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Analysis of waste management processes of fruits and vegetables in a food retailer

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Abstract

Food wastage, which represents food loss and waste, is raising more and more attention due to its environmental, social and economic impacts. Numbers show that one-third of all food produced for human consumption is ultimately lost or wasted. Besides, food production and resources may not be enough for the future as the world's population is constantly growing. Therefore, tackling food wastage is vital to feed everyone sustainably. Indeed, all players of the food supply chain have an important role to achieve such a sustainable goal. Although food wastage generated by retailers is not quite significant in the European Union, these amounts are higher in Portugal. Thus, companies in this sector are adopting proactive strategies to be more sustainable.

This project was conducted in the Sustainability and Circular Economy Department of a retail leader in Portugal, Sonae MC, with the objective of analysing the waste management processes of fruits and vegetables business line. Since this commodity represents a considerable portion of the retailer breakages, there is a considerable interest in improving its current practices.

This thesis describes all the processes of combating food wastage from the retailer under study and then suggests improvements regarding the fruits and vegetables wastage. All processes are presented according to the waste management hierarchy defined by the European Waste Framework Directive. The retailer has essentially three action axes to tackle this problem: reduce, reuse and recycle. All its practices and initiatives are described here from repackaging, price discounts, internal and external donations, recycling products to waste recovery and disposal. Since there is still room to improve, some innovative opportunities are also presented, such as the ethylene filter, consumer awareness campaigns, redesigning PDAs (personal digital assistants) lists, staff training and making a collaboration with a company that recovers energy from waste.

Since the retailer is highly interested in the donation process (one of the best strategies to combat food wastage), the impact of a in-store staff training to raise awareness on this subject has also been studied. A Difference-in-Differences (DiD) approach is used to estimate the impact of such training in the company's donations. It was noted that the intervention resulted in increases of 125% in the total amount donated (in euros), 41% in the total quantity donated (in units) and 125% in the total tax benefits retained (in euros).

Reducing and combating food wastage is an established goal of Sonae MC. The definition of alternative waste management processes helps the retailer to know exactly how this issue is being tackled, as well as the advantages and limitations of each one. Besides, some opportunities presented in this project are already on target for Sonae MC and others could be used as future pilot-projects. These innovations could lead to a reduction in the environmental, economic and social impacts of retailer breakages, such as the staff training. The training effort results in a positive and significant economic impact on the donation process, as well as, a mitigation in environmental and social impacts. Therefore, staff training about donations is beneficial not only for the retailer but for all food supply chain.

Resumo

Tanto as perdas como o desperdício alimentar estão a atrair cada vez mais atenção devido aos seus impactos ambientais, sociais e económicos. Os números mostram que um terço de todos os alimentos produzidos para o consumo humano acabam por ser perdidos ou desperdiçados. Além disso, é possível que no futuro a produção alimentar e os recursos disponíveis não sejam suficientes, dado o constante crescimento da população. Portanto, combater o desperdício alimentar é essencial para alimentar todos de forma sustentável. Todos os intervenientes na cadeia alimentar têm um papel importante para alcançar esse objetivo. Apesar de na União Europeia os desperdícios gerados pelos retalhistas não serem muito significativos, estes valores são superiores em Portugal. Então, muitas empresas deste setor têm introduzido estratégias para serem mais sustentáveis.

Este projeto desenvolveu-se no Departamento de Sustentabilidade e Economia Circular de um retalhista líder em Portugal, a Sonae MC, com o objetivo de analisar os processos de gestão dos resíduos de frutas e legumes. Como estes produtos representam uma parcela significativa dos resíduos do retalhista, existe um interesse notável em melhorar as práticas atuais.

Esta dissertação descreve todos os processos de combate ao desperdício alimentar do retalhista em estudo e propõe melhorias relativas à linha de negócio de frutas e legumes. Todos os processos estão apresentados de acordo com a hierarquia de gestão de resíduos definida pela Diretiva Europeia de Enquadramento dos Resíduos. O retalhista tem essencialmente três eixos de ação: reduzir, reutilizar e reciclar. Todas as suas práticas e iniciativas estão aqui descritas, desde o reembalamento, descontos nos preços, doações internas e externas, produtos de reciclagem, até à recuperação energética e destruição dos resíduos. Uma vez que ainda existe margem para melhorias, algumas oportunidades são também apresentadas: como o filtro de etileno, campanhas de sensibilização, reformulação das listas dos PDAs (assistentes pessoais digitais), formação dos funcionários e colaborações com uma empresa que recupera energia a partir de resíduos.

Como o retalhista está muito interessado no processo de doação (uma das melhores estratégias para combater o desperdício alimentar), também se avaliou o impacto de uma formação dos colaboradores das lojas para sensibilizá-los para este tema. A abordagem *Difference-in-Differences* (DiD) é utilizada para estimar o impacto dessa formação nas doações da empresa. Observou-se que a intervenção resultou nos seguintes aumentos: 125% no valor total doado (em euros), 41% na quantidade total doada (em unidades) e 125% no total de benefícios fiscais retidos (em euros).

Combater o desperdício alimentar é um objetivo constante da Sonae MC. A descrição de processos alternativos na gestão dos resíduos ajuda o retalhista a perceber exatamente como lidar com este problema, assim como as vantagens e limitações de cada um. Além disso, apesar de algumas das oportunidades apresentadas aqui já estarem a ser estudadas pela empresa, outras podem ser usadas como futuros projetos-piloto. Estas inovações poderão levar a diminuições dos impactos ambientais, económicos e sociais, como é o caso da formação de colaboradores. A aposta nessa intervenção tem um impacto económico positivo e significativo no processo de doações, assim como uma atenuação dos impactos ambientais e sociais. Portanto, esta formação dos colaboradores é favorável não só para o retalhista como para toda a cadeia alimentar.

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To my best friends, thank you for always being there and for teaching me the true meaning of friendship. I cannot imagine better persons to grow up with.

Lastly but uppermost, I would also like to thank all my family (including Max) for their support, care and patience. Thank you for making me one of the luckiest people in the world, I can only hope to always make you proud. In particular, to Rafael, thank you for always showing me the brightest side of life.

Sofia Figueiredo

"If you do not know where you are going,
Any road will get you there."

Lewis Carroll

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Abbreviations and Symbols

FAO	Food and Agriculture Organisation
UN	United Nations
FSC	Food Supply Chain
SDG	Sustainable Development Goal
FL	Food Loss
FW	Food Waste
FSA	Food Standards Agency
EU	European Union
FUSIONS	Food Use for Social Innovation by Optimising Waste Prevention Strategies
GFN	Global Food-Banking Network
OECD	Organisation for Economic Co-operation and Development
FCAN	Food Chain Analysis Network
Defra	Department for the Environment,Food and Rural Affairs
REFRESH	Resource Efficient Food and dRink for the Entire Supply cHain
GHG	Greenhouse gas
WRI	World Resources Institute
WRAP	Waste and Resource Action Programme
PERDA	Project to study and reflect on food waste
CNCDA	*Comissão Nacional de Combate ao Desperdício Alimentar*
ENCDA	*Estratégia Nacional de Combate ao Desperdício Alimentar*
APED	*Associação Portuguesa de Empresas de Distribuição*
F&V	Fruits and Vegetables
IPSS	*Instituição Privada de Solidariedade Social*
SGRU	*Sistema de Gestão de Resíduos Urbanos*
RSU	*Resíduo Sólidos Urbanos*
TMB	*Tratamento Mecânico e Biológico*
W2E	Waste to Energy
W2R	Waste to Resources
TCM	Transfer Conflict Management
MAP	Modified Atmosphere Packaging
ROI	Return Over Investment

kg	Kilogram
kcal	Kilocalories
Mt	Million tonnes
Gt	Billion tonnes
m^3	Cubic meters

Chapter 1

Introduction

Thousands of food kilograms are wasted every day while there are people starving. This fact places food wastage as one of the central societal topics in discussion nowadays. Food supply chains have the challenge to match supply and demand, while dealing with perishable products that can not be stored for long time. All the efforts to combat food wastage can not only stand on the economic aspect of the problem. The social and environmental impact must be considered. Consequently, more and more companies are adopting proactive sustainable strategies and developing sustainable supply chain management practices to address this issue.

1.1 Motivation

The Food and Agriculture Organisation (FAO) of the United Nations (UN) estimates that one-third of all food produced in the world for human consumption is lost or wasted, reaching 1.3 billion tonnes per year (FAO, 2011). In other words, tonnes of food never reached the consumer's table, yet 3 billion people nowadays have poor or inadequate diets (Global Panel, 2018).

Food wastage, which includes both food loss and food waste, not only means a missed opportunity for the economy and food security but also a waste of all the resources used for growing, processing, packaging, transporting and marketing food. Therefore, food waste is receiving particular attention from everyone. Grown but uneaten foods have significant economic, environmental and ethical impacts. Economically, these foods represent a wasted investment that can reduce farmers incomes and increase consumers expenses. The externalised costs that go into food, from the water needed to grow it to the fuel required to transport it, cool it, and cook it, are huge. Environmentally, food wastage inflicts a lot of impacts, including unnecessary greenhouse gas emissions and inefficiently used water, energy and land, which in turn can lead to diminished natural ecosystems and the services they provide. The wasted energy could have been put to a different use, or conserved all together, meaning fewer burned fossil fuels and emitted pollution. Moreover, if the food wastage was a country, it would be the third-largest CO_2 emitting country in the world (FAO, 2015). Additionally, when food is placed into landfills, it breaks down anaerobically, which means methane is released into the atmosphere. Methane is 25 times more impactful

to climate change than carbon dioxide. Food wastage has also a social impact due to the world's hunger and malnutrition problems (Pires and Vaz, 2013). Indeed, one in every nine people in the world do not get enough food to eat (FAO et al., 2019).

By 2050, the world population is estimated to increase from about 7 billion in 2012 to 9.6 billion people (Nikos Alexandratos, 2012; Ranganathan, 2013). Consequently, the food production will need to be 60-70 percent higher than in 2005/2007, in order to meet the demand. Making better use of the food and resources already available would help to meet the future demand with a lower increase in agricultural production. Achieving sustainability in the food system is imperative in the globalised world. Working towards such an achievement is a huge contribution to the Sustainable Development Goals (SDGs) defined by the UN. In particular the SDG 2 which focuses on resolving hunger and malnutrition, and, most importantly, SDG 12 which specifically calls for a halving of food waste across the globe by 2030 (Global Panel, 2018).

Food wastage happens worldwide and in all stages of the food supply chain, from initial agriculture production down to final consumption, and there are several factors which contribute to this issue. The lack of coordination among food producers and distributors, as well as inefficient purchase and meal planning among consumers, further increases the wastage of food (Ulf Sonesson, 2010). Additionally, the later a product is lost or wasted along the supply chain, the higher the environmental cost. Therefore, retail wastage has a higher accumulated environmental impact due to being at the end of the food supply chain. In the retail industry, the current trends exacerbate the problem. The fierce competition that characterises this business results in a wide variety of products, including perishables, as demanded by customers. Thus, there are more and more products in stores that, if not sold, will be wasted.

The circular economy seems to have growing attention in the retail business and its benefits may be an added value solution. A circular economy for food consciously emulates the natural systems of regeneration, in order to eliminate wastage. The main idea is that the wastage of one cycle can be used as feedstock for another cycle. For that reason, it is imperative to find out more options to value food wastage or make the best of it, specially in the retail sector. As fruits and vegetables have the highest overall wastage rates (Global Panel, 2018), the focus of this work will be on this commodity group.

1.2 Project Scope

This thesis was developed within the MobFood mobilising project. This research and technological development project results from a joint reflection of several agro-food agents, who seek to respond to the challenges related to the promotion of a more competitive national food industry. The vision of the MobFood project is to act as a laboratory for the research, development and innovation of new processes, products and services with high technological content and thus contribute to the evolution of the whole value chain of the agro-food sector (from raw material to final consumer), both at national and international level.

The MobFood Logistics work-package, which seeks a sustainable and collaborative agro-food logistics chain, allowed the realization of this thesis with a food retail Portuguese leader, Sonae MC, SGPS, SA (from now on referred to as Sonae MC). This company has been part of the Sonae group since 1985 when the first supermarket was opened in Matosinhos. With a history of more than 30 years of continuous growth, Sonae MC has a distinctive position in several business areas, providing a broad range of high-quality products and services at competitive prices. In order to contextualise, this company has more than 32,500 employees, more than 1,000 stores distributed throughout the national territory and consolidated in 2018 more than 4,000 million euros of turnover (Sonae MC, 2018). The presence in several business areas occurs through a diversified portfolio of brands and formats.

This thesis took action in the scope of the Sustainability and Circular Economy projects of Sonae MC, where it was possible to visit several stores in order to understand the entire after-breakage process (i.e., after the product loses its commercial value) and all the existing options to value food wastage.

1.3 Objectives

The project raised from the company's necessity to value, even more, their fruits and vegetables (F&V) breakages, since it is one of the most wasteful business areas. A product breakage occurs from the moment the product loses its commercial value to be sold. Another concern to be addressed is the subjectivity of the store staff to value the F&V breakages since these products do not have a specific and explicit expiration date.

The project aims at analysing the food breakages, more precisely the fruits and vegetables (F&V) breakages, from the retailer's stores in the whole continental territory, identifying the different options to reduce or value these breakages, and defining its benefits and constraints. In addition, improvement opportunities for the processes practised by the studied retailer and its impacts will be presented. Furthermore, since food donation is one of the preferable strategies practice by the retailer to avoid food wastage, a detailed and scientific analysis was conducted to understand the impact of performing staff training on this subject. This analysis compares different variables of interest before and after the intervention (staff training), between stores that have been treated (treatments) and stores that were not (controls). The results obtained will enable the retailer to recognise if the staff training effort is beneficial and valuable.

1.4 Dissertation Structure

The dissertation is structured as follows. 2, provides a theoretical context of the current food wastage problem both globally and nationally. In 3, the wastage problem of fruits and vegetables (F&V) globally and in the context of the retailer are described, introducing the F&V business line and its current processes to combat and value its wastage. 4, presents the proposed improvement opportunities for these processes. Focusing entirely on one waste management option, 5, intends

to analyse if a staff training to raise awareness about donations is beneficial and valuable, studying its impact on different variables of the donation process with a Difference-in-Differences (DiD) approach. Finally, in 6, the main conclusions are drawn, as some future approaches and studies in the scope of retailing sustainability.

Note that, since the wastage of food is a sensitive subject, detailed information such as the identity of individual participating stores and companies associated with the retailer, as well as the exact values of their breakages and donations are not disclosed in this study.

Chapter 2

Literature Review

This chapter intends to provide the reader with the knowledge to thoroughly understand the developed work. Therefore, a theoretical background on the problem of food wastage is provided and is divided into seven main sections. Section 2.1, describes the most relevant concepts regarding the food wastage problem. Then, the magnitude of the food wastage is presented with its origins and causes (Section 2.2), as also some relevant numbers on this issue (Section 2.3). Later, a few strategies and initiatives implemented to combat food wastage are detailed in Section 2.4. In Section 2.5, an overview of the impacts caused by food wastage is provided. Finally, the situation of this problem in Portugal is described in Section 2.6.

2.1 Concepts and Definitions

The food wastage problem has been acknowledge already in many papers and several researchers mentioned this issue in their studies. However, there is no consensus among scholars on the definition of some concepts of this topic. This section aims to clarify the definitions of the most misunderstood concepts on this subject, which will be mentioned later in this thesis.

The difference between food loss and food waste is essential for all researchers to have an equal measurement of these parameters quantities in the food supply chain (FSC), in order to not having any inconsistencies. The 'best before' and 'use-by' label distinction provides the consumer with the knowledge to be able to reduce food waste at home. Therefore, it is a good first step to combat food waste. In addition, the distinction between co-product and by-product will be also described, since they are important concepts for the FSC and are mentioned later on, despite not being the focus of this work.

The concept of 'breakage' will be used within the retailer scope, meaning any product that has no longer commercial value but is not yet considered waste. Therefore, all data analysed in this thesis refer to breakage, since it result from products discarded by the retailer due to expiry dates, sales aesthetics or decrease in quality.

Food Loss and Waste

Numerous terms are often misused as synonymous, such as food waste, food loss, bio-waste and kitchen waste, while at the same time the same word is often used with different meanings (Thyberg and Tonjes, 2016; Buzby and Hyman, 2012). Several definitions found in the literature relative to food loss and waste are presented in Table A.1 of Appendix A.

One of the most widely accepted definitions of food wastage was given by FAO (2011) as the decrease in edible food mass throughout the part of the supply chain intended for human consumption. Therefore, food that was initially meant to human consumption, but which happen to get out of the human FSC, is considered as food wastage even if it is then directed to a non-food use (feed, bioenergy, etc.). Besides, FAO (2013) introduced the term "food wastage" as any food that is lost or wasted. Thus, it includes both food loss and food waste. However, these concepts have different meanings.

Lipinski et al. (2013) define food loss (FL) as the food that spills, spoils, incurs an abnormal reduction in quality such as bruising or wilting, or otherwise gets lost before it reaches the consumer. Usually, these losses are unintended and caused by inefficiencies in FSCs, typically at 'upstream' and midstream segments, such as production, post-harvest and processing stages (Parfitt et al., 2010). The inefficiencies in FSC may be the result of poor infrastructure and logistics, lack of technology, insufficient skills, knowledge and management capacity, and lack of access to markets (FAO, 2013).

Food waste (FW), by Lipinski et al. (2013), refers to food that is of good quality and suitable for human consumption but that does not get consumed because it is discarded, whether or not after it is kept beyond its expiry date or left to spoil. Typically, but not exclusively, according to Parfitt et al. (2010), FW occurs at the end of the FSC (retail and final consumption stages). It is usually the outcome of conscious decision to throw food away, oversupply in markets, negligence or individual consumer shopping and eating habits (FAO, 2013). In addition, Global Panel (2018) refers that excessive grading and sorting of fresh produce, to ensure the aesthetic quality and appeal of fresh to consumers, can lead to waste.

"Best before" and "Use-by" Labels

Labels provided on the packaging of food, such as "use-by" and "best before", are intended to provide consumers with information regarding the freshness and safety of foods. However, the label misunderstanding can confuse consumers and may lead them to throw away edible food they believe is no longer safe to eat. This is one of the common reasons for food waste in households (European Commission, 2016a). According to the Food Standards Agency (FSA) only one-third of people correctly interpret these terms and more than a quarter thought that food past its "best before" date could be unsafe and should be thrown away (Ward, 2007). A study prepared by European Commission (2015) has found that just under half (47%) of Europeans understand the meaning of "best before" labelling and somewhat fewer (40%) are aware of the meaning of "use

by". Therefore, clarifying the meaning of these dates and changing how they are used, displayed and interpreted by consumers can prevent and reduce food waste.

The "best before" label indicates the date until when the food retains its expected quality (European Commission, 2016a). Food containing this label is still safe to consume after the indicated "best before" day on the condition that storage instructions are respected and packaging is not damaged. However, it might begin to lose its quality, like flavor, texture or some nutritional values although health issues are not likely to be a problem.

The "use-by" label mark the date until when the food can be eaten safely and appears on highly perishable food, such as fresh fish, fresh minced meat, and so on. From a food safety perspective, it is recommended that no food be used after the expiration of the "use by" date. Meanwhile, the life of these products can be extended beyond this date, if they are frozen properly (European Commission, 2016a). Additionally, there are other processes that can be practised to extend the expiration date, such as salt curing, freezing, canning, smoking, commercial sterilisation, or pickling. These processes are mostly used in processing industries (HACCP Mentor, 2016).

Co-product and By-product

The distinction between by- and co-products is not always consistent. While a co-product is produced along with the main product and carries equal importance, a by-product is a substance or object resulting from the production process, whose the main purpose is not the production of that item. Therefore, by-products are not planned and must have a legitimate and direct end-use, without any further processing. Meanwhile, co-products are wanted products since they can be used in other production processes or even sold. Indeed, they have a significantly higher financial value than by-products (Akhtar, 2012; CNCDA, 2016).

2.2 Sources of Food Wastage in Food Supply Chains

According to O'Connor et al. (2016), FSC is "the connected series of activities used to produce, process, distribute and consume food" and usually is divided into five stages: production, handling and storage, processing and packaging, distribution and market, and consumption. Moreover, Sgarbossa and Russo (2017) indicate that a sustainable FSC is responsible for processing raw materials into final products and managing recovery systems that enable all post-life treatments. In FSCs, the reverse flows of products concern the by-products, co-products, recycling, substitution, reuse, disposal, refurbishment and repairing products and other waste, particularly packaging (Manzini and Accorsi, 2013).

Before implementing any action to reduce food wastage, it is necessary to start with a diagnosis of where, why and how this wastage occurs. Hence, a detailed analysis of the FSC reveals the magnitude of the problem in each stage. Figure 2.1 presents some examples of how food wastage can occur at each stage.

Lipinski et al. (2013) and several researchers consider that a product reaches the end of a FSC when it is consumed, discarded or otherwise removed from the food chain intended for direct

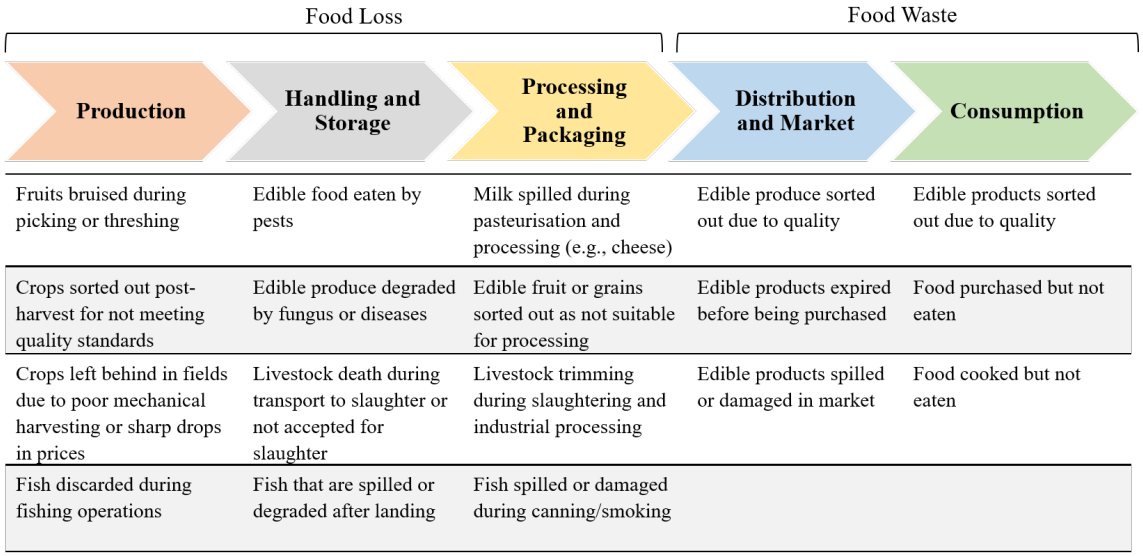

Figure 2.1: Sources of food wastage along the FSC. Source: Lipinski et al. (2013).

human consumption. Others, to account for environmental impacts, also consider the "end-of-life" stage, based on a life cycle approach (FAO, 2013). Therefore, all processes through which the product goes, after being discarded or removed, are also considered. Furthermore, it is highlighted that the later a product is lost or wasted along the FSC, the higher the environmental cost, as impacts arising during processing, transport or cooking, are added to the initial production impact (FAO, 2013).

The share of food wastage varies significantly between developed and in developing regions (Figure 2.2). Food losses occur mainly in developing countries as they take place in the early stages of the FSC. Most common losses are connected with financial and structural limitations in transportation and storage infrastructures, agricultural production, harvesting and post-harvest handling. This can be combined with climatic conditions, pests, fungus and diseases that are favourable to food spoilage (FAO, 2013). Moreover, a lack of management resources is also a reason for so many losses in these regions, because of poor order forecasting and inefficient factory processes (Lipinski et al., 2013).

Nevertheless, food waste takes place mainly at the end of the chain. Although developed countries have an integrated and mechanised supply chain, food waste on the consumption level represents the most significant source from all stages. A key aspect of food waste lies within consumer behaviour and lack of communication in the supply chain. On the consumer level, there can be insufficient purchase planning or exaggerated concern over "best-before" dates (FAO, 2013). In the distribution stage, food is discarded intentionally due to restrictive quality standards, according to size or aesthetics. Ineffective stock management and improper handling and storage

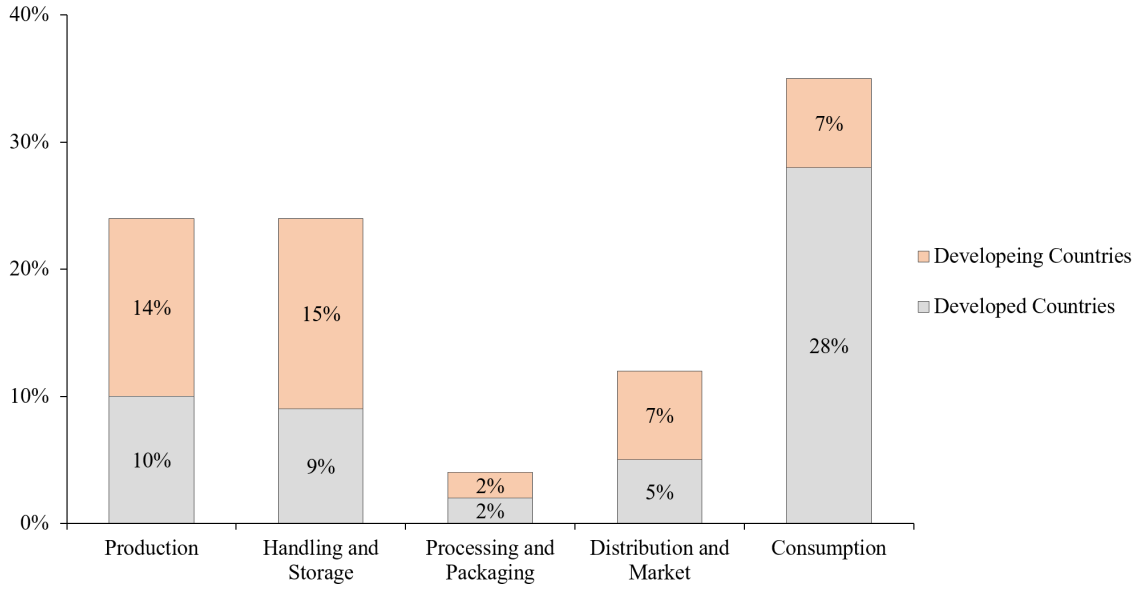

Figure 2.2: Share of total food wastage by stage of the FSC. Source: Lipinski et al. (2013).

are other reasons for retail food waste (FAO, 2013; Pires and Vaz, 2013).

One of the big problems in developed countries is that food waste occurs mostly in big cities, especially on the consumption level. Consumers in developed countries waste more due to the low cost of food compared to disposable income, leading to an increase in the quantities purchased and bigger meals and portions prepared (Rayfuse and Weisfelt, 2012). In these countries, there are also high standards of food aesthetic appearance. This is mostly due to the lack of awareness of food production and wastage processes.

A lot of research has been done to discover what causes such a large amount of food to be wasted in households (Abeliotis et al., 2014; Williams et al., 2012; Aschemann-Witzel et al., 2015). One critical issue causing massive amounts of food waste in households is a lack of basic knowledge about food labelling, food safety basics, food handling and optimal storage. Fridges are often too warm because many households are unaware of the importance of keeping the fridge at the right temperature (Ward, 2007). Furthermore, many families are sensitive to food hygiene. Therefore, they do not want to take a chance in eating food that pass its "best before" date, even if the food looks excellent and is still edible (European Commission, 2015). Another essential factor responsible for big amounts of food being wasted is the planning issue. The 'buying too much' and 'lack of shopping planning' problems are frequently cited as causes of household food waste (Ward, 2007). Moreover, according to Ward (2007), lifestyle changes can lead to high waste, where changes towards healthier eating or diets mean that people buy more fresh fruits and vegetables with short shelf lives. In order to successfully combat food waste, people need to begin to understand the food waste issue and acknowledge the dimension of the problem.

A crucial aspect of food waste generation often lies within retail provision, where the competitiveness of the market forces retailers to provide varied food in large quantities. Since retailers

have the power to influence people's buying decisions with their marketing strategies, it has been shown that they may be one of the reasons why people waste food (Bio Intelligence Service, 2010). For instance, 'two for one' deals and bigger packages at reduced costs can lead to purchasing goods that are unplanned and unneeded. Although these types of promotions might seem like money-savers, products usually end up being discarded.

The food service sector is also very relevant to the food waste subject. The portions sizes are a significant cause of food waste, as the consumers only eat 92% of the food that they serve themselves (Bio Intelligence Service, 2010). Another important point is the difficulty of anticipating the number of clients, leading to overstocking. Furthermore, the practice of taking leftovers home from restaurants is not universally accepted across Europe (France, for example), although it can have a strong potential to reduce food waste in this sector. Therefore, inefficiencies in all of the FSC lead to wastage at every stage. Moreover, according to Williams (2012), the more stages there are in the supply chain, the higher the risk to loss or waste food.

2.3 Food Wastage in Numbers

Some research reports on food wastage provide a good overview of the problem magnitude. According to FAO (2011), one-third of all food produced globally for human consumption is lost or wasted, which can reach a total of 1.3 billion tonnes per year. These numbers are worrying due to the fact that around 820 million people in the world do not get enough food to have good health, which is about one in nine people (FAO et al., 2019).

Regionally, as can be seen in Figure 2.3, about 56 percent of total food wastage occurs in the developed world — North America, Oceania, Europe, and the industrialised Asian nations of China, Japan, and South Korea — whereas the developing world accounts for 44 percent of the wastage (Lipinski et al., 2013). However, on a per capita basis, according to Lipinski et al. (2013), North America and Oceania stand out from other regions, and Europe appears in second place. This is explained by the low population of these regions compared to the Asian regions. North America and Oceania together, and Europe have around 543 and 738 million of inhabitants, respectively, while only Asia has about 4.5 billion people (PopulationStat, 2019).

Approximately 88 Million tonnes (Mt) ($\pm$ 14 Mt) of food is lost or wasted in the European Union each year (Scherhaufer et al., 2018) and, based on anticipated EU population growth and increasing affluence only, this number is expected to rise to about 126 Mt in 2020 without additional prevention policy or activities (Bio Intelligence Service, 2010). O'Connor et al. (2016) estimates that each person in the EU throws out 173 kg of food per year. Figure 2.4, based on Table A.2 (in Appendix A), presents the exact quantities of food loss and wasted in EU-27 countries found by a *Eurostat* research in 2006, where the United Kingdom, Germany and the Netherlands are among the top three. Since most wasteful countries have a large surface area and a high population, they will naturally waste more food than countries with smaller areas and population. The exception seen in the list is Netherlands, which is a country with 17.2 million inhabitants (Eurostat, 2018). Besides, according to an infographic, the people who waste the most are those who live in the

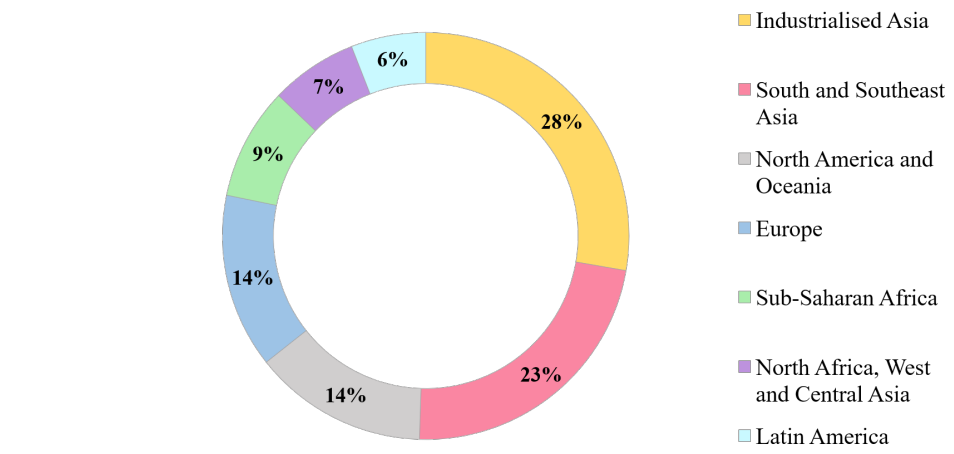

Figure 2.3: Share of global food wastage by region. Source: Lipinski et al. (2013).

Netherlands, with an average of 541 kg per person per year, and then comes the people who live in Belgium (345 kg per person per year) and Cyprus (327 kg per person per year) (European Parliament, 2017).

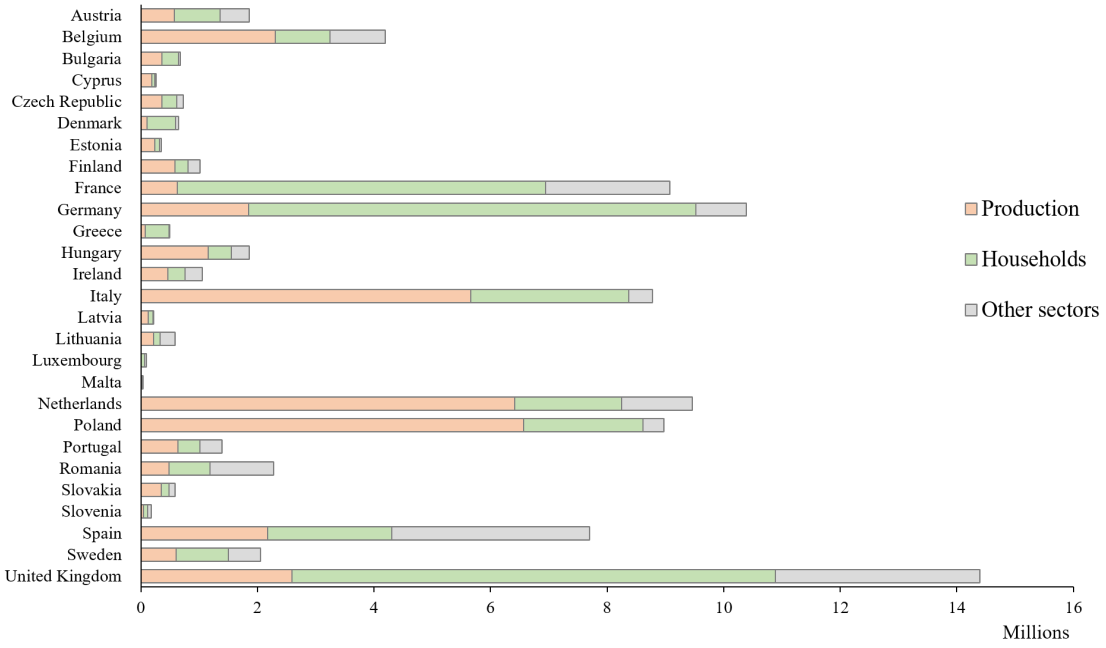

Figure 2.4: Total food wastage generation in the EU-27, in tonnes, by member state. Source: Bio Intelligence Service (2010).

Data on food wastage varies significantly by source. The reasons for this discrepancy are the different interpretation of the meaning of food waste and loss (i.e., the lack of a common definition) and the different methodologies used to measure it. Table 2.1 presents the share of food wastage

in the different stages of the FSC from a selection of several studies, showing that food wastage occurs throughout the FSC. Nevertheless, care must be taken when comparing results since the methodologies and definitions used are not homogeneous (Tribunal de Contas Europeu, 2016).

Table 2.1: Share of food wastage by stages of the FSC (in %), according to different studies.

	FAO, 2011 **(Europe)**	Bio Intelligence Service, 2010 **(EU)**	O'Connor et al., 2016 **(EU)**[1]
Production	23	34	11
Processing	17	19	19
Distribution	8	5	17
Consumption	52	42	53

[1] Note that the study recognises a relatively high uncertainty about this estimate. Particularly, for production sector data, estimates are based only on data from six countries and uncertainties estimated at ± 17% are likely to be underestimated. Besides, the Distribution share includes the catering, unlike others.

According to the most recent research prepared by FUSIONS' European project (Food Use for Social Innovation by Optimising Waste Prevention Strategies), the sectors contributing the most towards food wastage are households (47±4 million tonnes - 53%) and the processing stage (17±13 million tonnes - 19%) (O'Connor et al., 2016). Together, these two sectors account for 72% of the EU food wastage, although there is considerable uncertainty around the estimate for the processing sector. The remaining 28% of food wastage consists of 11 million tonnes (12%) from catering, 9 million tonnes (11%) from production and 5 million tonnes (5%) from wholesale and retail (O'Connor et al., 2016). Furthermore, it should be pointed out that this data analysis includes the current 28 European states, as Croatia joined the EU in 2013.

Moreover, Lipinski et al. (2013) consider that wastage varies significantly depending on the type of food. Figure 2.5 presents the shares of global food wastage for each commodity, in terms of weight and calories.

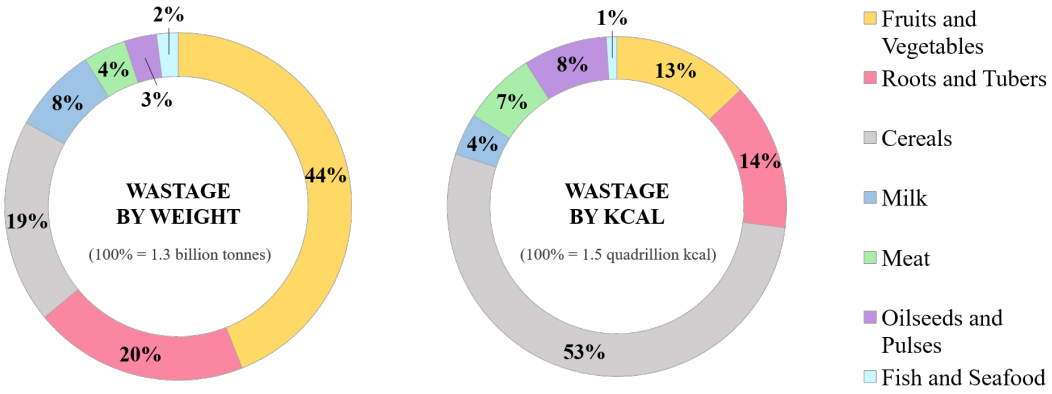

Figure 2.5: Share of global food wastage by commodity. Source: Lipinski et al. (2013)

Food wastage quantities vary when food commodities are compared based on weight or kilocalories (kcal). Fruits and vegetables commodity is the largest source of food wastage on a weight basis, while cereals constitute the highest percentage by kcal. This disparity primarily results from differences in water content, where much of the lost and wasted weight in fruits and vegetables is water. Natural product characteristics such as shelf life, demand fluctuation, and storage requirements also have a significant influence on the level of waste (Mena et al., 2011). Nonetheless, reducing the wastage of fruits and vegetables is essential since these foods provide people many essential vitamins and minerals, such as vitamin A, vitamin C, and potassium needed for leading healthy lives (Thomas and G., 2002).

2.4 Strategies and Initiatives to Reduce Food Wastage

Food waste has gained increasing attention from politicians, media and general public. Furthermore, some awareness-raising campaigns and various joint initiatives in the political, scientific and civil society have also contributed decisively to increase interest on this topic (Baptista et al., 2012). Some initiatives and programmes that already tackle the challenge of food wastage are presented in Table A.3 of Appendix A.

Nowadays, there are also a broad range of strategies for reducing food wastage. Literature reviews, expert interviews, author insights and internet websites suggest practical and cost-effective approaches which could be implemented to reduce the food wastage problem. Figure 2.6 presents a non-exhaustive subset of approaches available to reduce food wastage in each stage of the FSC (Lipinski et al., 2013). Approaches listed under the production, the handling and storage, and the processing stages focus on reducing food loss, and those listed under the distribution and market, and the consumption stages on reducing food waste.

As mentioned above, all actors in the FSC need to be involved in combating food wastage. It is important to note that many technical solutions can be effective only when other parts of the FSC are too. Lipinski et al. (2013) mention, as an example, that if farmers have no immediately access to a market to sell their harvest surplus, improvements on farm storage will ultimately lead to reductions in food wastage in the next stages of the FSC. Moreover, Baptista et al. (2012) states that a better communication (i.e., proximity) between FSC players should be established. Therefore, a collaborative FSC approach is essential to combat food wastage.

The extent to which governments contribute to combating food wastage is also an inherent element of a success on this issue. Some government's possible actions to minimise food wastage are: set binding food wastage reduction goals; introduce legal standards for food labelling and clarify consumers of each terminology; fund or create more consumer awareness campaigns; improve school food education; support research programmes; develop regulations and politics to use of optimal packaging, instead of minimising packaging; favour the donation and re-use of wasted food; prevent the food waste disposal; encourage the proximity of all actors in the FSC; and set more tax incentives to combat food wastage or to lead to the best treatment of it (Lipinski et al., 2013; European Commission, 2016a; Baptista et al., 2012). According to CNCDA

Production	Handling and Storage	Processing and Packaging	Distribution and Market	Consumption
Facilitate donation of unmarketable crops	Improve access to low-cost handling and storage technologies	Re-engineer manufacturing processes	Facilitate increased donation of unsold goods	Facilitate increased donation of unsold goods from restaurants and caterers
Improve availability of agricultural extension services	Improve ethylene and microbial management of food in storage	Improve supply chain management	Change food date labeling practices	Conduct consumer education campaigns
Improve market access	Introduce low-carbon refrigeration	Improve packaging to keep food fresher for longer	Change in-store promotions and improve inventory systems	Reduce portion sizes
Improve harvesting techniques	Improve infrastructure (e.g., roads)		Provide guidance on food storage and preparation to consumers	Ensure home economics taught in schools, colleges and communities

Figure 2.6: Possible approaches to reduce food wastage (not exhaustive). Source: Lipinski et al. (2013)

(2016), in France, beyond strong consumer awareness campaigns, supermarkets have to donate by law "good quality" food that is approaching its expiration date, being forbidden from marketing or selling these products at lower prices. Moreover, it is also reported that the Italy government approved a draft law to reduce the tax on garbage in proportion to the quantity of food donated by each establishment.

The food wastage issue has also become a part of many EU Framework Programmes and strategies like Horizon 2020, Sustainable Development Goals (SDGs) or Circular Economy Strategy. According to European Commission (2016b), the EU and its countries are committed to meet the SDG 12.3 target to halve per capita food waste at the retail and consumer level by 2030, as also reduce food losses along the food production and supply chains.

Looking beyond the current "take, make, and waste" industrial model, the circular economy strategy decreases the need of new raw materials by reusing the existing ones. This practice can be accomplished by rethinking how the product functions in a closed loop (Kok et al., 2013). Circular economy can be defined as "the circular (closed) flow of materials and the use of raw materials and energy through multiple phases" (Franklin-Johnson et al., 2016) and "an economy based on a spiral-loop system that minimises matter, energy-flow and environmental deterioration without restricting economic growth or social and technical progress" (Geng et al., 2008). One of the target goals of the circular economy is to reduce the use of natural resources, waste amounts, greenhouse gas emissions and the usage of hazardous substances, and to move to renewable and sustainable energy suppliers, thereby reducing pressure on the suppliers (Bastein et al., 2013).

The most supported EU framework for tackling food wastage and meeting the targets is related to a sustainable waste management hierarchy. In the following, it is presented an overview of this framework, which identifies and prioritise all options to manage food waste throughout the FSC.

Food Waste Management Hierarchy

In the 1970s, the waste hierarchy principles were introduced into European policy with the 1975 Directive on Waste (European Parliament Council, 1975) and the EU's Second Environment Action Program in 1977 (European Commission, 1977). The waste hierarchy was then clearly defined in European legislation in the Community Strategy for Waste Management in 1989 (European Parliament Council, 1989). Meanwhile, the waste hierarchy has been adopted globally as the principal waste management framework. Other frameworks encouraged by Japan and countries across Asia, such as the '3Rs', provide a similar approach to waste management by prioritising the options of reducing, re-using and recycling waste (Sakai et al., 2011; Shekdar, 2009; Yoshida et al., 2007).

The most recent European Waste Framework Directive defines the waste hierarchy, which aims to identify the options most likely to deliver the best overall environmental outcome (European Parliament Council, 2008). As illustrated in the inverted pyramid of Figure 2.7, the most favourable option is 'prevention', followed by 're-use', 'recycling', 'recovery' until 'disposal', the least favourable option. Although the Directive recommends the Member States to consider the social and economic impacts along with the environmental, the waste hierarchy primarily focuses on delivering the best environmental option. The proposed framework is an adaptation of the frameworks present in Papargyropoulou et al. (2014) and Buchholzer (2015).

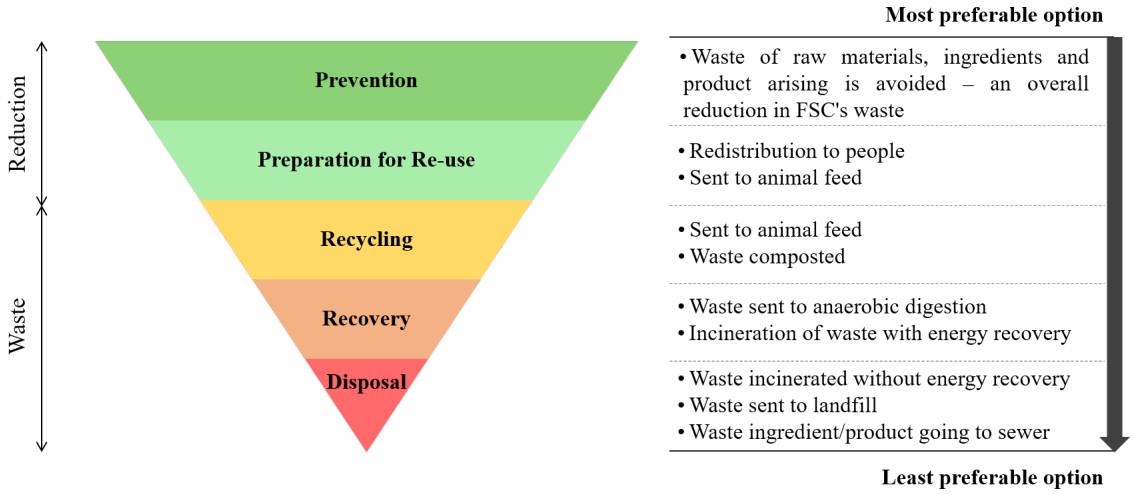

Figure 2.7: Waste management hierarchy. Adapted from Papargyropoulou et al. (2014) and Buchholzer (2015).

The interpretation and application of the waste hierarchy within the context of food waste is the key to food's materiality and temporality (Papargyropoulou et al., 2014). Unlike other waste

materials such as glass, metals, paper and plastic, food's properties change within a relatively short amount of time. For this reason, the time dimension is crucial to the transition of food into food waste. The waste management hierarchy is relevant for a further understanding of the retailer's different options in food waste management.

The Directive of European Parliament Council (2008) describes the options of the waste management framework, as follows:

- Prevention: It consists of measures taken before a substance, material or product has been converted into waste, intended to reduce the quantity of waste, the adverse impacts on the environment and human health, and also the content of harmful substances in products. It is the most sustainable and highly pushed form of waste management.

- Re-use: It refers to the continued use of products or components for which they were initially intended. It involves minimal processing, such as checking, cleaning, repairing and/or refurbishing. As a result of the minimum processing required, the animal feed may appear in the reuse or recycling option.

- Recycle: It applies to the used, reused or unused items, that would otherwise be considered waste, and processing them back into raw materials, ready to be used into another product. The difference between recycling and reuse is that recycling involved re-manufacturing the product, whereas re-use can be as little as a fix-up. (Kellett, 2015).

- Recovery: It can refer to two things - the recovery of materials or the recovery of energy from waste materials. The recovery of materials involves recycling, composting and other such activities. The recovery of energy, such as incineration or sing biomass boilers, is a way of getting the most out of otherwise useless waste (Kellett, 2015).

- Disposal: It is based on any non-recovery operation, such as dumping in landfills or incinerating the waste.

Regarding the recovery and disposal options, Figure 2.8 shows the trend and forecasted development of bio-waste treatments in EU-27 (Hanssen et al., 2011). The bio-waste includes all "biodegradable garden and park waste, food and kitchen waste from house-holds, restaurants, caterers and retail premises, and comparable waste from food processing plants" (Bio Intelligence Service, 2010). Many European countries already have restrictions on landfilling of organic waste (i.e., bio-waste) according to the landfill directive and national legislation. Therefore, as can be seen in Figure 2.8, bio-waste is being directed away from landfills. Meanwhile, the use of biological treatments, such as home composting, anaerobic digestion, industrial composting and mechanical biological treatment (MBT), is increasing over the years.

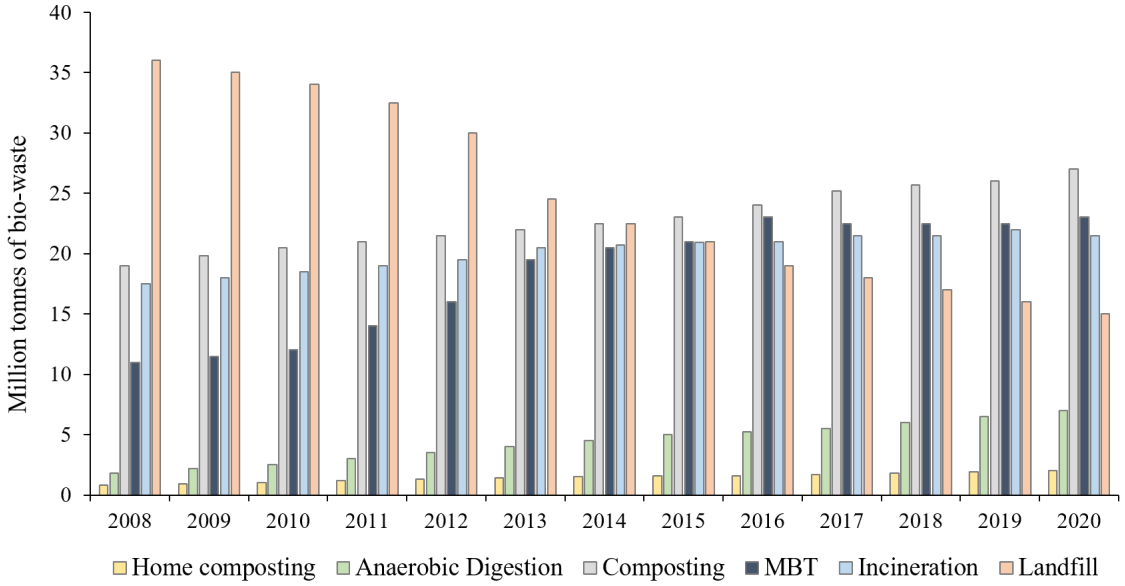

Figure 2.8: Trend and forecasted development of bio-waste treatments in EU-27. Source: Hanssen et al. (2011).

2.5 Impacts of Food Wastage

The environmental, social and economic impacts of food wastage are becoming more and more evident, as global food security is becoming more imperative. When edible food is not consumed, all of the energy and resources used to produced it are wasted. The food sector from production until consumption is considered to be one of the largest consumers of energy and other resources, such as freshwater, cropland and fertilisers (Kummu et al., 2012).

However, it is not just food wastage that is associated with considerable environmental impacts. According to Tukker et al. (2006), several studies have shown that food production also cause 20 to 30% of various environmental impacts of private consumption. A significant influence are agricultural processes, such as the fertiliser application or the livestock farming. Environmental impacts of food production and consumption are further exacerbated when food is lost or wasted, rather than consumed. A range of studies have already addressed the issue of food wastage and its environmental impacts in a national context (e.g. for UK in Johnso and Hannah (2009) or for Portugal in Pires and Vaz (2013)), for specific products (e.g. for tomato in Bernstad et al. (2016)) or for different stages of the FSC (e.g. Johnso and Hannah (2009); Brancoli et al. (2017); Scholz (2013)). The environmental impacts of food wastage cover all emissions deriving from the different stages of the FSC. FAO (2015) report that the highest carbon footprint of wastage occurs at the consumption stage (37% of total). For example, a single tomato spoiled at the harvesting stage will have a lower carbon footprint than tomato sauce wasted at the retail store, since the harvesting, transportation and processing accumulates additional greenhouse gases along the FSC. Therefore, the later in the FSC a product is lost or wasted, the higher are its environmental impacts, since all emissions coming from upstream stages of the FSC are included in the overall

impact of the wastage (Scherhaufer et al., 2018).

According to FAO (2013), the global volume of food wastage is estimated to be 1.6 billion tonnes (Gtonnes) of "primary product equivalents", while the total wastage for the edible part of food is 1.3 Gtonnes. Meanwhile, the total agricultural production (for food and non-food uses) is almost 6 Gtonnes. The same report claims that, without accounting for greenhouse gas (GHG) emissions from land-use change, the carbon footprint of food wastage is estimated to be 3.3 Gtonnes of CO_2. Hence, if food wastage were a country, it would be the world's third-largest emitter of CO_2, right after China and the United States (Goodwin, 2017; FAO, 2015). In other words, 4.2 tonnes of CO_2 are produced by every tonne of food wastage, which is equivalent to the emissions of one in five cars in the EU (Netherlands Nutrition Centre, 2014). These high GHG emissions accelerate the climate change. Furthermore, the methane gas, produced at landfills by food waste, further aggravates climate change and global warming. FAO (2015) report that the contribution of food wastage emissions to global warming is 87%, which is almost equivalent to global road transport emissions.

Regarding the blue water footprint (i.e., the consumption of surface and groundwater resources), the total food wastage produced every year consumes about 250 km^3, which is equivalent to the annual water discharge of the Volga river, or three times the volume of Lake Geneva (FAO, 2013). Moreover, it takes 1.4 billion hectares of land to grown food that is ultimately lost or wasted, which is one-third of the world's agricultural area or the size of China (Goodwin, 2017). Therefore, the world is wasting 30 percent of the world's fertile land, which could be used for other meaningful purposes, such as research (FAO, 2013).

In addition to the environmental impacts, food wastage also results in direct economic costs, due to all the resources and processes spent in the FSC. According to FAO (2015), the economic value, in 2012, associated with the food wastage was about 936 billion dollars, which is the range of the GDP (Gross Domestic Product) of Indonesia or the Netherlands. Moreover, Goodwin (2017) refers that 99% of companies had a positive return on their investments to curb food wastage in operations. In particular, for every $1 invested in things like training staff to lose less food in production, $14 or more were saved. Therefore, it is essential to carefully analyse these possible investments and its impacts on the companies (as will be done later in Chapter 5, with staff training on the donation process).

Today, over 820 million people suffer from hunger, corresponding to about one in every nine people in the world (FAO et al., 2019). Besides, this number is increasing since 815 million people were starving in 2017 (FAO et al., 2017). The reduction of food wastage is essential, not only to avoid pressure on scarce natural resources (land, water, energy, fertilisers) and the world's hunger, but also to decrease the need of raising food production by 60-70% in order to meet the 2050 population demand (Nikos Alexandratos, 2012). The world's population is projected to grow from about 7 billion in 2012 to 9.6 billion people in 2050 (Ranganathan, 2013). Consequently, more than half of this growth will occur in sub-Saharan Africa, a region where one-quarter of the population is currently undernourished.

2.6 Situation of Food Wastage in Portugal

Although the Eurostat study in 2006 concluded that Portugal lost and wasted around 1.4 million tonnes of food (Bio Intelligence Service, 2010), the study PERDA (*Projeto de Estudo e Reflexão sobre o Desperdício Alimentar*) from 2012 reveals a value of roughly 1 million tonnes lost and wasted each year along the FSC (Baptista et al., 2012). This means that each Portuguese wastes annually 96.8 kilograms of food (CNCDA, 2016). Moreover, these tonnes of food waste matches up almost 17% of all food produced for human consumption in Portugal, which is considered lower than the referred in the international literature on the subject (Pires and Vaz, 2013). The reasons referred for this difference could be: the small scale of Portuguese agro-industries, which in turn make them easier to manage; low productivity in some commodities that force producers to be efficient; families change of habits due to the economic crisis.

Figure 2.9 shows, according to the analysis carried out in PERDA, the quantities of food wastage along the FSC (CNCDA, 2016; Pires and Vaz, 2013). Almost the totality of wastage occurs at the initial and final FSC stages. Indeed, the most efficient stage in using food products is food processing, where losses are minimal and reused in other productive processes. Meanwhile, retail contributions to food wastage in Portugal are higher than internationally (comparing this results with the ones referred in section 2.3). Therefore, it is essential to look carefully at this sector.

Figure 2.9: Annual food wastage along the FSC in Portugal. Source: Baptista et al. (2012).

Baptista et al. (2012) also concluded that, regarding the commodities, almost 75% of all food wastage is composed of vegetables, cereals, fruits and dairy products. The main factors, identified by PERDA (Baptista et al., 2012), that influence food wastage are very similar to those mentioned in the previous section 2.4.

In Portugal, the year 2016 became the National Year of Combating Food Waste (CNCDA, 2016). Considering 2016 the year of "combating food waste and promoting efficient management of food", the Republic Assembly created the National Commission for Combating Food Waste (CNCDA or *Comissão Nacional de Combate ao Desperdício Alimentar*), aimed to promote waste reduction through an integrated and multidisciplinary approach (Diário da República, 2018). As such, the CNCDA prepared a proposal for a National Strategy to Combat Food Waste (ENCDA or *Estratégia Nacional de Combate ao Desperdício Alimentar*). The ENCDA is structured around

three strategic objectives - prevention, reduction and monitoring - which are broken down into nine operational objectives, that are materialised in an Action Plan with 14 transversal and multi-disciplinary measures (Diário da República, 2018).

Although Portugal is not at the top of the list of countries that waste more food, there are several organisations and initiatives that actively combat food wastage (CNCDA, 2019b). For instance, the Re-Food and the Zero Waste movement (DariAcordar), which brings together meals that would otherwise be thrown away and redistributed them, or "Fruta Feia", that creates an alternative market for "ugly" fruits and vegetables in order to change consumption patterns (Refood; PASC; Fruta Feia). Additionally, APED (Portuguese Association of Distribution Companies) has been promoting various awareness campaigns on this topic. In February 2019, APED launched the "Knowing the Difference, Makes the Difference" campaign on 1,200 stores, online platforms and social networks. This campaign aims to help consumers to interpret and distinguish different indications of validity or durability (date labelling), thereby helping them to profit from food consumption and, above all, to avoid food waste (CNCDA, 2019a; APED, 2019).

All players of the FSC are committed to reducing food wastage in Portugal, trying to achieve the SGD 12 of halving food wastage by 2030 (CNCDA, 2019a). Retailers are no exception and have tried to adopt several actions to reduce and combat wastage. Some of the initiatives are: optimise purchases and stock control; control the store temperature and product layout; expose first the goods with the shortest shelf life left; price discounts when the product expiration date is getting closer; donate food that is “unsaleable” to charity; handle food properly; separate organic waste from the recyclable; educate the personnel about this issue (CNCDA, 2019b).

Despite all the initiatives taking place to reduce food wastage, no investigations have been found to study the potential of the waste management options currently used in food retail. It is important to start collecting and understanding all these options, to improve them and analyse its ’win-win’ potential. The ’win-win’ potential means to understand if what is being done is beneficial to all FSC and if the impacts of that are positive.

Chapter 3

Problem Description

Fruits and vegetables are well-known sources of useful nutrients in the form of vitamins, minerals, dietary fibre and other phytonutrients including flavonoids, carotenoids and phenolic compounds that may lower the risk of cancer, heart disease and others illnesses (Kader, 2002). However, these products are also highly perishable and often prone to pests and diseases, making them disproportionately susceptible to both loss and waste (Global Panel, 2018).

This chapter describes the wastage of fruits and vegetables (F&V) problem worldwide and in the scope of the studied retailer, introducing its current processes for combating and valuing this waste.

3.1 Wastage of Fruits and Vegetables

Globally, 45 percent of F&V, in a market of 252 billion euros, go to waste (FAO, 2013). Furthermore, more than 50 million tonnes of F&V are being discarded across Europe every year only for aesthetic reasons (Quinn, 2018). However, it is not only for this reason that this commodity has the highest overall rate of wastage (Global Panel, 2018).

The commodity of F&V is the most fragile and most susceptible to weather conditions and mechanical damage along the FSC. A significant quantity of F&V is discarded in the initial phases of the FSC due to overproduction, plagues and other reasons, like those mentioned in Section 2.2. Besides, high-quality standards in the EU leads to food being discarded in the distribution stage, before it even reaches the consumers. On the consumer level, the most likely reason for throwing away F&V is that they get mouldy very fast and they do not appear to be ideal.

In Portugal, the situation is identical to what happens globally. Figure 3.1 presents the food wastage of fruits, vegetables and roots and tubers at each stage of the FSC. It is possible to see a trend for higher wastes in the distribution phase, except for vegetables, which present significant losses in the production phase due to the tomato pulp industry and its harvesting regime practised in Portugal. (Baptista et al., 2012).

Therefore, the commodity of Fruits and Vegetables (F&V) is one of the most wasteful, especially in retailers. The fact that it regards perishable products makes it challenging to manage the

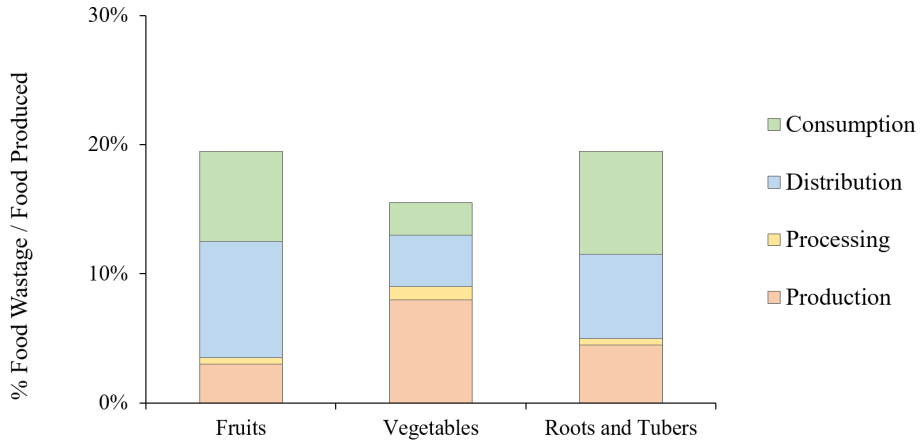

Figure 3.1: Food wastage at each stage of the fruit, vegetable and tuber supply chain. Source: (Baptista et al., 2012)

stock, mainly due to the seasonality. Consequently, the market is flooded with the same product in a concentrated period. Furthermore, the quality criteria demanded and the non-explicit expiration date also influences the high waste of this commodity (Global Panel, 2018). In addition, it is also verified the highest utilisation rates of F&V breakages in the least preferable options of the waste management hierarchy (Figure 2.7). Hence, the breakages of these products are mostly being sent to landfills or incinerators without any energy recovery. To change this situation, there is still potential to study what can be done. This work tackles the F&V wastage at the retailer level.

3.2 Retailer Scope

The core activity of the retail sector is to sell products. However, food waste is inherent to the ordinary course of business and is generated primarily in the stores. The waste is a cost to the retailer, in terms of unsold food as well as for waste treatment. Therefore, Sonae MC is devoting a concerted effort to this issue. The company believes that what is a loss today, tomorrow can be perceived as an added value for the economy, society and the environment. Moreover, for Sonae MC, preventing food waste is a cause shared by different areas throughout the FSC.

The group of products with highest impact in the breakage flows, in terms of volumes, are fresh bakery products (representing 29% of Sonae MC breakage, in 2018), and fresh fruits and vegetables (representing 19% of Sonae MC breakage, in 2018). Since the value of fresh bakery products is lower than that of F&V, the share of breakage of F&V, in terms of value, is significantly higher than that of bakery products (17% and 8% respectively). It should be noted that, although the group of fish and meat products do not have large volumes of breakages (7% of Sonae MC breakage, in 2018), it is the most relevant group in terms of value, being 24% of all Sonae

MC breakage. However, for these products, the reuse, recycling or recovery processes are more complex due to food safety issues, and there are already legal actions defined for this.

Since F&V business line is one of the most wasteful groups, both in volume and in value, it has several impacts associated, such as economic, social and environmental. Besides, this group of products has also potential to be used in more favourable options of the hierarchy. Therefore, this project focused on the waste management processes of F&V. In the next subsections, the business line of F&V will be described, presenting the products with the highest breakages, as well as, the current processes of Sonae MC to combat and value waste.

3.2.1 Fruits and Vegetables Business Line

In 2018, the F&V business line accounted for about 8% of Sonae MC's net sales. However, it is also almost one-fifth of all their breakages. This business line is divided into three categories and twenty-eight subcategories (see in Table A.4 in Appendix A). Figures 3.2 and 3.3 show the distribution of breakages by categories and subcategories of F&V, respectively, in 2018. Note that the 'Others' fraction is all subcategories with shares below 5%.

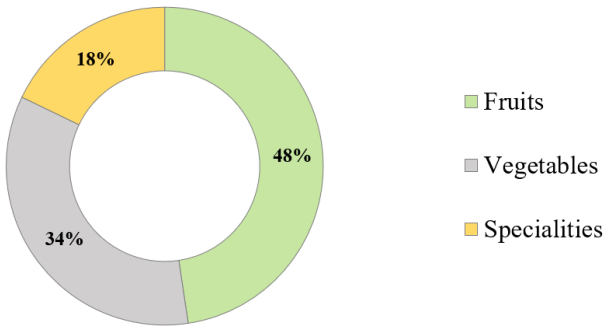

Figure 3.2: Share of F&V breakages of the retailer by category.

Fruits have the highest share of breakage due to the largest variety of products in this category. Besides, in some stores, vegetables are stored in fridges, ensuring the optimum storage temperature, while the fruits are more susceptible to people's touch, temperature changes and thus to become waste. Meanwhile, the specialities category includes longer shelf life products. Thus, it has less breakages compared to the others.

Regarding the subcategories, the 4th and 5th range products have the highest breakages. These products are all those varieties of fresh fruits and vegetables, alone or mixed, which during the post-harvesting processing are subject to specific procedures (such as selection, sorting, husking, cutting and washing) and then packaged in envelopes or sealed food trays (Iascone, 2017). The 4th and 5th range products are 'ready-to-use' or ready to be consumed after cooking products. Although these products generally have a longer shelf life, there is also a wide variety in this subcategory to meet the needs of all customers. The products of processed vegetables are the most

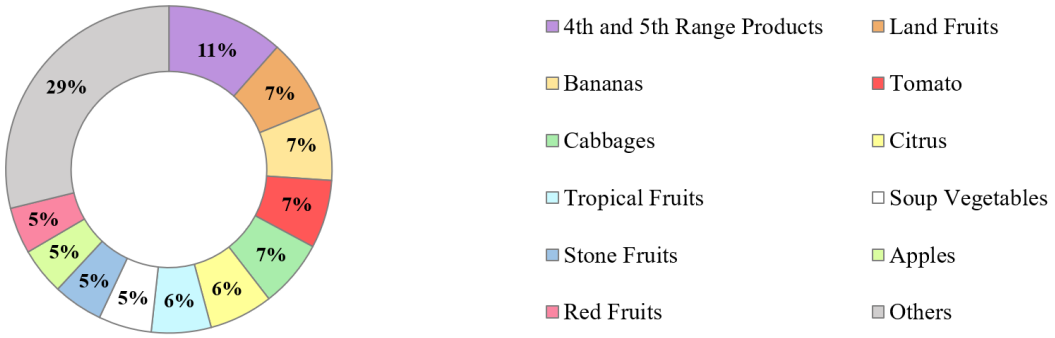

Figure 3.3: Share of F&V breakages of the retailer by subcategory.

wasted in this subcategory. Furthermore, land fruits (such as watermelon, cantaloupe, honeydew melon or melon), bananas, tomatoes and cabbages are also subcategories to consider carefully, as they are the next with more breakages.

Each store has a team dedicated to each line of business. In the case of F&V, it was observed that the number of team workers depends on the store format. As stated in Chapter 1, Sonae MC has several business areas and store formats. This thesis focus just on the grocery retail area and the following store formats: Continente (urban hypermarkets), Continente Modelo (large supermarkets) and Continente Bom Dia (Proximity supermarkets). In Continente stores, which is the largest store format, there is always a fixed team for F&V with 15 FTE (full-time equivalent) and 1 supervisor, working exclusively for this line of business. However, in small store formats (Continente Bom Dia), teams are small and usually have only one person responsible for the F&V area. The teams work plan is set every week and displayed at each store. An example of a work plan from a Continente store is shown in Figure A.1, in Appendix A.

3.2.2 Current Food Waste Combat Processes

For more than 20 years, Sonae MC has been working to reduce and combat food waste throughout the FSC. Moreover, they are continuously trying to add economic, social and environmental value to unavoidable waste. Therefore, the company has a specific team just dedicated on that purpose. In 2016, with a renewed ambition, the 'Transformar-te' project was created to reduce and value the food waste through a range of diversified actions. These actions have three perspectives: reduce, re-use and recycle.

Figure 3.4 represents the mapping of a food product, like F&V, from the moment it arrives at the store until it leaves, including the most used processes for combating food breakage and waste. Food products, especially fresh ones, are usually shipped to stores in the early morning. After the arrival, the teams of each area sort out the new products and those in shelves.

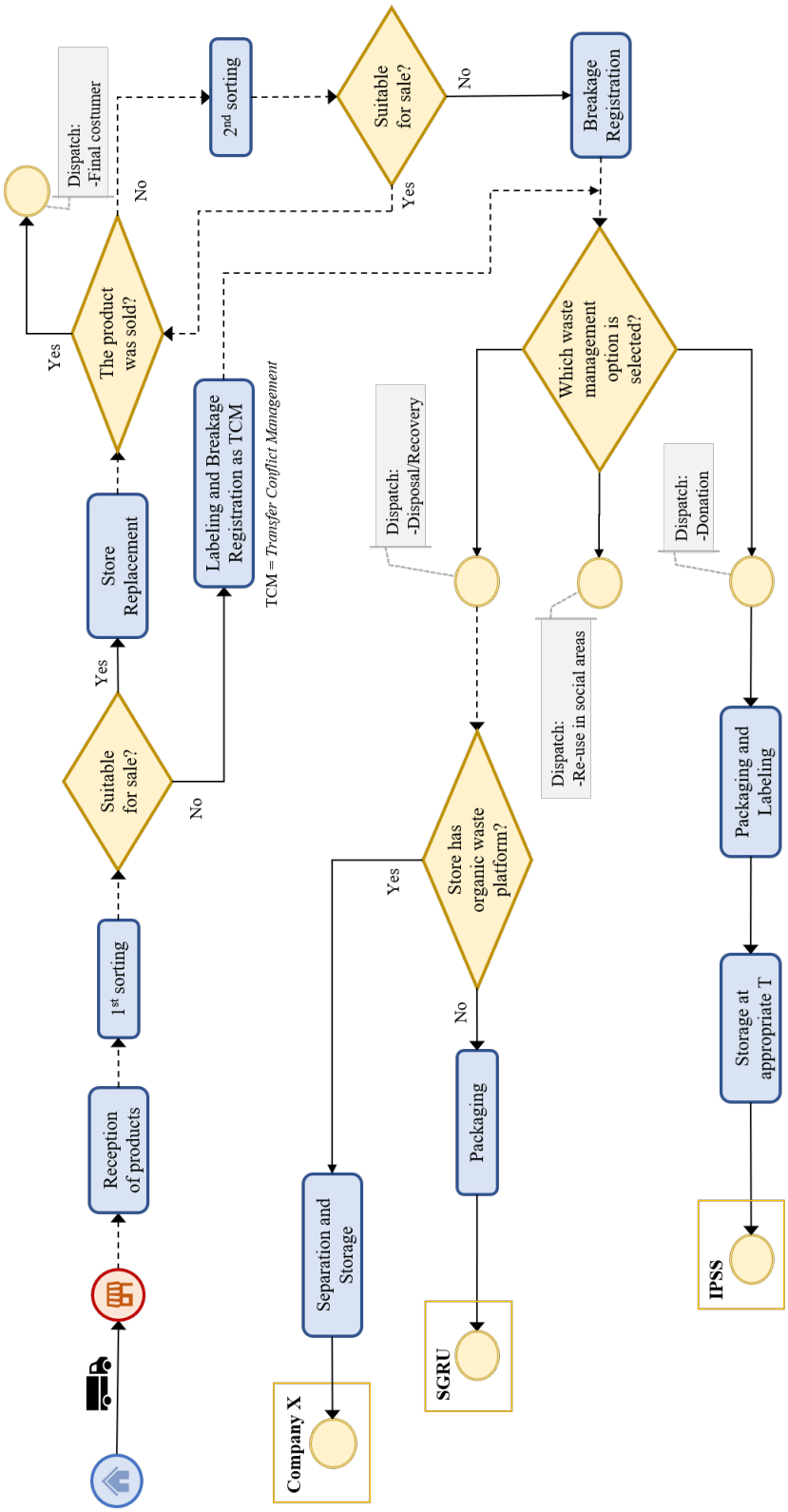

Figure 3.4: Mapping of the product flow in a store.

Regarding the new products, if it is suitable for sale (i.e., it has commercial value) and it is missing in the shelf, it will be replenished. If not, the product is considered breakage, registered as TCM (Transfer Conflict Management) and forwarded to waste management options. When the product is replenished on the shelves, it may or may not be sold. If not sold, the product may continue to have commercial value in the next sortings. When the product loses its commercial value, it is considered as breakage, recorded as such and forwarded to waste management options. The initiatives taken by the retailer within each level of the waste management hierarchy (Figure 2.7) will be described below.

Prevention

The prevention initiatives practised are the re-packaging of products and the price discounts on end-of-life products (called 'pink labels'). The re-packaging happens mainly in sliced fruits that are getting ripe. The discount 'pink labels' occurs on products approaching the "use-by" or the "best-before" dates and it is usually the store manager who decides whether to give a discount. Additionally, Sonae MC promotes many customer awareness campaigns by distributing good-practice guides, implementing education programs in schools or stimulating and financing innovative projects related to the food waste issue.

Re-use

The unavoidable waste is re-used, giving the products a second life through internal donations or to community institutions. Internal donations give employees access to a few products in the social areas of each store. Regarding external donations, Sonae MC donated 7.6 million euros of surplus food to around 900 institutions in 2018 (SONAE, 2018). The Portuguese Government has launched an incentive for donations, giving tax benefits, as long as the beneficiary institutions are classified as IPSS (*Instituições Particulares de Solidariedade Social*). The IPSS seeks to answer to social emergencies and to support the most vulnerable citizens through a close relationship with them and a cooperation with the State.

The company has a documented donation procedure, from 2015, with rigorous criteria on what products can be legally donated. Many barriers to food donation are related to legal and food safety issues. In addition, it may be difficult for store staff to understand whether or not they can donate F&V since these products do not have a specific expiration date.

Recycling

The food breakages that are not reused can be recycled. In other words, they can be transformed and reintroduced into new food life cycles. Examples of the recycling initiatives practised by the company are the banana bread ("Panana"), jams and chutneys also sold at Sonae MC stores. "Panana" is a bread made with bananas without commercial value due to being overripe. Bananas

are one of the fruits with higher demand in stores, requiring restocking in large quantities. However, they are not always sold before becoming too ripe. This new introduced product enables the annual rescue of more than 80,000 bananas that would otherwise be wasted.

Similarly, jams and chutneys are produced using fruits and vegetables in the same conditions. Jams of pumpkin and nut, tropical fruits, orange, banana and tomato, as well as the onion chutney are the circular economy products sold nowadays. These products are produced by a company from the jam, marmalade, jelly and chutneys business area. All breakages used in these products are collected at stores in the regions of Viseu and Guarda.

Sonae MC is continuously looking for new solutions to make the most of its breakages. Below, a pilot-project that the company studied to tackle this issue is presented.

Pilot-projects

In the F&V business line, there was a pilot-project to sell vegetables to a company that prepares daily soups for canteens. The purpose of this project was to give an end-use to vegetables that had no commercial value, mostly for aesthetic reasons, but that had all nutritional content. However, since this process involves a highly complex operation and is associated with significant logistics costs, this project did not move forward.

Recovery or Disposal

Once all efforts are exhausted, all waste will be collected by Urban Waste Management Systems (SGRUs or *Sistema de Gestão de Resíduos Urbanos*). In-store, there are two types of waste: the recyclable waste and the urban solid waste (RSU or *Resíduos Sólidos Urbanos*). Recyclable waste is sorted by an appropriate company that will prepare it for sale. Thus, the retailer's goal is to increase revenue from this waste. Alternatively, there is also a large amount of RSUs, where arround 50% is organic waste (including organic food waste, such F&V waste). In this case, the main idea is to reduce the costs of this waste by avoiding landfill.

The food waste is only sorted in stores if the local SGRU supports a differentiated collection of organic waste. Since monetary cost is still small between mixed and sorted waste, in Portugal, there are few SGRUs that support differentiated collection. Sonae MC only sorts out food waste if the SGRU has a specific purpose for organic waste, unlike landfill. Therefore, this only occurs in 85 stores of Porto and Lisbon with 2 specific SGRUs (Company X in Figure 3.4), but there are 23 active SGRUs throughout Portugal. In these 85 stores, organic waste goes to composting. A nutrient-rich compost is produced and can return to the land, improving the growth of plants and gardens.

Moreover, in some regions of Portugal, there are infrastructures of mechanical and biological treatment (TMB or *Tratamento Mecânico e Biológico*) (EGF, 2018). In these regions, the sorting of organic waste is performed at TMB facilities instead of within the stores (about 30 stores). However, this is not the best option since the sorting will be done by a machine with all region waste and the quality will not be the same. Therefore, Sonae MC has been looking for innovative

solutions and projects to treat its organic waste since, by 2023, the selective collection of organic waste will be mandatory (ZERO, 2019). Thus, they are currently studying some pilot-projects that are presented below.

Pilot-projects

In 2016, Sonae MC implemented the Waste to Energy (W2E) pilot-project, an initiative that reflects the transition from a linear model of material production, to a circular model. The W2E pilot-project allows a local organic waste treatment with the production of energy. An Anaerobic Digestion facility was implemented in the GaiaShopping hypermarket to treat the food waste produced at the store. This process consists of a food grinder, an anaerobic digestion system and a cogenerator to produce energy. This anaerobic digestion system uses methanogens (methanogenic bacteria) to break down the organic waste, producing methane-rich biogas used in the generation of renewable energy. In addition to biogas, the system also enables the production of a compost, which has the potential for commercialising as an organic soil fertiliser. For this, it needs to be pasteurised at 70 °C for one hour. Moreover, the waste used cannot contain any packaging, which requires an employee to perform this task.

This solution, with capacity adjusted to the average amount of material goods produced by a large supermarket, is innovative as it allows: local recycling of organic waste produced from the stores; reduction of the amount of waste sent to the landfill; production of energy and fertiliser and, ultimately, reduction of GHG emission by avoiding the transportation of waste. Sonae MC (2016) reports that 216 tons of organic waste was treated within this pilot-project and 50 thousand m^3 of methane were produced.

Recently, the company is starting a new pilot-project, the Waste to Resources (W2R) project, in two stores in Braga. This project considers a more straightforward process that consists of dehydrating food waste after grinding. It is a project with great potential as the equipment occupies a small space (small-scale equipment), it is not expensive and it is easy to use. This process already exists in several international retailers, but it is pioneer in Portugal. For now, Sonae MC is analysing the results of the process and studying possible destinations for the dried waste, which can be used for composting or bio-fertiliser production. One of this project achievements is the reduction of the waste weight since all water has been removed in the process.

Chapter 4

Improvement Opportunities for Waste Management

This chapter presents the improvements found in the processes of combating food waste, in the scope of the F&V business line of the retailer under study. Given the short time of this project, it was not possible to implement and study all the improvement opportunities. Some of them are already on target for Sonae MC, and others could be used as future pilot-projects. For confidentiality reasons, company names related to some opportunities are not disclosed. The remainder of this chapter is organised into sections by level of the waste management hierarchy, similar to the previous Chapter 3 (Section 3.2.2).

4.1 Reduction

As mentioned before, Sonae MC claims that breakage reduction or prevention comes first than all other options, which is also in line with the waste management hierarchy. Two opportunities on this subject were proposed to the retailer: an ethylene filter and a customer awareness campaign.

Ethylene Filter

The main proposed opportunity that helps prevent breakages in the F&V business line is an ethylene absorber (also called an ethylene filter) developed by company Y. In order to better understand the product's potential and all food safety information relevant for Sonae MC, the company Y was contacted and details on the filter were retrieved.

Its discreet but patented high-tech filter removes the ethylene from the immediate surroundings of fresh produce. The ethylene gas is a naturally produced plant hormone. F&V produce this hormone and use it as a signal to increase respiration, as also to speed up the natural maturation and ripening process. Ethylene production is also affected by stress, such as higher temperatures and mechanical damage in the form of bruising.

The filter is designed in 3 layers. The ethylene is absorbed by an active ingredient (a blend of clay and minerals) in the middle layer. The absorption occurs via chemisorption, which is a

process of making chemical bonds and is much stronger than physisorption, that relies on weaker intermolecular forces (van der Waals forces). The active ingredient is enclosed on one side by a food-grade BOPP film, which is waterproof and gas impermeable, and on the other side a medical-grade Tyvek membrane, which is ethylene permeable and also waterproof.

Most F&V are sensitive to ethylene. Thus, the presence of this gas affects how long products can be stored and sold after harvest. Indeed, the level of ethylene production and sensitivity varies between products. Some fruits produce very little but are extremely sensitive, while others produce large amounts. For example, unripe bananas, avocados and kiwis are very sensitive to ethylene, but emit large amounts when ripe (The Engineering ToolBox, 2004). However, some F&V, such as the coconut and onions, neither produce nor are sensitive to ethylene.

The filter is entirely safe to be placed in direct contact with food, under FDA and EU standards. Besides, it is physically sturdy and durable so that it is perfectly adapted for use in cold and humid environments. Since oxidation processes do not occur, there is no chemical release. Therefore, no harmful by-products are produced. Furthermore, it can be disposed as normal household waste (also an RSU) since it is not harmful to the environment. All legal compliance declarations were provided by international identities.

There are 4 formats of the ethylene filter: the loose filters that are packed conveniently in handled cartons and ready for hand insertion into retail or food services; the transit sheets that are produced in small and large sizes for use in transit cases or other larger packages of loose fruit; the pads that are provided to growers and pickers as a filter into a berry pad, pre-inserted (before the fruit) into punnets and clam shells; and, ultimately, the labels that provide an automated packaging solution with the active material printed onto a normal package. Moreover, the filter can be used in synergy with other technologies or more often to replace them, such as chilling and modified atmosphere packaging (MAP). Fundamentally, the earlier the filter is placed on FSC, the more efficient it will be. Therefore, for Sonae MC, the ideal would be to collaborate with the producers to place the filter in the initial stages of the FSC.

The company Y has been working with numerous retailers, producers and suppliers all around the world, successfully achieving their proposed goals. From the results of other commercial tests, the ethylene filter may help the retailer to improve and extend quality and sensory shelf-life of the products; reduce in-store waste; increase store sales and on-shelf availability; increase satisfied returning customers and reduce complaints. Results show that product's freshness and lifespan can be extended by two or three days, depending on the F&V type. The only type of F&V that does not benefit from the filter, until now, is broccoli. As broccoli releases other gases than ethylene, such as sulphur, it harms the filter's active ingredient (i.e., not works efficiently).

All filter formats and prices were requested to the company Y and presented to Sonae MC, as well as, use conditions and possible benefits. The retailer is currently evaluating if it will move on with a commercial test of this filter or not. If such happens, the a possible pilot-project was already designed with the following steps:

- Identify a category or subcategory F&V with high breakages, due to quality and ripeness reasons, not for handling or expiration dates (on packaged products). From Figure 3.3 and

other insights, bananas and tomatoes could be a proper kickoff .

- The F&V selected must be from the same producer, origin, variety, harvest day and packaging day.
- Identification of two stores (one as control and one with the filter) with similar waste and sales volume within a minimum of 12 weeks.
- In stores, it will be necessary to note the breakage levels for both groups, specifying all causes.
- Finally, with all data, it will be possible to have statistical analysis and calculate indicators, such ROI (Return Over Investment).

Customer Awareness Campaigns

To reduce F&V waste at households, the development of awareness campaigns on how consumers store their F&V at home, was also proposed. The right temperature and relative humidity, as well as, the proper disposition of the products are critical to F&V storage. By lowering the products temperature, the following effects are achieved: reduction of the respiration rate, water loss and sensitivity to ethylene; suppress of ethylene production; slowness of the microbial development (Government of Western Australia, 2016). However, there are some F&V (e.g., tropical fruits, bananas and some root vegetables) which are chill-sensitive and may be damaged at low temperatures (Champions for Change, 2011).

For retailers, it is very costly to control temperatures and relative humidity of all products, given the short time that F&V are exposed in store. However, Sonae MC already has some products of this business line displayed in fridges. For consumers, a strong appeal through social networks, websites or even in-store exposure may reduce waste at home.

The retailer has already launched some in-store tips regarding this topic, in the F&V area (as shown in Figure A.2, in Appendix A). However, as the font size is too small, it may not draw the consumer's attention.

4.2 Re-use and Recycling

This section proposes some improvements found within post-breakage processes, regarding the use of personal digital assistants (PDA) and the products directed to donations and social areas.

Furthermore, a baseline of data analysis was developed to help with the interpretation of breakages by valorisation option, by category and subcategory and by store. This baseline has been completed for one month only (2019 January), but it can now be replicated for the intended months. However, the data may not be absolutely correct due to some PDA missteps and possible errors, explained below. Moreover, this baseline will allow the finding of stores and categories with the

lowest rate-use in the donation, reuse or even disposal processes, and identify possible areas for improvement.

PDA Listings

Sonae MC relies upon PDAs, also known as enterprise digital assistants (EDAs), for mobile data applications in stores. Their PDAs have extra features for data capture, such as bar-code readers, to facilitate the scan of products or item codes.

One of the applications of the PDA is to register the breakages in the system, after removing the products from sale. In this record, it is necessary to enter the reason and destination of the breakage. The reasons can be 'Donations', 'Expiration Date', 'Depreciated' (loss of commercial value), 'Breakdown' (when there is a drop or packaging opens) and others. The destination types can be a specific institution in case of donation, 'social areas' to reuse or 'waste'.

One of the problems encountered, regarding this process of breakage registration, is the lack of sensitivity of the employee responsible for introduce the information. This person can misunderstand the reason or destination type, promoting an incorrect registration. In addition, all destinations can be associated with any reason, which promote the possibility of data errors. For instance, if the 'donation' reason is chosen (which we could argue that is not a reason by itself but a destination), there is a possibility to select the destination 'waste'. Besides, when this reason is chosen, it is not possible to know the actual reason for the breakage. Moreover, in a particular store there are institutions names, as possible destinations, that do not collect food there. Furthermore, all breakages that are used in a specific project (e.g., W2E or Panana) are not recorded with that destination since it does not appear as an option.

Therefore, it is necessary to redesign the lists of reasons and destinations, as well as to individualise them for each store. This opportunity will promote consistency in data and a more correct description of reasons and destinations, making it easier for staff to register the breakages. In addition, it will be possible to further analyse certain topics due to more accurate data. For instance, to analyse which reasons cause the biggest breakages or which destinations receive the most of these products.

Staff Education

Many obstacles to food donation are related to legal and food safety issues. F&V are hard to manage because they do not have a specific expiration date. Therefore, these products are only removed from the shelf when they are no longer appealing to the consumer. In such case, the store employee might also think that it is not suitable for donation. Therefore, staff education by raising awareness of the donation process could be a starting point to improve this valorisation initiative. Since this is currently a Sonae MC project, the impact of such education programs will be further analysed in Chapter 5.

4.3 Recovery

A new opportunity for a recovery project is a collaboration with company Z to treat the organic waste of Sonae MC. Although the core activity of company Z is the collection, treatment and disposal of urban wastewater, from various municipalities, a collaboration with Sonae MC could result in a new business model with benefits for both companies.

The treatment of wastewater is based on a system of biological treatment by activated sludge, under conventional or extended aeration. All sludge (primary and biological) goes through thickeners (gravitational and flotation, respectively) to concentrate and mix it. Then, the resulting sludge proceeds to an anaerobic digestion system for biogas production. This system is identical to that of W2E, explained earlier in Chapter 3. Through a cogenerator, this biogas will result in electricity, for auto-consumption, and calorific energy to heat the digesters. Finally, the thickened sludge is centrifugally dehydrated to be removed and forward to an environmentally suitable destination.

The idea of this collaboration would be to give an end-use, unlike landfill disposal, to the organic waste generated in the stores located near the facilities of company Z (target stores). Since company Z is not using the full capacity of the digesters, the recover of the organic waste collected would allow to use the remaining capacity to produce more electricity and heat. For the retailer, a positive aspect of this collaboration would be the cost savings of collecting and treating organic waste. Nevertheless, a further analysis of the synergies between the two companies needs to be performed to define a business model where the collaboration would work. To move forward with a possible pilot-project, company Z needs to know the types and quantities of waste generated at the target stores. Additionally, an estimate of the waste/water conversion rate used in the W2E project would help understand the potential of the waste to generate energy.

Chapter 5

Analysis of Staff Training about Donations

This chapter evaluates the impact of staff training on the donation process. Staff training is performed at the store level, aiming to raise awareness about products and conditions, in the process of reusing food breakages, rather than immediately disposing them. Essentially, this training helps standardise the entire in-store donation process. Regarding only the three store formats under study (mentioned before), Sonae MC performed this intervention in 38 stores in the country (13 in Porto and 25 in Lisbon). Initially, it was intended to have follow the start of staff training in a specific store, and analyse the impact achieved. However, since that was not possible, it was decided to conduct this detailed and scientific analysis with the data available.

A Difference-in-Differences (DiD) approach was used to estimate the impact of such training in the company's donations. Goodwin (2017) refers that for every $1 invested by companies in activities such as training staff to reduce food losses in production, $14 or more can be saved. By implementing our method, companies can evaluate the efficacy of their training. With such information, they can thereafter decide if investing time, people and money in staff training will be an effective solution to increase donations.

This chapter is organised as follows. Section 5.1 contains a literature review related with DiD method. Section 5.2 describes the dataset and the procedure for group constitution. The DiD model used and the obtained results are presented in Sections 5.3 and 5.4, respectively.

5.1 DiD Literature Review

The DiD method is a popular approach to estimate causal relationships related with a specific intervention or treatment. The difference in outcomes after and before the intervention in the treated group is compared to the same difference in a control group, i.e., with a group unaffected by the intervention (Bertrand et al., 2004). Its simplicity and potential to circumvent many of the endogeneity problems that typically arise when making comparisons between heterogeneous individuals represent some of the intuitive appeals of DiD.

Expositions of this approach at an advanced textbook level are provided by several authors, such as Meyer (1995), Angrist and Krueger (1999), Heckman et al. (1999), Angrist and Pischke (2009), Blundell and Costa Dias (2009), and Imbens and Wooldridge (2009). Snow (1854) is thought to be the first scientific study using explicitly a DiD approach, where the concern was whether cholera was transmitted by (bad) air or (bad) water. Then, the basic idea of the DiD appeared in the economic field. Here, DiD was first used to study the impact of minimum wages (e.g., Obenauer and Nienburg (1915) and Lester (1946)). Later on, DiD became relevant in other fields as well, such as psychology. Rose (1952) investigated the effects of a regime of 'mandatory mediation' on work stoppages using a DiD design. Following the same logic, Simon (1966) conducted an analysis of the price elasticity of liquor sales, noting that at that time prices were fixed by states.

Thereafter, DiD designs have been used to address many other important policy issues, such as the effects of minimum wages on employment (e.g., Card and Krueger (1994)), the effects of training and other active labor market programmes for unemployed on labor market outcomes (e.g., Heckman et al. (1998); Blundell et al. (2004)), the effect of immigration on the local labor market (e.g., Card (1990)), or the analysis of labor supply (e.g., Blundell et al. (1998)).

Regarding the food retail sector, there is also a considerable number of authors that analyse the effects of different interventions using a DiD methodology. Skuterud (2005) exploited the variation in deregulation dates between provinces to identify how retail employers adjust employment and hours of work when deciding to open on Sundays. Davis et al. (2009) measured the impact of the entrance of a mass merchandiser into the same area as a grocery store. Hilger et al. (2011) studied the effect of expert opinion on demand for experience goods (wines), transmitting quality information as opposed to solely shelf visibility. Basker (2012) estimated the effect of scanners on labour productivity of several retail stores. Surkan et al. (2016) evaluated a multifaceted supermarket intervention, promoting healthier alternatives to commonly purchased foods in the promotion of food sales. In-store interventions were product labelling, employee training, community outreach, and in-store promotions, including taste tests. Richardson et al. (2017) estimated the impacts of a new supermarket in a low-income desert, on residents' economic status and health. To the knowledge of this author, the DiD approach has not yet been used to estimate the effect of staff training in the donation process.

5.2 Empirical Setting

In order to perform this analysis, a dataset of donation values provided by the retailer under study was used. The data includes the donation history from more than 280 stores between 2017-01-01 and 2019-07-31. The store formats (DOP) considered, as previously stated, are Continente, Continente Modelo and Continente Bom Dia. The data used could be distinguished into donation-related data (month, donation amount and quantity, institution's tax benefit) and store-related data (store number and number of institutions that collect donations there). The amount donated is determined by the products' cost price. The tax benefits, as mentioned before, results from an

incentive for donations by the Portuguese Government, as long as the beneficiary institution is classified as an IPSS. Such tax benefit only depends on the IPSS fiscal framework, which relies on its activity and beneficiaries.

From this data, two stores types were selected: those whose staff went through a training process to increase awareness of products and conditions of the donation process, and those whose staff did not have such training. These groups correspond to the treatment and control groups, respectively. Since the treatment (staff training) started at different times for each store, it was necessary to match each treated store with a corresponding match, in order to use the DiD method. Such match was performed using an experimental heuristic, setting a control for each treated store based on similarities between the averages of total amount and total volume donated as of 2017-08. This date was chosen since it was the first moment of intervention (staff training) in all stores. The impacts on only 17 treated stores, match with 17 controls, was studied as a preliminary analysis.

All months prior the start of staff training at each treated store are part of the *pre-treatment* period and thereafter as *post-treatment* period. The *pre* and *post-treatment* periods of each control store was set to be equal to the one of the matched treated store. Therefore, every month without donation data in a store was removed for the matching store.

5.3 Model Specification

A Difference-in-Differences (DiD) approach (Angrist and Pischke, 2009) was used to evaluate the impact of staff training on the total amount donated to institutions, the total quantity donated and the total tax benefits retained. In this setting, the treatment group consists of stores who received staff training after certain point, while stores that did not received staff training constitute the control group.

DiD methodologies can be applied to more than two time periods, as is the case of this analysis (Angrist and Pischke, 2009). Here, the period of treatment is the period after the start of staff training in each (treated) store.

One of the key assumptions behind DiD is that, in the absence of treatment, the behaviour of the dependent variable would be similar in the treatment and control groups (Angrist and Pischke, 2009). Treatment induces a deviation from such common trend, from which a causal relation is extracted. Therefore, before performing the DiD regression, it must be confirmed that different *pre-treatment* trends in the dependent variable between the two groups do not exist, as this might affect the upcoming analysis. The following model was used to analyse the absence of such *pre-treatment* difference in trend:

$$X_{in} = \gamma_1 TREAT_i + \gamma_2 NrInst_i + \gamma_3 PopDens_i + M_n + \varepsilon_{in} \tag{5.1}$$

where i refers to the store, n to the corresponding month, X_{in} to the dependent variable by store i in month n (e.g., Amount Donated by store), $TREAT_i$ to a dummy variable equal to one when

store i is in the treatment group, and zero otherwise, $NrInst_i$ to the number of institutions assigned to store i and $Pop.Dens_i$ to the population density of the municipality where the store i is located. The coefficient of interest, γ_1, measures the difference in the dependent variable trends. The month seasonality effect (M_n) is also included since certain months (e.g., August or December) are weak periods of donations, due to being holiday periods. This variable, M_n, which encodes the month of the year of the donation, ranges from one to twelve (January to December). Besides, it was also included the institutions number of each store and the population density of the store municipality as fixed effects since this data varies from store to store.

This model was used for three dependent variables (X_{in}): (1) the total amount donated to institutions; (2) the total quantity donated and (3) the total amount of tax benefits retained. The following model was used to estimate the impact of staff training in the above variables:

$$\begin{aligned} X_{in} = \quad & \alpha_1 TREAT_i + \alpha_2 AFTER_n + \alpha_3 TREAT_i x AFTER_n + \\ & \alpha_4 NrInst_i + \alpha_5 PopDens_i + M_n + \varepsilon_{in} \end{aligned} \tag{5.2}$$

where $AFTER_n$ corresponds to one if the store staff were being trained at time n and zero otherwise. The coefficient of interest is α_3, which measures the difference in the dependent variable between the treatment and control groups. The model was also used for the three dependent variables as in the verification of *pre-treatment* trends.

5.4 Results

The verification of *pre-treatment* trends in the dependent variables was performed following the model presented in Equation 5.1. The results are presented in Table 5.1.

As can be seen, the coefficient of interest (γ_1) of the TREAT variable is statistically insignificant in all dependent variables. Therefore, there are no statistically significant differences in the *pre-treatment* outcomes trends (total amount donated, total quantity donated and total tax benefits retained) between the treatment and the control groups. Since the previous results validate the parallel trends assumption, the DiD method can now be applied.

Table 5.2 presents the estimates from Equation 5.2, using the total amount donated (in euros), total quantity donated (in units) and total tax benefits retained (in euros) as dependent variables.

The coefficient of interest, α_3, is positive and significant ($p < 0.01$) in the three columns. Thus, it can be seen that donations increase in the treated stores following staff training. Specifically, the treated stores donated 929.70 € more on average (an increase of 125%), 683.66 units more on average (an increase of 41%), and retained 20.16 € more on average in tax benefits (an increase of 125%) [1]

[1] To calculate the percentages, it was used the following *pre-treatment* average outcomes of the 17 treated stores: Amount Donated: 743.741 €, Quantity Donated: 1685.9 units and Tax Benefit: 16.12 €.

Table 5.1: Verification of *pre-treatment* trends.

	Dependent variable:		
	Amount Donated (euros)	Quantity Donated (units)	Tax Benefit (euros)
TREAT	−138.27	340.54	−1.42
	(97.20)	(210.57)	(1.40)
NrInst	135.88**	801.05***	5.82***
	(54.15)	(117.30)	(0.74)
PopDens	−0.08*	−0.09	−0.001**
	(0.04)	(0.09)	(0.001)
Monthly FE	Yes	Yes	Yes
Observations	411	411	401
NrStores	34	34	34
R^2	0.68	0.77	0.49
Note:			$^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

Table 5.2: Impact of staff training on the donation process.

	Dependent variable:		
	Amount Donated (euros)	Quantity Donated (units)	Tax Benefit (euros)
TREAT	−443.52***	18.64	−4.59***
	(96.14)	(176.56)	(1.63)
AFTER	162.54**	316.15**	3.38***
	(77.89)	(143.05)	(1.30)
*TREAT*x*AFTER*	929.70***	683.66***	20.16***
	(106.13)	(194.91)	(1.78)
NrInst	419.33***	640.17***	10.69***
	(39.26)	(72.10)	(0.67)
PopDens	0.11***	0.07	0.001*
	(0.03)	(0.06)	(0.001)
Monthly FE	Yes	Yes	Yes
Observations	921	921	897
R^2	0.64	0.69	0.62
Note:			$^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

This increase confirms that staff training, i.e., raising awareness about products and conditions, has a positive and significant economic impact on the donation process. Furthermore, the increase in donated food also leads to lower environmental and social impacts from retail breakages. Since more food is being reused for human consumption, less waste is being disposed at landfills. This also means that retailers will reduce their costs as the quantity of waste that SGRUs will collect in-stores will be lower. Therefore, the retailer's effort to donate more food in-store by introducing staff training is beneficial to Sonae MC. Besides, it is also valuable to all FSC, since the food is ultimately consumed rather than disposed of in landfills.

As stated earlier, only 17 treated stores in a total of 38 were analysed due to the short time to perform this analysis. Furthermore, the matching process used can be improved. For instance, using a combination of caliper matching with a Mahalanobis distance metric based on observable characteristics (Hegde and Tumlinson (2014); Chu et al. (2017); Narang and Shankar). In such case, the analysis would include more stores and, consequently, more observations, producing more robust results. In addition, as mentioned before, if it had been possible to follow a start of this intervention in-store, a better insight on donation process could be applied in this analysis. Nevertheless, the DiD approach can easily be applied to other interventions or changes made by the retailer.

Chapter 6

Conclusions and Future Work

This dissertation focused on the waste management processes of the Portuguese retail company, Sonae MC. The primary goal of this work was to promote a better valorisation of the retailer fruits and vegetables (F&V) breakages. Furthermore, another concern to be addressed was the subjectivity of the store staff to value these breakages as they do not have a specific expiration date. The F&V breakages were analysed, as well as, several waste management options were described following the levels of the food waste hierarchy. Consequently, some improvements opportunities in the processes of combating food waste were identified. Finally, a detailed and scientific analysis was conducted to understand the impact of performing staff training on one of the preferable strategies practice by the retailer to avoid food wastage, the food donation.

The project led to the conclusion that the retailer should continuously analyse its food wastage and all the available options to combat and value it. In addition, Sonae MC should remain striving, wherever possible, to improve its processes in order to give the best end-use to its breakages. These improvements could lead to a reduction in the environmental, economic and social impacts of the company.

In terms of reducing F&V breakages, the retailer can proceed with the ethylene filter as a pilot-project. This discreet but high-tech filter can be used in the F&V with higher breakages, due to quality and ripeness reasons. This ethylene absorber provides many advantages for the retailer and it is a valuable opportunity since it prevents (for longer) F&V breakages. The retailer is currently evaluating if it will move on with a commercial test of this filter or not. Additionally, more straightforward awareness campaigns can also help to reduce breakages.

Improvements in PDA lists, such as restructuring and individualisation by stores, should also be implemented by the retailer. This opportunity will make it easier for staff to register the breakages, avoiding mistakes, and it will promote more accurate data, allowing the analysis of certain topics.

Moreover, Sonae MC can create a collaboration with a wastewater treatment company to give a better end-use to the organic waste generated in stores, rather than landfill disposal. This opportunity is valuable for both companies, since one can produce more energy and heat from waste at its facilities, and the other saves on the costs of collection and subsequent treatment. Nonetheless,

a further analysis of the synergies between the two companies needs to be performed to evaluate the potential of the collaboration and define its business model.

Regarding the in-store staff training, the DiD estimates confirm that the economic impact on donations is positive and significant since all variables tested showed an increase benefit for stores following such training. Besides, having more food following the donation process reduces the environmental and social impacts related to food wastage. Therefore, the effort in training the staff in-store regarding the products and conditions on the donation process is beneficial and worthwhile to Sonae MC, as well to all FSC. For future research, the matching process can be improved. Instead of using an experimental heuristic, a combination of caliper matching with a Mahalanobis distance metric based on observable characteristics can be tested. Following this intervention in-store may also help to have a better insight in order to apply it in the analysis.

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Appendix A

Table A.1: Different definitions related to food loss (FL) and food waste (FW).

Reference	Concept	Definition
Lipinski et al. (2013)	FL vs. FW	Food Loss is the food that spills, spoils, incurs an abnormal reduction in quality such as bruising or wilting, or otherwise gets lost before it reaches the consumer.
		Food Waste is the food that is of good quality and suitable for human consumption but that does not get consumed because it is discarded, whether or not after it is kept beyond its expiry date or left to spoil.
FAO (2013)	FL vs. FW	Food Loss refers to a decrease in mass (dry matter) or nutritional value (quality) of food that was originally intended for human consumption.
		Food Waste refers to food appropriate for human consumption being discarded, whether or not after it is kept beyond its expiry date or left to spoil.
Linda Scott Kantor and Oliveira (1997)	FL	Food Loss usually refers to edible food, lost at any stage of the FSC, discarded or unserved restaurant-prepared food, or products that are unmarketable for aesthetic reasons, but otherwise edible and safe.
Grolleaud (2002)	FL	Food Loss refers to the total modification or decrease in food quantity or quality which makes it unfit for human consumption.
Parfitt et al. (2010)	FL vs. FW	Food Loss is the waste produced at the beginning of the FSC (production, post-harvest and processing stages).
		Food Waste is when it appears at the end of the FSC (retail and final consumption).
		Post-Consumer Waste is the food waste produced at households.
Gustavsson and Stage (2011)	FW	Food Waste is the edible food that is lost during any phase of the food system.
Himmelheber (2013)	FW	Food Waste occurs when edible items go unconsumed as a result of human action or inaction, often result of a decision made by business, governments or consumers.
Luca Falasconi and Segrè (2015)	FW	Food Waste refers to all the products discarded from the FSC, while still preserving their nutritional value and complying with safety standards.
Canali et al. (2014)	FW	Food Waste is the final destination of all food, and inedible parts of food, removed from the FSC.
O'Connor et al. (2016)	FW	Food Waste regards any food, and inedible parts of food, removed from the FSC to be recovered or disposed of, but not including food or inedible parts of food removed to be sent to animal feed or bio-based material/chemistry processing.

Table A.2: Total EU food wastage generation in tonnes, with best estimate by Member State. Source: Bio Intelligence Service (2010).

	Production	**Households**	**Other sectors**	**Total**
EU27	34 755 711	37 701 761	16 820 000	89 277 472
Austria	570 544	784 570	502 000	1 858 000
Belgium	2 311 847	934 760	945 000	4 192 000
Bulgaria	358 687	288 315	27 000	674 000
Cyprus	186 917	47 819	21 000	256 000
Czech Republic	361 813	254 124	113 000	729 000
Denmark	101 646	494 914	45 000	642 000
Estonia	237 257	82 236	36 000	35 5000
Finland	590 442	214 796	208 000	1 013 000
France	626 000	6 322 944	2 129 000	9 078 000
Germany	1 848 881	7 676 471	862 000	10 387 000
Greece	73 081	412 758	2 000	488 000
Hungary	1 157 419	394 952	306 000	1 858 000
Ireland	465 945	292 326	293 000	1 051 000
Italy	5 662 838	2 706 793	408 000	8 778 000
Latvia	125 635	78 983	11 000	216 000
Lithuania	222 205	111 160	248 000	581 000
Luxembourg	2 665	62 538	31 000	97 000
Malta	271	22 115	3 000	25 000
Netherlands	6 412 330	1 837 599	1 206 000	9 456 000
Poland	6 566 060	2 049 844	356 000	8 972 000
Portugal	632 395	385 063	374 000	1 391 000
Romania	487 751	696 794	1 089 000	2 274 000
Slovakia	347 773	135 854	105 000	589 000
Slovenia	42 072	72 481	65 000	179 000
Spain	2 170 910	2 136 551	3 388 000	7 696 000
Sweden	601 327	905 000	547 000	2 053 000
United Kingdom	2 591 000	8 300 000	3 500 000	14 391 000

Table A.3: Leading food wastage initiatives.

Organisation Initiative	Geography	Description
SAVE FOOD	Global	SAVE FOOD is a global initiative on food loss and waste reduction and is led by FAO and Messe Düsseldorf. Since 2011, it has worked with donors, development agencies, financial institutions and the private sector (particularly the food packaging industry) to develop and implement a program to reduce food loss and waste. The program rests on four pillars: 1) awareness raising; 2) collaboration with like-minded initiatives; 3) policy, strategy, and program development; and 4) support to FSC actors and organisations involved in food loss and waste reduction. (FAO)
Think.Eat.Save Campaign	Global	Think.Eat.Save is a campaign of the SAVE FOOD Initiative led by UNEP, FAO, and Messe Düsseldorf. The campaign seeks to galvanise widespread global, regional, and national actions to reduce food waste, and specifically targets food wasted by consumers, retailers, and the hospitality industry. The Think.Eat.Save website is a portal to showcasing ideas to provide a one-stop shop for news and resources, and to launch a call for everyone to take action on this global concern. (UNEP)
The Global Food-Banking Network	Global	The Global Food-Banking Network (GFN), founded in 2006, is a global non-profit organisation committed to creating, supplying, and strengthening food banks and food bank networks throughout the world outside the united States. GFN supports food banks and national food bank networks in more than 30 countries that are home to more than one-third of the world's undernourished people. Food banks acquire donated food, much of which would otherwise be wasted, and make it available to those in need through a network of community agencies that provide food to the hungry. (Global FoodBanking Network)
OECD Food Chain Analysis Network	Global	The Organisation for Economic Co-operation and Development (OECD) is an international organisation that works to build better policies for better lives. The Food Chain Analysis Network (FCAN) was launched by the OECD in 2010 and provides a broad platform for dialogue building on analytical work and policy experiences on emerging issues of relevance to the FSC. It consists of government officials, international organisations, industry stakeholders, consumers, academic experts, and non-governmental organisations. (OECD, 2010)
FUSIONS	Europe	FUSIONS (Food use for Social Innovation by Optimising Waste Prevention Strategies) aims to reduce food waste in Europe. It was a four-year project running from 2012 to 2016, funded by the European Commission. FUSIONS has 21 project partners from 13 countries, including universities, research institutes, consumer organisations, and businesses. FUSIONS aims to support the European Commission target of a 50 percent reduction in food waste and the Road map toward a Resource Efficient Europe. (FUSIONS)

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Table A.3: *Continued from previous page*

Organisation Initiative	Geography	Description
WRAP UK	United Kingdom	Established as a not-for-profit company in 2000, WRAP is backed by United Kingdom government funding from Defra (Department for the Environment, Food and Rural Affairs), the Scottish Government, the Welsh Government, and the Northern Ireland Executive. WRAP UK helps people recycle more and waste less, both at home and at work, which are practices that offer economic as well as environmental benefits. In particular, WRAP launched the 'Love Food, Hate Waste' campaign in 2007, to reduce food waste in the UK teaching consumers about this issue. (WRAP)
The Zero Waste	Europe	The Zero Waste is a programme in Europe since 2011 with the aim of guiding people to emulate sustainable natural cycles, where all discarded materials are resources for others to use. It concentrates on waste prevention as well on separate collections to maintain materials' utility, source separation of reusable products and components, various recyclable materials, food&garden waste and residual waste. (Zero Waste Europe)
REFRESH	Europe and China	REFRESH (Resource Efficient Food and dRink for the Entire Supply cHain) is a research project where 26 partners from 12 European countries and China will work towards the goal to reduce food waste across Europe by 30% by 2030 (Sustainable Development Goal 12.3), including reducing waste management costs, and maximising the value of unavoidable food waste and packaging materials. The Horizon 2020 Framework Programme of the European Union finances this research project. (Refresh)
Culinary Misfits	Germany	Started by two friends, Culinary Misfits seeks out the "ugly" vegetables at grocery stores, farmers markets, and restaurants and turns them into delectable dishes at the events they cater in the city (New CityZens).
Feeding 5000	UK or International	Feeding the 5000 born in 2009 by Tristram Stuart and is an initiative to organise the world to prevent "wonky" fruits, vegetables, and other food from being wasted. It is an event where unsold foods are collected from farmers, packers and wholesalers in order to prepare a meal that feeds 5000 people. (European Commission, 2014)
Pay-as-you-waste scheme	South Korea	The South Korean government banned sending food to landfills in 2005. Since 2013, South Koreans have been required by law to discard food waste in these biodegradable bags, priced according to volume and costing the average four-person family about $6 a month. By purchasing them, residents are effectively paying a tax on their food waste upfront. (Huffpost, 2019)
Disco Soup Day	Global	A Disco Soup is an event where participants cook and eat a meal together made out of food that would have otherwise gone to waste (e.g. 'ugly' food or the products which do not conform to commercial aesthetic standards), with music and a dynamic, fun atmosphere (Slow Food, 2019). It started in 2012 in Berlin, Germany, as a 'protest soup' against food waste that fed 8000 people. In 2019, the chosen day was April 27 and, in Portugal, was celebrated in Arouca (CMArouca, 2019).

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Table A.3: *Continued from previous page*

Organisation Initiative	Geography	Description
Refood	Portugal	The Re-food Movement is powered by the good will of the community and it includes action from institutions, retailers, businesses and especially local volunteers, which distribute food. Besides, it is sustained by ongoing resource activation. Refood's goal is to distribute food from food system actors (shops, restaurants) which is not going to be eaten to those who are in need. On 15 April 2013, Refood became a Private Social Solidarity Institution (i.e., IPSS). (Refood)
DariAcordar	Portugal	DariAcordar is an association which promotes solidarity with support from political, economic and social groups (City Council, Parishioners Commissions, Private Social Solidarity Institutions) which want to cooperate to raise social solidarity. The association has given rise to the "Zero Waste" movement which makes partnerships with institutions through solidarity associations and pass meals and food products for those who need them. (PASC)
Dose Certa and *Embrulha* (Lipor)	Portugal	*Dose Certa* is a Lipor's project that seeks to reduce and combat food waste while promoting the importance of sustainable food at restaurants (canteens, restaurants, hotels, etc.). *Embrulha* was born of a need identified with *Dose Certa*, where it allows to prolong the life of the meal's leftovers in the restaurants, instead of going to waste. (Lipor)

Table A.4: Retailer classification of F&V in categories and subcategories.

Category	Subcategory
Fruits	Bananas
	Citrus
	Land Fruits
	Stone Fruits
	Seasonal Fruits
	Tropical Fruits
	Red Fruits
	Apples
	Pears
	Grapes
	Packaged Fruits
Vegetables	Lettuce
	Garlic and Onions
	Potatoes
	Cabbages
	Salad Vegetables
	Soup Vegetables
	Exotic Vegetables
	Tomato
	Packaged Vegetables
Specialities of F&V	4^{th} and 5^{th} range
	Aromatics
	Olives and Lupins
	Mushrooms
	Dehydrated
	Tree Nuts
	Take Out
	Processed

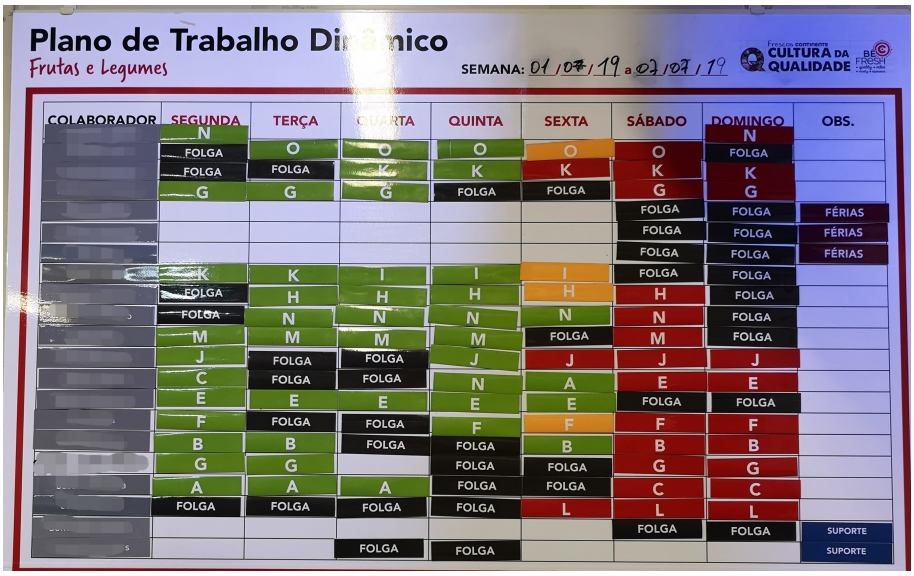

Figure A.1: Example of a work plan of F&V team from a Continente store.

Figure A.2: Examples of in-store tips, in the top right corner, regarding the F&V preservation.