export their products." (P0207)*

It could be said that the company is more demanding in order to obtain the new product according to their needs, which are that it should be biodegradable, work in their manufacturing processes, meet the targeted performance and cheap. This was somewhat different from that of the researcher who was concerned with discoveries and creating novel material.

"The fundamental things they don't care about, that they don't care about, are if you will make a discovery or something; they just want you to develop the material they want." (P0207)

2.4. Absorptive Capacity

Absorptive capacity can be seen in the researcher's effort to acquire information that would help in the product design and improve the prototype, such as critical features of the customer's process, existing formulation and price expectation.

"…has to show us the details, of course that is confidential, the existing formulation." (P0207)

"Look at the specification and the film that, that we use, that they're using now. Look at their process to see what the critical features of that process might be." (P0207)

Obtaining a large amount of feedback from the company was emphasised during the interviews. Feedback was acquired from regular meetings and discussions; for example, feedback on the choice of raw materials, the extent to which the new product worked on the product production process and any additional treatments that were required to work with the new product, especially all of those significantly increasing the company's cost of production.

"…also the production or any treatment, in research or in any production and additional treatment. Even very simple things that will significantly add cost to their final product." (P0207)

"…send the material to them, ask them to check if it is okay or just produce that in their industrial line?" (P0207)

Besides acquiring feedback from the company, exploration of the references, such as research publications, existing design and formulations that were patented, were undertaken by the researcher to look for the possibility of adopting the existing design or processes, as well as avoiding patent issues with the new material.

> *"…do literature research to find out what, what products or similar products or concepts have already been published." (P0207)*

The key to success is to understand what the company wants in order to adopt bioplastics, which are cheap and high performance, not far off the conventional plastics and work in the existing process, then deliver that particular product.

3. The outcomes of co-innovation

Biores explained that the output of co-innovation was to make biodegradable new materials according to the company's wishes and the expected output were cost and performance.

In terms of price, the company is very concerned with profit margins after using new materials and wants high performance. The company can accept if the price of bioplastic is slightly higher and does not significantly affect profit. Companies often compare conventional plastic prices and performance, and of course this is very difficult to achieve with bioplastics.

> *"I'm worried about costs. We're always worried about if they will be able to make profit from these new products." (P0207)*

> *"Cheap, slightly higher to retain the profit." (P0207)*

> *"…but still they're very cheap. And also their mechanical properties are very good. So they are just hard to replace." (P0207)*

In addition, the company wants minimal change and to use the existing production machine because to buy a new machine that has an industrial scale requires huge capital expenditure. From this fact, bioplastic product innovation is incremental because of minimal change to the production system, having the same performance as the conventional plastic, and the same convenience.

> *"They want the change to be small." (P0207)*

> *"They want the product, new product, biodegradable product, to still be produced by their existing line…" (P0207)*

However, an essential outcome is a biodegradable feature to minimise negative environmental impacts.

4. The drivers and success factors

Based on the facts presented by BioRes, the key to successful co-innovation is to respond to demanding customer's requirement in terms of cost and performance and that are emphasised to be applied to the production process that already exists in the company. In general, the desired change is not a radical one.

> *"They just want to buy a product that will do their job. Right. And they don't want to spend more money to buy that product." (P0207)*

> *"Okay change the formulation, change the material, but use the same machines to produce the materials." (P0207)*

An important point for the success of prototyping is the upscale of the lab scale to mass industrial scale. This process is very difficult because of the characteristics of industrial scale machines that are difficult to replicate in lab conditions; in fact sometimes there are characteristics that are missed and new ones discovered during the trial, resulting in failure during the trial.

> *"If you really want to industrialize, yes, you have to move this scale into a very massive scale. Yeah, in a factory. And that's really difficult to, why we see a lot of papers published reporting these that, okay, very potential, but actually, not really applied much to the market." (P0207)*

In order that bioplastics can be widely adopted commercially, pressure from the government and massive behaviour change is needed. The government needs to set strict rules to force the industry to obey, or provide incentives to encourage initiatives from the plastic industry, because basically this industry is reluctant to change.

> *"If there's no such pressure from the government, I think ... Normally, they don't want to change." (P0207)*

> *"We really need the government to get involved to provide some initiatives." (P0207)*

Behavioural change is needed not only from industry but also from consumers or end users. However, this change is very difficult because all parties are comfortable with cheap, conventional, high performance plastic for various daily needs.

> *"Behaviour change, not only the industry but also the end user." (P0207)*

“Behaviour change, but that's very difficult. If we use bioplastic to replace those traditional things that's a good thing ...” (P0207)

5. The dynamic roles of customer and supplier

The apparent dynamic is that customers tend to be demanding in co-innovation. The customer also has the role of directing the R&D and its progress. P0207 expressed that companies encouraged the product development to be carried out faster and meet the requested specification but did not seem concerned with the mechanism or novelty of the product. Meanwhile, university researchers act as the experts, who are more likely to follow customer requests.

“They want data and stuff. And they normally don't want you to spend time thinking about the mechanism.” (P0207)

Nevertheless, engagement with customers is important to be able to know what is needed by the industry.

“…because the thing you developed may not be the thing they want. So, you still have to engage with them.” (P0207)

Appendix G-2: Benchmark case: PackCons

PackCons is a material and packaging specialist who has work experience in packaging consultancy and is involved in bioplastic packaging product development in multinational organisations in the UK. PackCons has relevant experience and knowledge in bioplastics packaging as well as a broad understanding of the packaging industry, which includes quality and design, new product development, the customers and the actors in the supply chain. Extracts from the interview with PackCons are presented in the following sections.

1. The process of co-innovation

Based on the interview with PackCons, the processes of co-innovation were divided into three phases; first is the product development between the biopolymer producer and converter, both having agreed to develop products that can be produced with defined processes and also accepted by the market. In this stage, the retailer and end user were not involved as they were also quite ignorant about the development. Second, once the viable product is ready, the biopolymer producer and converter promoted the new product to the product manufacturer and retailer, involving them to bring the new bioplastic packaging to market. The third phase was to scale up the production to an industrial scale.

> *"The biopolymer producer and the converter… We want a new product; it has to process in this particular way and produce products which we can sell." (PackCons)*

> *"The retailer and the end user will not be so involved… until it can be proved to be a viable product..." (PackCons)*

In the first phase, the biopolymer producer initiates the process by approaching the converter and retailer to promote and create demand for bioplastics. This was then followed by the product development phase, in which joint meetings, discussions, trials and feedback were conducted to develop a product that can be converted into efficient or viable processes and cost at the converter's manufacturing plant, which would then also meet the product manufacturer's expectation. In this phase, the feedback loop was essential for product development at the biopolymer producer side.

> *"… Joint meetings to discuss exactly the process and to look at the various stages, because it may well be that the converter can feedback to the biopolymer producer…" (PackCons)*

> *"That feedback loop between the converter and the biopolymer… that gives us something which is relatively easy to convert that the product manufacturer would want." (PackCons)*

PackCons added the detailed activities in this phase, which occurred at the biopolymer producer's side as follows: identify what the converter wants; then make the prototype that works at the converter's process as the converter is also confirmed to have a viable converting process. The next activity is to improve the product to reach a specific efficiency rate.

> *"…first stage quality control within the biopolymer producer …what the converters said they wanted. Your second quality stage is … we have a viable process … the product that is made is the one that is required at the right efficiency." (PackCons)*

The second phase starts when the viable bioplastic packaging is ready; the product manufacturer would then trial the bioplastic packaging at their plant using the real production scale. When conducting a trial, the product manufacturer must interrupt the regular production and switch to trial mode, where the product manufacturer tries to use the new packaging for the product. Hence, for this trial, the product manufacturer sacrificed machine hours and raw materials which eventually became a significant cost. PackCons added that following the production trial, the biopolymer producer and converter conducted market research to review the market response and forecast the demand. In this activity, the biopolymer producer and converter approached product manufacturers and retailers, provided product samples to be used for some periods and followed-up who would continue using bioplastic packaging.

> *"Then we get to the product manufacturer who will also interrupt their production to run the plastic at their plant with exactly the same product." (PackCons)*

> *"Producer would work, and say to the retailer, and say we will give you this product for six months, and then we will come into anybody else that wants it." (PackCons)*

PackCons explained that the third phase was to scale up the product into industrial capacity up to thousands of tonnes a year. This phase required substantial capital investment on the biopolymer producer and converter's side, hence the continuation of the project would be decided based on feedback from the market research, from which the production capacity and requirements from the product manufacturer could be estimated.

> *"The next thing is to scale up..." (PackCons)*

> *"The biopolymer producer and the converter are not going to make that huge investment until such time as they have the confidence, which is the feedback…" (PackCons)*

2. The mechanisms of co-innovation

2.1. Joint activities

The joint activities in the co-innovation, which were extracted from the interview with PackCons, involved the biopolymer producer, converter and product manufacturer.

> *"So, the activities, which we will do together, is we will look at the producer obviously, they will be working, and then the product manufacturer and the converter." (PackCons)*

At the initial product development stage, the co-innovation mostly involved the interaction between the biopolymer producer and the converter. This stage aimed to develop and trial a product that would work for the converter. Then, once the viable bioplastic packaging was ready, the product manufacturer and/or retailer would be involved to test the market response. The market research was a shared responsibility among biopolymer producer, converter and product manufacturer.

> *"...the biopolymer producer and the converter would, individually, make sure that the plastic produced is economic to produce and will convert effectively." (PackCons)*

> *"…We want to find out whether or not it's going to go into the marketplace… a shared responsibility... biopolymer producer, the converter and the product manufacturer." (PackCons)*

PackCons mentioned the other joint activities are meetings, discussion and trials, which then create a feedback loop that facilitates goal congruence, creating the same objectives regarding the product development.

> *"They would have joint meetings to discuss exactly the process and to look at the various stages." (PackCons)*

PackCons mentioned the development activities were heavier for the biopolymer producers as they put enormous resources, such as time, effort, works for significant R&D, followed by product introduction to the converter, product manufacturers, retailers and the market in general.

> *"...it's going to be that heavy in terms of the biopolymer producer, because of the fact that they are investing in research and development to produce the plastics..." (PackCons)*

However, the converter and retailer also contribute to the significant efforts made to conduct trials using the real production scale, for example, by shifting the regular production schedule, preparing the production facilities for trials, allocating engineers and personnel to run the trials, cleaning and returning the facilities back to regular production.

> *"… the converters production schedule will be impacted by a trial of the biopolymer." (PackCons)*

> *"…structured trial, lots of people, they're your best engineers, your best people … The nine to five window and then after that, you have to clean it all down again..." (PackCons)*

> *"That's huge costs. Then you must clean it down because you cannot have one polymer polluting another one." (PackCons)*

2.2. Joint resources

As mentioned previously in the joint activities, PackCons stated that the biggest resources were from the biopolymer producer, which invested a large amount of financial and non-financial resources, i.e. people, time and others, for the initial product development because of their interest in selling the product. These resources were typically from the biopolymer producer alone and were used for R&D to provide data and evidence that the bioplastic would work.

> *"…heavy in terms of the biopolymer producer, because of the fact that they are investing in research and development to produce the plastics… prove the plastic works…" (PackCons)*

> *"… they're going to put in financial investment. And they're going to put in people investment, and time investment, and any other investment you can think of…" (PackCons)*

"… it's in their interests to sell their product. And that's going to be an individual investment." (PackCons)

After achieving a certain level of viable product to be introduced to the customer, the biopolymer producer will involve the converter and product manufacturer in sharing the resources for further trials, which aim to make the product work in the converter's and product manufacturer's production systems.

"…you're looking at shared investment… across the biopolymer, producer and the converter and the product manufacturer," (PackCons)

The joint resources in the co-innovation are mainly related to R&D, i.e. many trials on a small scale up to real production scale, in which engineers, personnel are needed to run the development project, and the raw material, plant operators and machine time required to run the trial. All of these resources are extremely costly as PackCons exemplified the cost of the trial at the biopolymer producer was tonnes of raw material provided for the real production scale trial. While at the converter's and product manufacturer's real production trial, the contribution would be the plant time, which included shifting the regular production schedule and allocating people to the trial, then moving back for normal production. Labour cost was high as it included paying the best people in the project and possibly overtime. All of these were estimated to be 2.5 times higher than the normal production cost.

"…and the costs that the converter contributes will be in terms of their plant time. So, the biopolymer producible make some plastic and give it to the converter…." (PackCons)

"The idea is not to run it on the pilot plant but to run it as a production." (PackCons)

"And they have their best people there for the trial. So the labour costs then will be high."

"So a trial of one day will cost you two and a half days' money." (PackCons)

PackCons estimated that the converter and product manufacturer's resources invested in the co-innovation reached approximately 10% of the total project development cost. These resources were the plant time for trial on the real production scale, which impacted significantly on the cost of production. The other spending was the cost occurred in conducting the market research.

> *"...the converter contributions will be in terms of their plant time." (PackCons)*

> *"… they will do market research. And their 10% will come from market research." (PackCons)*

2.3. Relationship management

PackCons considered the biopolymer producer and converter relationship to be very close as they were aiming to develop new packaging which would be economically viable in the conversion process.

> *"...they are very close together, to actually develop something which is going to be economically viable." (PackCons)*

Based on PackCons's explanation about the relationship and communication in the co-innovation, the customer expected the product to meet a certain specification of plastic properties or performance and seemed to be quite demanding.

> *"The converter will say I want something which melts more easily, more malleable. Biopolymer will say, can't do that. The converter would then say but you must." (PackCons)*

PackCons considered that the most significant contribution of each partner in the co-innovation is honesty, candidness and openness to each other. Each partner would have to communicate which product works and which does not, and accept suggestions and solutions. PackCons also indicated the importance of trust, in which the supplier would give the best support to the customer. On top of that, PackCons highlighted several times that honesty was the essential key.

> *"… say up front, this works, this does not work… accept the fact that they have had this answer from somebody who's an expert." (PackCons)*

> *"The honesty is very key... you have to trust that they are doing their very best for you, for the product." (PackCons)*

2.4. Absorptive Capacity

The information needed by each partner during the product development and trial is related to the degradation of the plastics, how the bioplastic packaging will meet a set of standards and, more importantly, whether the bioplastic works efficiently in the manufacturing process.

> *"Right now this, in terms of developing the product, we need to know that our product degrades as it's supposed to, reprocesses as it's supposed to, efficiently. And that it meets the requirements of the necessary standard." (PackCons)*

> *"…biopolymer producer needs to know from the converter that the material converts at the right rate." (PackCons)*

> *"The converter needs to get from the product manufacturer, the information that the product can be made from the converted material at the right rate." (PackCons)*

The information is acquired in the form of feedback. PackCons exemplified that the biopolymer producer received feedback to modify the biopolymer so that the converter would be able to transform it into lighter packaging. (PackCons)

> *"If a different polymerization characteristic is required by the converter, they can go back to the biopolymer producer and say this is too heavy... can you make something lighter?" (PackCons)*

PackCons highlighted that most of the information was acquired from a feedback loop obtained from the frequent discussions and regular meetings with all partners. The meetings between the biopolymer producer and converter were more frequent than the joint meeting with all partners.

> *"So, the converter, the producer and the converter, will be having great discussions, very often and then they will feed back into the product manufacturer less often." (PackCons)*

> *"The biopolymer converter and biopolymer producer will have meetings very often, maybe once every six weeks. The joint meetings between the biopolymer producer and the converter and the product manufacturer may well be every three months." (PackCons)*

Based on the interactions with all partners, they learned about the progress of the product development and whether it should be carried on to the next stage. All partners also learned the dynamics of the bioplastic packaging market, which changes rapidly.

> *"…talking to each other very regularly try and get this thing through. And then you add on the 10% once they have come to their next stage." (PackCons)*

> *"So they learned from the end user and the retailer, the dynamics of what is required. It may well be if you have a project, which is two years long, the dynamics have changed." (PackCons)*

Accordingly, the learning was implemented into a decision to scale up from trial to industrial scale. This decision will only be made when the feedback from the retailer and product manufacturer has led to a certain degree of confidence about what would be the product and production capacity required and how high the potential demand would be.

> *"The next thing is to scale up. So, you go from a product, which can produce one ton a year to a plant which can produce 1,000 tons a year or 10,000 tons a year." (PackCons)*

> *"The biopolymer producer and the converter are not going to make that huge investment until such time as they have the confidence, which is the feedback from the retailer and the product manufacturer, that this is what's required and now how much tonnage they'll be looking for." (PackCons)*

The learning is also used to make any necessary adjustment to the product, such as enhancing the appearance, adding new characteristics to the bioplastic packaging to promote sales and cope with the market changes. However, this action often needs to wait for a revenue stream to be earned, to avoid many uncertainties. Therefore, the market dynamics need to be constantly reviewed, as the direction of the project might not be relevant to the current market trend and all partners need to ensure that they make the right investment in the bioplastic packaging development project.

> *"So therefore, if the product needs to be polished, to be embellished to have new characteristics, they can do that because they can see a revenue stream comes in; until a revenue stream comes back, everything is speculation." (PackCons)*

> *"The dynamics of the situation, in terms of our end user marketplace and our retail marketplace, need to be constantly reviewed. So it is, it is not a uniform marketplace; you may well be, at the beginning of your project, making a product which you think is required by the marketplace. If it is a long development, the marketplace may have moved." (PackCons)*

> *"…have to be constantly aware of the end user marketplace in order to make sure that they invest the correct amount of time and money in it. And it's done at the right time." (PackCons)*

3. The outcomes of co-innovation

The outcome of co-innovation would be product that can be converted at a feasible cost as well as meeting the market expectation, which could be driven by concerns for the environment.

> *"The most crucial point for the bioplastic product development, is that it can be converted. Because many bioplastics that have been produced were not well converted." (PackCons)*

> *"Yes, yes, And they have, the joint objective of the meeting is to come up with something which is going to help everybody be saleable, and be convertible and not be too expensive." (PackCons)*

> *"Yes, it has to work, has to meet the requirements of the marketplace." (PackCons)*

> *"The marketplace is driven by many, many, many things... If I buy something, though, and it does the planet good, that makes me feel good." (PackCons)*

PackCons also emphasised the importance of being biodegradable and compostable at the end of life of the bioplastic packaging. PackCons added that the ideal bioplastic would be made from renewable resources and degrade uniformly into a harmless substance regardless of the media for biodegradation. For example, bioplastics could biodegrade at the same rate in different soil characteristics.

> *"...ideal plastic. It's going to be made on a renewable source trees. Yeah. It's going to degrade uniformly regardless of the soil that it's put in." (PackCons)*

> *"…and it is going to degrade into harmless components? Hmm!" (PackCons)*

An example of uniform degradation is that of oxo-degradable plastics, which use oxygen for their degradation and hence are independent of the soil characteristics. However, these plastics are not in the bioplastics category; in fact, oxo-degradable plastics release harmful micro-plastics into the environment.

> *"So this is where oxo-degradables do score because they just need oxygen to degrade. They don't need, it doesn't matter what soil you put them in... what microbiological profile... but they don't score because they fragment the plastic into micro-plastics..." (PackCons)*

PackCons also added that it would be ideal if the bioplastics were to degrade into a compost that improved the fertility of the soil.

“In a perfect world what you would want the plastics to degrade back into would be the life that lives in the soil, which improves the fertility of the soil.” (PackCons)

However, current bioplastics have not yet met the ideal, as PackCons gave the examples that PLA biodegrades into greenhouse gas, and the available compostable plastics have not added nutrients to the soil.

“PLA for example... it degrades into massive quantities of carbon dioxide greenhouse gas, which is not really where we want to be.” (PackCons)

“…that compost has an, is a physical-based structure... nutrients... water... to make plants grow better, bigger. What if we take a plastic that is compostable?... It provides one thing only... It provides some structure.” (PackCons)

4. The drivers and success factors

PackCons explained the key success of co-innovation for bioplastic packaging is to develop biopolymer material that can be converted into packaging and works in the existing manufacturing process at the converter and product manufacturing plants. And this would be the most essential, as PackCons stated that many bioplastics are currently available but only some of them could work with the manufacturing processes.

“The most crucial for the bioplastic product development, is that it can be converted. Because there are many bioplastics that have been produced which were not well converted.” (PackCons)

“So, the most important thing is there are lots of different plastics around today but only some of them can be converted.” (PackCons)

PackCons explained the drivers of the bioplastic packaging industry, including co-innovation among the actors in the supply chain, would be the market and demand. The demand would be more in the future, and this is determined by the consumers.

“Your marketplace is then driving innovation. But, and this is this is the first time I've ever seen it in this particular sector. It is really quite fascinating.” (PackCons)

“It's very relevant because of the fact that you can see the demand is there.” (PackCons)

“…and it is, it is a demand that isn't just for products and information. It is for knowledge, that the thing works, for confidence. The demand for confidence is, is there being expressed in the most remarkable way.” (PackCons)

"If you don't spend enough on your ticket, you'll miss the bus. Simple as that. There are other people out there doing similar developments today. If you choose not to invest enough money enough time, then somebody else will come along with something which does a very similar job and you will lose everything." (PackCons)

Even though there is concern about the environment and sustainability issues, the actors in the bioplastic industry would still be concerned more about making sales and profit. It was expressed by PackCons that often salesman would be more likely to be concerned about sales targets and bonuses and retailers would promote sustainability to enhance their brand.

"If there are dynamics or adjustments, then you can make those adjustments once you have the marketplace because... when the biopolymer producer sells some biopolymer, when the converter sells, when the product manufacturer sells, they will make a profit." (PackCons)

Co-innovation needs to involve a wider range of stakeholders in the industry, such as the government, NGOs, financial institutions, and policy makers, in order to ensure people with many different interests pull in the same direction; for example, by exploring the best ideas and solutions for plastics, providing recommendations to the government, and investing funds in product development.

"We need organisations like, as I said, Ellen MacArthur and Greenpeace..." (PackCons)

"They bring some good ideas, but there isn't somebody looking at every single idea... We need this "blockchain" style organisation to know what everybody is doing, and picking out the best parts and bringing them together to benefit the world." (PackCons)

"The other things are recommendations from companies or NGOs like WRAP... that supports the environmental processes of government... to invest in industry." (PackCons)

...to communicate with people who will give them money, bankers or NGOs, because they can't do it from their profit." (PackCons)

Other than that, PackCons implied the need for regulations and standards that work universally and also stated that the current standard was not yet properly designed.

> *"We need to know that our product degrades as it's supposed to, reprocesses as it's supposed to, efficiently, and that it meets the requirements of the necessary standard. At present we have an awful standard for recyclability, which is EN 13432." (PackCons)*

PackCons also inferred that market change is inevitable but there are not many players in this business, and incumbents are still reluctant to make a move to bioplastics. Thus, there is an opportunity for the new player to capture the bioplastics market.

> *"Get into the bioplastic business because the changing market is inevitable. But currently not many are playing." (PackCons)*

> *"You'll see the company involved in the petrochemical... at this moment in time they are not investing significantly ." (PackCons)*

> *"They have incredible inertia regarding doing new things and bioplastics are going to take significant advantage of that." (PackCons)*

5. The dynamic roles of customer and supplier

The role of bioplastic producer, converter and product manufacturer in the co-innovation was clearly identified by PackCons. The bioplastic producer was considered as the driver both of the product innovation and the collaboration. The biopolymer producer is the expert who could determine the performance of the bioplastic packaging being processed by the converter and product manufacturer.

> *"The bioplastic producer only makes money when they… so, they are the driver." (PackCons)*

> *"The physical properties, how it works, is best determined by the biopolymer producer. So that, that information will come from them." (PackCons)*

The converter was considered to be the "middle man" or the connector between the biopolymer producer and the market. The converter's role was to create the most efficient conversion to transform the biopolymer into packaging and then sell it to the product manufacturer or the retailer.

> *"You have to then make sure that you have both ends of the production chain tied up – the producer and the product manufacturer... and the converter is in the middle." (PackCons)*

> *"Whether or not those properties restrict or are made easy… and the conversion processes… is to be established by the converter." (PackCons)*

"And once they have a prime producer of a bioplastic all they have to do is to efficiently convert one material into what the other wants to buy." (PackCons)

"Their job is to sell the film. They are the converter."(PackCons)

Thus, PackCons considered the converter's role to be the most crucial. On the other hand, the converter would benefit the most because the converter's input is minimal. In fact, once the work in establishing demand has been created by the biopolymer producers, the converter will receive orders from the product manufacturers or the retailers. The converter needs to focus only on creating the most efficient conversion process while having the opportunity to obtain different viable options from biopolymer producers.

"…the most crucial call for the bioplastic packaging product development is going to be from a converter." (PackCons)

"So therefore, work has already been done between the prime producer and the retailer."

"And once they have a prime producer of a bioplastic all they have to do is to efficiently convert one material into what the other wants to buy. So really, as far as the converter is concerned, then they'll convert whatever is commercially available to do. Their input in it is minimal because of the fact they have just got to find the most efficient way to do the job."

Finally, PackCons considered that the roles of the product manufacturer and retailer are market research selling, and introducing the bioplastic packaging to the end users.

"…are effectively the people who will sell it to the end user. They will know because of their market research exactly how to introduce it to the end user... to actually get the message across... we now need the retailer to polish it to make it attractive to the end user." (PackCons)

In brief, PackCons highlighted that the role of each partner in the co-innovation should be in providing information for each partner in order to develop the right material for the converter and the right packaging for the product manufacturer.

"And the role of each partner is for the biopolymer producer to put on, provide as much data as possible." (PackCons)

The dynamics in the co-innovation were many, and PackCons identified the common problems as being the time and commitment to run a trial at the converter's or product manufacturer's real production plant and sharing confidential information.

PackCons explained the problems arising during this trial are to agree a schedule for the trial that will not only work for the people involved in this project but will also impact the normal production schedule. On the converter's side, the impact would have a higher cost as the converter would also lose the opportunity to produce, then sell and sometimes has to pay overtime to catch up.

> *"The common problem between them is time and commitment." (PackCons)*
>
> *"The converters will be fitting in the work, to try it, at a time when they are already producing plastic for somebody else." (PackCons)*
>
> *"The conflict opportunity exists because the converter has to plan the interruption to their production to run the material... means that they make no money on that day." (PackCons)*
>
> *"They'll have to run for 12 hours on the day and after that will have to run for another 12 hours, so they will run the extra time at overtime rates." (PackCons)*

Other difficulties were related to honesty in sharing confidential information, such as revealing the cost of production to each other.

> *"…different parts of the process being honest about the cost that they have. Not very common." (PackCons)*

Appendix G-3: Benchmark case: InopackDir

InopackDir works in an NGO that manages innovation, research and funding and InopackDir's primary focus is supporting innovation R&D projects in the UK in sustainability, particularly sustainable plastic packaging, in which bioplastics plays an important role. InopackDir also has knowledge and experience of plastic recycling and consultancy for developing sustainable packaging solutions, in which some of the responsibility includes setting up a variety of programmes which utilise biodegradable materials for packaging, such as meeting compostable standard EN 13432 requirements and to develop the best applications.

1. The process of co-innovation

InopackDir explained that co-innovation follows the normal product development process. It starts with the design stage, in which the direction of the product development is established, and the bioplastic material was considered.

> *"…start with a, effectively a product brief and design brief nuance, to manufacture a piece of packaging, either to replace an existing packaging... perhaps for a new product. And the decision will be made at an early stage to say we want to use biomaterials." (InopackDir)*

> *"The design process will get underway, hopefully, with some notion of material selection..." (InopackDir)*

The next stage was the prototyping stage, in which a small scale bioplastic was tested and improved in a reiterative process to produce a working prototype that was ready for the real production process.

> *"But they may go through various iterations of prototyping. Reiterating, and at some point, you would hope that they'd actually start utilising the target material." (InopackDir)*

> *"But ultimately, you'll get to a position where you have a working prototype of the product." (InopackDir)*

Subsequently, the prototype was used for certification application, for example the EN 13432 certification for biodegradability and compostability. The certification process might take up to 12 months and claims should not be made before the product has been certified.

> *"…then is when, in my experience, the certification applications will be made... usually EN 13432." (InopackDir)*
>
> *"The time it takes to actually undertake the test, which is measured in months, and the waiting lists, again, anecdotally and maybe at the moment can be anything up to 12 months, so it can be a huge timeline." (InopackDir)*
>
> *"…unless you do get it officially certified you can't make claims..." (InopackDir)*

Afterwards, the company prepared for scale-up, which is to use the new bioplastic on a real production scale. Problems that occurred were mostly related to the consistency of the prototype, whether it would have the same performance as the traditional plastics, and work well in the real production system, where temperature, machinery and other aspects were not the same as in the prototype environment.

> *"So, bio materials don't form in the same way as traditional plastics and processing temperatures are less well understood, particularly processing at scale, and other factors such as consistency might not get the same kind of snap fit... often will have uncertain results." (InopackDir)*

Additionally, the company would have to find a material supplier that was able to supply, and provide support in utilising, the material, and find a product manufacturer that will use the bioplastic packaging. Then all partners signed a business contract to work together.

> *"If they set out to produce a piece of bio-packaging, they work with a material supplier, they work with their target manufacturers, and they get there on a contract basis." (InopackDir)*
>
> *"They'd have the foresight to ensure that the manufacturing supply chain that they were wanting to use could also adapt and adjust to utilising the bio material." (InopackDir)*

2. The mechanisms of co-innovation

2.1. Joint Activities

InopackDir mentioned the most important activities were to share updates on the progress and potential issues, and jointly resolve any problems in the project.

"The most important thing I believe, is the involvement of everyone to resolve the problem..." (InopackDir)

"So it's, really that's important, to get everybody all to bottom out all potential issues and answer all the potential problems…" (InopackDir)

Regular update meetings were useful to ensure that everybody working on the project understands the action plan and obtains the necessary approval or agreement.

"Update meeting and ensuring that everybody understand the change need to be made." (InopackDir)

"I think it would be more regular updating, to bring the production of the packaging, it's obviously important to always get their approval." (InopackDir)

2.2. Joint resources

It can be inferred from the interview with InopackDir that the shared resources between the biopolymer producer, packaging and product manufacturer were time and expertise, materials for development and resources related to product testing. InopackDir also added information about the material degradability as one of the essential resources.

"If all the agents in the supply chain work together in a way that probably the be… time and thought…" (InopackDir)

"And most people will get to a functional piece of bio packaging." (InopackDir)

"…but other elements of resources, obviously that pilot thing, and a lot information about their degradability..." (InopackDir)

2.3. Relationship management

InopackDir mentioned the importance of building good relationships, liaising with the downstream supply chain and ensuring each partner benefited by the collaboration.

"I think my understanding, it's really really important cause with your production to get everyone downstream to be involved in your business development in bioplastics." (InopackDir)

"Obviously, you need to ensure they're all affected and they understand the parameters..." (InopackDir)

"Again, it is more important to liaise with your customer when you're building out the analysis towards the end of life." (InopackDir)

The involvement of each partner in problem solving should be based upon transparency.

> *"The most important thing, I believe, is the involvement of everyone to resolve the problem..." (InopackDir)*

> *"Open transparency. That to me is the most important thing." (InopackDir)*

2.4. Absorptive Capacity

The packaging manufacturer side often require data and information about the bioplastic materials available in the market and the required manufacturing processes.

> *"…little bit, erm for example, people at the packaging manufacturer at the moment ask what material is available around, what processes, that kind of knowledge." (InopackDir)*

> *"On the production side, things like one of the fail rates, the actual…"(InopackDir)*

And during co-innovation, the essential information needed from the production side was the actual fail rate during the implementation of the new material. Moreover, InopackDir added that users needed different information such as the handling issues and breakdown rate.

> *"From the consumer perspective or from the user perspective, things like handling issues... genuine rate that this will break down." (InopackDir)*

> *"…a lot want information about their degradability." (InopackDir)*

InopackDir also noted the importance of considering the waste private sector that needed information regarding sorting mechanisms for the biodegradable and compostable plastic packaging.

> *"…from the waste private sector, what does break down, what they can break down, what probably does not." (InopackDir)*

Learning from each partner was obtained through their involvement in resolving problems together and their openness with each other.

> *"When we have been about to develop the project, the most important thing is the involvement of everyone to resolve the problems..." (InopackDir)*

> *"…open with each other so there is knowledge about this development..." (InopackDir)*

The regular activities for learning are mostly through regular meetings, in which everybody was updated on current progress, and understood the required actions and changes to be made.

> *"…update meeting and ensuring that everybody understands the changes that need to be made." (InopackDir)*

3. The outcomes of co-innovation

InopackDir explained that instead of just developing biodegradable or compostable plastic packaging, it is crucial to develop biodegradable or compostable packaging that can be clearly identified during waste sorting, either manually or by machine. This feature would prevent mixing the biodegradable and compostable waste, hence minimise contamination in the recycling waste and organic waste.

> *"Packaging that can be clearly identified." (InopackDir)*

> *"So you run the risk of mixing it. Because if I've got a pack of compostable it looks just like the non-compostable doesn't it? What are you going to do? Which bin am I going to put it in?" (InopackDir)*

InopackDir added that non-biodegradable bio-based plastic packaging should be at least recyclable.

> *"…bio-based product that can't biodegrade... at least you have to recycle that. But that is not biodegradable." (InopackDir)*

In short, InopackDir emphasised that bioplastic packaging product development must consider the existing end of life waste stream system and facilities.

4. The drivers and success factors

Before addressing the driver and success factors to develop bioplastic packaging through co-innovation, InopackDir showed the underlying conditions in the bioplastic packaging industry that need to be addressed and also that impact on whether co-innovation would work or not.

InopackDir emphasised many times during the interview that the major challenges for bioplastics product development and co-innovation were related to its end of life. Design of the product rarely considered the end of life waste stream, which is associated with local authorities, and private waste and recycling companies.

> *"The problem, of course, is that they very rarely consider the end of life options. And in an ideal world, if you were designing a piece of bio packaging for a target customer, you'd also want to engage with the end of life streams for that packaging." (InopackDir)*

> *"...potentially have to engage with hundreds of waste companies and local government" (InopackDir)*

InopackDir exemplified a shift to biopolymer in an aeroplane company and believed that the end of life solutions had significantly impacted the changes in the direction of the project. Therefore, co-innovation for product development that uses novel material such as bioplastic packaging should also consider the holistic supply chain engagement.

> *"…projects where airlines would be considering shifting to biopolymers... it's remarkable how many inputs and changes in direction can come by considering the end of life solutions." (InopackDir)*

> *"So ideally, you would like to see a holistic approach, where the whole supply chain was engaged in the process, at least for when you are pioneering the use of biomaterials in the new sector." (InopackDir)*

Moreover, InopackDir shared a few examples of the complexities of adopting bioplastic packaging. First, the biodegradable and/or compostable materials were not widely accepted in the waste collected by local authorities, and there were different waste collection systems applied by different local authorities.

> *"Because again these materials are not widely accepted by local authorities where organic waste is supposed to be..." (InopackDir)*

> *"I take that as one of the factors... even just in the UK the local authorities sometimes do not agree on the waste collection, the days, different contacts..." (InopackDir)*

Secondly, InopackDir also mentioned the current standard for biodegradable or compostable materials, EN 13432 certified the materials using the industrial composting facility and therefore the assumption of biodegradation could not be applied to other biodegradation processes.

“The private sector can lobby the central government to deliver things like standardised collection, or a guide about the collection, but central government doesn't have substantially direct responsibility towards the collection processes.” (InopackDir)

“EN 13432 is only certified for industrial, which is industrial composting and been broken. it makes certain assumptions…”(InopackDir)

With respect to the bioplastic certified by EN 13432, there are implications when the material is used for consumer product packaging. The consumers or end users' understanding of compostable and biodegradable packaging is lacking. Consumers are often confused when sorting bioplastic packaging waste, and many do not have home compostable standard facilities.

“People think that the word "compostable" is simple, but it's not. Because, is that home compostable? Is that good? Is that good home compostable?” (InopackDir)

“Sandwich waste is compostable and people put it into their home compostable and they are surprised when it doesn't happen because it's industrial compostable.” (InopackDir)

“And then a lot of people don't have very much knowledge about compostable standards.” (InopackDir)

Another challenge was related to the amount of time needed to build adequate infrastructure that can handle bioplastic waste and establish regulations, which might take years, while the rate of packaging innovation is much faster.

“Then you've got to make sure that these tools are practical and in place... and that again can take years for the infrastructure to be made. That's another challenge.” (InopackDir)

“Packaging innovation is at a remarkably faster rate than the waste infrastructure.” (InopackDir)

InopackDir illustrated a complicated circumstance in which key stakeholders, i.e. private sectors, local government and consumers, were "disconnected" and unable to resolve bioplastic packaging waste problems. The new packaging was commercialised by manufacturers who rarely considered the end of life waste stream and the packaging disposal would then have to follow different waste collection regulations from local authorities, which employed private waste companies to execute the collection processes. At this point, the local authorities have less influence over the packaging producers.

“There's been an interesting example where the local authority, private sector, consumer…” (InopackDir)

“So almost all the decisions related to the introduction of new packaging to the market are delivered by, within the private sector.” (InopackDir)

“But most of the decisions about the immediate disposal of the packaging are in the hands of the public sector. Even if the public sector is employing the private sector, there's paper waste collection, deciding the range, which to waste ,which to collect...” (InopackDir)

“…this disconnect. The public sector, predominantly the local government, not central government, has very little influence over the range of packaging that the private sector makes.” (InopackDir)

Therefore, InopackDir confirmed that the end of life stream, complexities with end users, waste collection, local authorities and central government policy had created uncertainties and a reluctance to move into this business or the bioplastic packaging industry. InopackDir also highlighted the necessity to have a roadmap or clear guide for bioplastic packaging product development that also addresses the end of life waste stream.

“Roadmap to revision for bio derived packaging to be collected effectively... to be taken back to the production side.“ (InopackDir)

As inferred by InopackDir, the key success for co-innovation in bioplastic packaging is working with a holistic approach that engages the whole supply chain.

“So it's almost a perfect problem, where not one of the key stakeholders in the group would bring people together.“ (InopackDir)

“So ideally, you would like to see a holistic approach where the whole supply chain was engaged in the process, at least for the time when you are pioneering the use of biomaterials.” (InopackDir)

5. The dynamic roles of customer and supplier

In brief, InopackDir mentioned the importance of each partner taking part in problem-solving. In addition, some of the problems occurred during the scale-up phase, in which the company needed to adapt the supply chain to the new material and occasionally the raw material supply was limited.

“For example, like I said earlier, they're all very tangible at the moment, real issues with your supply chain might change. Not just supply chain and their faces parameter but

having thought ultimate material that are not readily available and they probably don't have the supply chain." (InopackDir)

Appendix G-4: Benchmark case: MasterbatchCo

MasterbatchCo provides technology that helps conventional plastic biodegrade into a non-harmful substance in the environment. This company was established in 2015 and is located in the UK. The product of this company is a drop-in masterbatch, which is an additive put into the extrusion of polymer that takes place in the packaging manufacturing process. MasterbatchCo is a start-up and has made significant achievements in this field, winning green business, an innovation with global impact award, and secure funding for research and collaboration with large companies in the plastics industry.

MasterbatchCo does not produce bioplastics, but produces technology targeted at plastics leakage into the environment by helping conventional plastics to biodegrade into non-harmful substances. MasterbatchCo works with a manufacturer to produce this technology in the form of a drop-in masterbatch, which is in pellet form, to be added when melting the polymer in the extrusion process at the packaging manufacturer. Final products that use this technology will perform as conventional plastic, which is also safe for recycling. When the plastics escape from the recycling, the time-controlled biodegradation technology will trigger the breakdown process.

MasterbatchCo provides a highly valuable perspective regarding co-innovation because this company has successfully developed an additive for conventional plastic to biodegrade in the same way as bioplastics. MasterbatchCo's approach has addressed the challenges that bioplastics cannot deal with. Furthermore, in the development of the technology, MasterbatchCo has collaborated with academia, government and companies. For example, MasterbatchCo is currently working with a large manufacturer to extend the technology for more types of plastic, such as PLA and PET.

1. Process of co-innovation

The process of co-innovation in developing a drop-in masterbatch product is summarized according to INNOVP-A-0217's explanation. The product development with the client started at the administrative stage, and the clients were requested to complete a questionnaire that asked for information about the existing polymer/plastic and technology used by the client, the application to the client's product, and the supply chain details.

The next stage is the internal development, in which the internal "black box" R&D innovation team creates an initial development, conduct many trials and apply high-stress testing for many prototypes. These procedures aim to generate enhanced features or a product that gives a high level of confidence for testing at the next stage. All the people, activities and data in this stage were highly confidential.

Then at the pre-production run, the product was tested using the client's real production scale. In this stage, MasterbatchCo achieved a high rate of success in delivering the client's initial requirement, but occasionally the client requested additions or modifications, which also caused additional pre-production runs to be performed.

The subsequent stage was production and market testing, in which the marketing team distributed product samples for the customer to try, promoted the biodegradability as the advance feature that would enhance the client's sustainability actions, and finally obtained feedback from the market. Moreover, after a specific duration, the products were collected to validate their dormant time and biodegradability.

From the above processes, INNOVP-A-0217 highlighted that the crucial stages from the technical perspective were first, the customer completing the questionnaire and providing as much detailed information as required in the form; second, setting of the dormant time; and third, prototyping, trials, rigorous testing at the internal R&D division. INNOVP-A-0217 noted that having a lot of prototype testing at the internal R&D division was beneficial in order to obtain enhanced features and a high level of confidence in the pre-production and market trial.

2. Mechanisms of co-innovation

MasterbatchCo implemented three co-innovation mechanisms that involved a wide range of stakeholders and were not limited to B2B relationships between packaging and product manufacturer. CEO-A-0313 explained that the first mechanism was working with NGOs and academia. This collaboration aims to build a deeper understanding of plastic pollution, explore new insights related to the technology to be developed and comprehensive existing systems that can fully support the application of the technology.

> *"We work with broader stakeholders, like NGOs and academia, to, to develop a deeper understanding of the issues around plastic pollution… not just the technology but ensuring that the overall system around the technology is fully supportive." (CEO-A-0313)*

The second mechanism was B2B collaboration with customers who were positioned as an innovation partner. This collaboration is short-term, targeted at the most widely used plastic packaging applications, for example, in synthetic resins such as Polyurethane and Polyester. Also, technology development was focused on specific applications such as barrier layers for food packaging.

> *"…work with them as a kind of an innovation partner to develop something that would, that would ultimately solve the barrier layer issues…. on kind of a short-term development." CEO-A-0313*

The third mechanism is a collaboration in longer-term venture programmes, where MasterbatchCo aims to open a new market by working with the most prominent players in the market, for instance, extending the technology for application to the agriculture industry and non-woven packaging. This mechanism is still under development, which is currently at the R&D stage, and through this mechanism, MasterbatchCo is keen to leverage partners' insight and expertise.

> *"The third area, that is longer term ventures programmes… And we want to unlock a whole new market and work with one of the biggest players in that market to leverage their insights and expertise." (CEO-A-0313)*

2.1. Joint activities

CEO-A-0313 explained briefly that MasterbatchCo collaborates with customers, such as brand owners and packaging manufacturers to develop a packaging solution, for example, developing the masterbatch for barrier solution in the food packaging.

> *"…develop something that would, that would ultimately solve the barrier layer issues…" (CEO-A-0313)*

The joint activities were inferred from the explanation of the co-innovation process described by INNOVP-A-0217 and CEO-A-0313. The joint activities were sharing information and learning with the customer to understand the supply chain, which was useful in the determination of dormant time, pre-production trials at the customer's plant site, sharing information, a feedback and improvement loop during the product development and market release, and the collection of the product at the disposal stage to validate its biodegradability.

From the CEO-A-0313, joint activities involve a broader range of stakeholders, for example, NGOs and academia, to develop an in-depth and comprehensive understanding of the issues around plastic pollution and gather insights for developing the right technology and solutions that work with the overall system.

2.2. Joint resources

From the interview with CEO-A-0313, the most crucial resources for product development were people, which included scientists with a multidiscipline background, i.e. polymer science, biology and chemistry, that blended well in creating a unique intelectual property. Sophisticated leadership skill was also crucial for creating a productive environment where people with complementary expertise work to create a synergy, be willing to learn and understand whole issues, problems or technology, and share their best ideas to deliver a greater outcome that would contribute to the company's agenda.

> *"…people... scientists that combine polymer science, biology and chemistry..." (CEO-A-0313)*

> *"Leadership to ensure that you create the kind of culture that all those different disciplines are buying into… the collective agenda that you're trying to achieve." (CEO-A-0313)*

INNOVP-A-0217 outlined that from the technical standpoint the R&D capability was considered to be the crucial resource that enabled MasterbatchCo to develop the product carefully before it was presented to the customer at the pre-production run.

In line with that, CEO-A-0313 pointed out that other resources included infrastructure and tools, which were adopted from other industries such as automotive, pharmaceutical and molecular science. These resources would produce unique techniques, methods and approaches that ultimately would create a highly differentiated capability that would also be difficult to imitate.

> *"…combining those different industry experiences… gives you a kind of, a real differentiation in terms of your capability." (CEO-A-0313)*

Resources that needed to be built individually by MasterbatchCo were the innovative technologies that would become MasterbatchCo's intellectual property. Then MasterbatchCo would engage with other companies in collaboration only after MasterbatchCo had mastered that intellectual property. In general, MasterbatchCo provides technology and expertise, and partners provide a project budget, funding or share costs, thus each partner ought to provide complementary resources. One example of sharing resources was with one of the largest PET manufacturers in the world, which provided additional capabilities and investment in this development project with the aim of extending MasterbatchCo's technological capability to cover PET.

"In the first instance, it's by ourselves because you want to own the IP." (CEO-A-0313)

"…broader partnership ventures for grounds maybe where you share the cost… maybe bring in cash where you bring in capabilities that they don't have." (CEO-A-0313)

The interviews with INNOVP-A-0217 about the stages of product development implicitly showed the contribution of resources by the customer, such as machine time and people working on trials in the customer's real production line.

2.3. Relationship management

MasterbatchCo positioned the customer as an innovation partner in a short-term collaboration for a product development project. This collaboration aimed to provide a packaging solution for customers, for example, developing a barrier layer for food packaging.

"…as a kind of an innovation partner to develop something that would, that would ultimately solve the barrier layer issues. … on kind of a short term development". (CEO-A-0313)

In this relationship, CEO-A-0313 underlined honesty as the key to a good partnership. Related to product development, INNOVP-A-0217 also noted the importance of honesty from customers, as good partners would share confidential information about their manufacturing processes, which helped MasterbatchCo to simulate real conditions in the lab, hence increase the success of the prototype and the overall project.

INNOVP-A-0217 exemplified that there would have to be trust and confidence between the two parties, but occasionally, a particular client retained a piece of confidential information. In managing this issue, INNOVP-A-0217 explained that communication, both written and verbal, was essential to ensure the client understood the importance of the information to provide the right technology, to give the desired effect, to give a workable solution for the client as well as give assurance that MasterbatchCo will not share information with any third party. Although a certain client did not expose all their confidential information, MasterbatchCo would be using its expertise to be able to give the right solution.

Conversely, MasterbatchCo showed high integrity when working with customers by being honest with them regarding whether there are available solutions or not, always delivering the promised solution, and providing reliable technological solutions.

> *"We're very honest… we don't promise something that we can't deliver. So we have very good integrity." (CEO-A-0313)*

2.4. Absorptive capacity

CEO-A-0313 explained that the scope of the external information that significantly contributed to product innovation was broad and data-driven. The information was not only related to the packaging application, consumers' expectations, manufacturing process and supply chain but also the comprehensive system that included the circular economy, end of life waste stream, recycling and government policy. This information was obtained from lab tests, academic research and abundant feedback from the customers, NGOs and government.

> *"We primarily keep focused on packaging applications… and we've got data bases." (CEO-A-0313)*

> *"Because we're evidence-based and data driven." (CEO-A-0313)*

> *"You have the fact that recyclers don't want this... it doesn't fit the circular economy from that perspective." (CEO-A-0313)*

One example of the absorptive capacity inferred from the interview with CEO-A-0313 was regarding the limitations of bioplastic in the end of life waste stream. Bioplastic is only compostable in industrial composting, whereas in the UK only 4% of people can access industrial composting. Currently, the government does not seem to have an agenda to increase industrial composting facilities. Based on an understanding of this information, MasterbatchCo has developed a solution in the form of a masterbatch that allow plastics to be recycled, but when the plastic waste leaks to the environment, it will biodegrade without industrial composting.

"Most governments that I speak to in the world aren't scaling up industrial composting... And only 4% of people in the UK have access to industrial composting." (CEO-A-0313)

The exploitation of this understanding can be inferred by the product strategy, which targets high impact solutions where the problems are the biggest and so is the market. Accordingly, MasterbatchCo would suggest a solution to work within the system and possibly to disrupt the system as well. Furthermore, MasterbatchCo focuses on a solution for Polyurethane and Polyester to biodegrade, as both contribute up to 32% of the plastic waste that ends up in the natural environment.

"…you have sold, advised the whole system that you're either able to work within that system or you're taking steps to disrupt the system." (CEO-A-0313)

"So of the 32% of plastic that winds up in the natural environments… we focus on that first because it's where the issue is biggest and where the market is biggest." (CEO-A-0313)

The interview with INNOVP-A-0217 showed that customers were involved in product development as driven by two combinations of effort: first, the marketing approach to the customer, and second, the customer's approach to MasterbatchCo looking for solutions for sustainable packaging. Regarding the latter, packaging manufacturers and brand owners currently receive pressure from the market, asking for initiatives or actions regarding the plastic pollution that also puts their brand under pressure. However, the availability of workable or scalable solutions is limited.

INNOVP-A-0217 explained how the information from customers that helped product development was related to the details of the existing polymer or plastic used by the client, the existing technology, the application to the customer's product, the customer's supply chain process, storage and distribution periods, the shelf life in retail stores, consumption by the end user, and disposal and its location. All of this information was obtained from a standard questionnaire that must be completed by the customer before product development begins. This questionnaire facilitates understanding of the customer's need for a solution, then enables MasterbatchCo to provide useful advice, work on an efficient scale-up for a pre-production run and create a BT product with a dormant time that suits the customer's supply chain process.

CEO-A-0313 added the data gathered from the result of prototype testing, which is performed by third-party ISO-accredited laboratories. The tests applied strict criteria to prove biodegradability in a variety of applications, using a different combination of additives, inks or resins. The test results were fed back to the innovation team for the improvement of the product being developed, and used as evaluation and a learning database for continuous improvement in the future. Examples of tangible product improvements can be seen from the initial masterbatch, version 1.1, which produced biodegradation of polyurethane films within 226 days and polypropylene rigid packaging within 336 days, then experienced many improvements until the final version of the masterbatch, i.e. version 2.3.

> *"A network of ISO accredited laboratories that perform testing… produces data test reports …feeding back into the innovation team… we have learning coming through from that." (CEO-A-0313)*

> *"So understanding how your technology performs in different resins and different types of packaging applications … so you're kind of continually improving it." (CEO-A-0313)*

CEO-A-0313 looks at strategic level information and feedback, which were not only important for product improvement being worked on with the customer but also gave a broader picture of the solutions that were actually needed by the market and the improvement of MasterbatchCo's core technology. CEO-A-0313 also added that working with customers facilitated MasterbatchCo to have continuous learning, thus advancing the product and solutions.

> *"But really, the real insight is actually on the specific applications… to ensure that we're delivering, you know, what the market needs, to probably, to what we think it needs." (CEO-A-0313)*

> *"With the actual customers, we're continually learning… advancing the performance of the masterbatch." (CEO-A-0313)*

Based on CEO-A-0313's standpoint, customers seemed to lose confidence in the existing solutions due to false claims and greenwashing. Furthermore, having co-innovation with MasterbatchCo has allowed the customers to learn based on the data and evidence that new technology now exists that is reliable for sustainable packaging solutions. Customers also learn that the application of disruptive technology in this area has the consequences of disrupting the entire system, has significant changes end to end, including the customer's engagement, manufacturing and quality control for all in the supply chain. Lastly, customers learn more about MasterbatchCo as being a company with integrity and always providing the best for customers, and this will in turn create a good collaboration culture.

> *"There's a credible technology in this state that maybe they didn't appreciate before, because a lot of greenwashing and other false claims have been made." (CEO-A-0313)*

> *"Can't just have a disruptive technology… if they really wants to do things differently, they have to change end to end." (CEO-A-0313)*

> *"They realize that we have great integrity…. And that's important, not just in the science, but in the culture." (CEO-A-0313)*

3. The outcomes of co-innovation

The results of co-innovation were very significant for technological improvement and product performance. CEO-A-0313 explained that continuous learning from customers resulted in continuous improvement of BT products. In return, the customer accepted and fully supported the product because it can be applied seamlessly without significant additional processes, slowing the production process and reducing the efficiency of the production processes and customer supply chains. When viewed from a technical point of view, INNOVP-A-0217 added that the quantity of BT mixed into the normal polymers during the converting process was small amounts, only 2% of the total mixing; hence it is efficient for the converting process and does not contaminate the recycling system.

> *"With the actual customers we're continually learning, you know, so we're continually advancing the performance of the master batch." (CEO-A-0313)*

> *"So by ensuring that you're seamless in the manufacturing processes…" (CEO-A-0313)*

Besides technical performance, CEO-A-0313 also added the outcome of co-innovation is the improvement in the aesthetics of the packaging that uses BT.

“Besides performance, aesthetic, you know, that looks good.” (CEO-A-0313)

These performances are essential because this product does not significantly impact customer profitability, which contrasts with bioplastics.

"But it's, it's, you know, not, not compromising in any way in terms of the profitability.” (CEO-A-0313)

“…a solution for existing packaging … and not have such big cost implications.” (CEO-A-0313)

Regarding environmental performance, BT masterbatch effectively degrades certain plastics into a substance that resembles grease or wax in less than a year. The natural environment fully assimilates this biodegradation, and ultimately it only leaves carbon dioxide, water and biomass, which are not harmful to the environment. This has been proven through a series of tests, including the ecotoxicity test. Although BT makes plastic biodegradable, MasterbatchCo has considered the impact of contamination on the recycling process and created a solution. Also, INNOVP-A-0217 mentioned that the success of BT products was due to the accuracy in determining the appropriate dormant time that triggers biodegradability of the plastic packaging at the disposal phase according to the customer's supply chain timeline. INNOVP-A-0217 explained that within the dormant time, the plastic that uses BT will remain as regular plastic and can be recycled as usual. However, when the plastic enters the recycling process after the dormant period, the plastic transforms into a non-solid material, hence would not be recognised as plastics by the waste sorting machine nor entered the recycling process.

“…biodegrade rigid packaging applications like polypropylene detergent bottles within 336 ..... our now to version 2.3 of our master batch, and that is performing better ….” (CEO-A-0313)

“It's fully assimilated or fully consumed by the natural environment...” (CEO-A-0313)

“… a solution for existing packaging to help it biodegrade and not impact recycling.” (CEO-A-0313)

In terms of innovation, the main idea of MasterbatchCo’s product development is to create comprehensive solutions by "reinventing plastic". In this regard, CEO-A-0313 and INNOVP-A-0217 emphasised that BT is not a bioplastic, but has a drop-in masterbatch, an additive that helps the normal plastic packaging to biodegrade, by transforming it into no longer being a polymer. CEO-A-0313 also gave an analogy that BT is like the “Intel Inside" of biodegradability as plastics that have BT in them will be perishable within the natural environment without leaving negative impacts. CEO-A-0313 envisioned that BT would be broadly adopted and become the new standard for all plastics in the future.

> *“It is about reinventing plastic… and in the future all plastics are expected to use BT thus creating a new normal where all plastic would have our technology in it.” (CEO-A-0313)*

> *“… we'd like to be the "Intel Inside" of biodegradability.” (CEO-A-0313)*

Ultimately, CEO-A-0313 concludes that the BT product has become a credible solution for customers by having such performance.

> *“So anybody who really wants to prove a credible solutions solution… is using one of our, our master batches.” (CEO-A-0313)*

Co-innovation not only has a significant impact on product improvement but also generates data and evidence related to biodegradability in various types of plastics, especially those most widely used as well as those most contaminating to the environment. All these data would be shared with governments who are now continuously exploring solutions and are expected to be adopted in new policies.

> *“I think the other big way is that on the back of the data that you're generating, …governments can enshrine that in policy.” (CEO-A-0313)*

4. The drivers and success factors

MasterbatchCo uses a different approach in providing solutions to plastic pollution as this company does not develop bioplastic due to its limitation in coping with the complex challenges, such as scalability and supply of biopolymer on an industrial scale, possible migration when in contact with food, contamination at the recycling process, and the limitations of the industrial composting infrastructure.

> *"Bioplastic is very limited in terms of its scalability, it has a lot of the challenges … big challenges with supply.” (CEO-A-0313)*

"You have the fact that recyclers don't want this... contaminants, …it needs in most cases industrial composting, to biodegrade." (CEO-A-0313)

CEO-A-0313 shared that the key for new technology to be accepted by the market was first to meet product performance, such as traditional packaging that can be applied to existing manufacturing processes and supply chains. This statement means that the existing players, namely brand owners and packaging manufacturers, do not need to make drastic changes if they apply BT as the product works efficiently and seamlessly without adding processes to the production and customer supply chain, and therefore would not impact the customer's profitability.

"It performs and, and works as traditional packaging would… the functionality that you know, consumers and brands expect." (CEO-A-0313)

"… not compromising in any way in terms of the profitability... So if you're slowing them down or you're impacting the efficiency… the manufacturers maybe don't want to support." (CEO-A-0313)

CEO-A-0313 also added that new technologies such as BT must be able to work within the overall system, such as circular economy, end of life, and recycling. As such, the solutions offered by MasterbatchCo were data-driven and evidence-based as well as being seen as more flexible, working within existing systems or disrupting them.

"… beyond through to the circular economy, end of life …you're either able to work within that system or you're taking steps to disrupt the system." (CEO-A-0313)

"Because we're evidence-based and data-driven." (CEO-A-0313)

Regarding the technical area, INNOVP-A-0217 mentioned the keys were: first, that the questionnaire at the beginning of the collaboration captured detailed and comprehensive information for developing a suitable product; second, the determination of dormant time that does not disrupt the existing consumer supply chain; and finally, the percentage of BT added to the material mixture was very efficient so that it does not significantly impact the production process, recycling or the cost of production.

Last, an interesting finding from the technical side was the efficient scale-up from the laboratory to a real production scale due to the consistency and stability of the prototype over time. INNOVP-A-0217 exemplified that it took only a few hours in the laboratory and took up to 48 hours in the real production; hence the stability of the deployment of the masterbatch over time in the real production is essential. In addition to this success was the openness of the co-innovation partner to share confidential information about their manufacturing process, which helped MasterbatchCo to simulate the real conditions within the internal R&D.

5. The dynamic roles of customer and supplier

The role of MasterbatchCo in co-innovation is as a driver of innovation, not only for customers but for various stakeholders. In relationships with customers, MasterbatchCo acts as a provider of technological solutions, especially for various packaging applications, for example, developing BT to solve the barrier layer problem in food packaging. Moreover, for various stakeholders, MasterbatchCo has conducted studies with academia, built databases and provided input to the government, as described in the outcome of co-innovation section.

> *"We work with various stakeholders to drive innovation." (CEO-A-0313)*

> *"We primarily keep focused on packaging applications … for example, you know, most food packaging … would ultimately solve the barrier layer issues." (CEO-A-0313)*

CEO-A-0313 stated in the interview that the customer's role is as an innovation partner, in which the customer, in particular the bigger company, provides resources, including funding and MasterbatchCo shares costs as well. By working in a partnership, both parties contribute capabilities in areas that are not owned by partners and can be regarded as complementary.

> *"…work with them as a kind of an innovation partner to develop something." (CEO-A-0313)*

> *"…doing that with some of the bigger players, you know, so they can maybe bring in cash where you bring in capabilities that they don't have." (CEO-A-0313)*

INNOVP-A-0217 explained that the two most crucial contributions from the customer were: first, the honesty of the customer to share confidential information, such as the exact material currently used, that enabled

MasterbatchCo to address the right solution; and second, the customer's feedback was highly valuable to improve the technology and give awareness of solutions needed in the future. For example, solutions for PET plastic, which are used in many applications, often in the form of flexible films, were made a priority for product development by MasterbatchCo. Occasionally, problems and issues arise where the clients retain some confidential information. Therefore, written and verbal communication is essential to note the importance of the information to provide the right technology, to give the desired effect, to give a workable solution and to ensure non-disclosure agreement. Furthermore, even though the customer did not provide some confidential information, MasterbatchCo utilised its expertise and still managed to give the right solution.