Better sustainability in the food supply chain through technology: A consumer perspective

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Abstract

The achievement of the United Nations Sustainable Development Goals is pushing towards improving the sustainability of food supply chains. Food waste and food safety are among the most critical sustainability issues in the food supply chain. Previous studies have analysed the use of supply chain 4.0 technologies for reducing food waste and enhancing food safety but have neglected consumers as direct users of technology, not studying their preferences and buying behaviour. Through a survey study, this research aims at providing insights about ways in which those supply chain 4.0 technologies that can be used by consumers could be exploited for better sustainability. We investigate consumer openness to technology and consumer buying behaviour for food products in relation to sustainability. Results indicate that consumers can be ready to embrace technology. Their awareness of sustainability represents an opportunity for companies to offer tailored products and accessible services that can influence consumers towards more sustainable choices.

Keywords: food supply chain, sustainability, food waste, food safety, supply chain 4.0, technology

Paper type: Research Paper

1. Introduction

Sustainability is not a brand new concept, but only in recent years has the topic started to gain momentum in virtually all industries. Sustainable Development is defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Bruntland Report, 1987), and according to the "triple bottom line" view, it includes the dimensions of Environmental, Social and Economic Sustainability (Carter and Rogers, 2008). In fact, the real challenge of sustainability and sustainable development is to balance the fine line between the economic needs of today and the duty to protect the environment and the society in which we live. In this regard, the United Nations sent a strong message in 2015 by declaring the Sustainable Development Goals (SDGs), which represents a plan of action for people, the planet and prosperity (United Nations, 2015).

With regards to SDGs, the food sector plays a crucial role in the sustainable development of communities and the planet, given its significant social and environmental impact (Campoy-Muñoz et al., 2021; Kubícková et al., 2021). Therefore, there is an urgent need to respond to the challenge of moving towards more sustainable food supply chains. Sustainability issues are on the agenda due to the presence of perishable goods, unpredictable supply variations and stringent food safety and sustainability requirements (Verdouw et al., 2016), and we can find a link between the food industry and SDGs. According to this view, one of the main challenges is to ensure the right level of resources to produce food for future generations. This is related to the Responsible Consumption and Production goal (SDG 12), especially with the Target 12.3, which calls for "halving per capita global food waste at the retail and consumer levels and reducing food loss along production and supply chains (including post-harvest losses)" by 2030 (FAO, 2019). According to FAO, one-third of the food produced worldwide is lost or wasted, which amounts to about 1.3 billion tons per year. Food loss and waste are translated into roughly US$ 680 billion in industrialised countries and US$ 310 billion in developing countries

(FAO, 2019) – and this represents one of the key challenges for the sustainable development of all humankind (Moraes et al., 2021; Carolan, 2021), which is called upon to seek out not only methods for food waste management, but also, and especially, for preventing food waste (Joshi and Visvanathan, 2019; Knezevic et al., 2019). Another aspect is the challenge faced in order to ensure food safety for final consumers. There is the need, for example, to avoid food borne infections to preserve health (Dani and Deep, 2010) and to guarantee the authenticity of products so as not to damage consumer trust and confidence in food purchases: traceability in this regard is essential (Tan et al., 2020). The attention to food fraud and food safety is increasing systematically. This objective is related to the broader Good Health and Well Being Goal (SDG 3) (FAO, 2019). The World Health Organization (WHO) has estimated the incidence, mortality, and disease burden due to foodborne hazards and has stated that the global burden of FBD (Foodborne Diseases) is comparable to those of the major infectious diseases, HIV/AIDS, malaria and tuberculosis (Havelaar et al., 2015). One of the most famous examples of foodborne illnesses is mad cow disease, which broke out in 1986, above all in the UK.

Consequently, the avoidance of food waste and the assurance of food safety are very high on the agenda (Esparza et al., 2020; Campoy-Muñoz et al., 2021). A possible solution that may help to improve the levels of food supply chain sustainability by reducing food waste and enhancing food safety is represented by Supply Chain 4.0 (SC 4.0) and its technologies (Azevedo et al., 2021; Nandi et al., 2021). "Supply Chain 4.0 is a transformational and holistic approach for supply chain management that utilises Industry 4.0 disruptive technologies to streamline supply chain processes, activities and relationships to generate significant strategic benefits for all supply chain stakeholders" (Frederico et al., 2019).

Scientific literature is rich in studies that discuss how supply chain 4.0 technologies can be deployed and combined to create a sustainable food supply chain, claiming that a relationship between food sustainability and SC 4.0 technologies exists (Cañas et al., 2020, Kayikci et al., 2022). However, from a supply chain perspective, it seems that the literature

has traditionally focused on the upstream stages of the food supply chain in the analysis of the relationship between technology and sustainability, especially investigating the business-to-business channel. However, it is recognized that the successful adoption of technologies can be fostered through a pervasive approach that also involves the downstream stages of the chain, and that proactively follows demands for sustainability coming from the market and consumers (Bloemhof et al., 2015). If consumers have traditionally been seen as the passive receivers of the products and external to the supply chain planning process, modern consumers instead play an active role in it (He et al., 2020): they expect to access a whole range of information, compare prices and share their experience and knowledge with other consumers, influencing the buying behaviour and habits of peers, also with regards to the acceptance of technology (Bianchi and Andrews, 2018; Sousa et al., 2021) and their expectations in terms or products and services (De Kervenoael et al., 2016). Previous contributions overlooked consumer acceptance, which plays a crucial role in the diffusion of these technologies along the supply chain, especially in those stages where consumers have an active role (Tsai et al., 2014; Rollin et al., 2011), e.g., in the retailing stage.

For this reason, the objective of this study is to provide the food industry players with insights and guidelines about ways in which they can exploit technology for better sustainability, by understanding the level of consumer acceptance in the utilisation of those SC 4.0 technologies they can access when they buy food products. In particular, this research focuses on investigating consumer openness towards technology and the consequent buying behaviour for food products in relation to sustainability in terms of reduced food waste and improved food safety. In doing this, we conducted a survey on Italian consumers. Since Italy is one of the major markets in Europe for food products (Nielsen, 2019) and because it is a representative nation worldwide, being part of the Group of Seven (G7) countries, our sample group represents a relevant field of application .

The remainder of the paper is organised as follows: Section 2 presents the study's theoretical background, along with the research gap and the research questions. Section 3 describes the adopted methodology for the empirical part of the research. Section 4 presents the results, which are discussed in Section 5. Section 6 concludes the paper with final remarks and future research directions.

2. Literature review

A first element characterising the role of consumers in the adoption of SC 4.0 technologies for the sustainability of the food chain is consumer attitude towards sustainability. When sustainability becomes an element of purchasing decisions when consumers buy food products, they seem to care about the social and environmental impacts of their actions; in this sense, marketing policies can influence the behaviour of individuals regarding their approach to reducing or managing food waste (Mondéjar-Jiménez et al., 2016). At the same time, thanks to an increasing awareness of the importance of sustainable practices (Miranda-Ackerman and Azzaro-Pantel, 2017), they are also expecting companies to be committed to making an impact in terms of the social and environmental sustainability of the food sector (Butler, 2018),. However, according to other studies, affordability and quality are still the main driving factors behind a vast majority of purchases, especially for younger people (Anic et al., 2014), notwithstanding a growing interest in sustainability matters (Martins, 2019). This emerges in the light of how consumers approach the trade-off between price and quality, which is also intended in terms of the relationship between price and expiry date, as based on a dynamic pricing approach (Chung and Li, 2013). Such an approach, for instance, would allow consumers to buy food at a discount that would otherwise be discarded (Adenso-Díaz et al., 2016; Moustafa et al., 2018). The behaviour of consumers in relation to the expiry date of food products represents a driver in the generation of household food waste (Moreno et al., 2020).

On the one hand, this could be explained by the fact that consumers might not be fully aware of the amount of food waste generated every year, and it seems that they underestimate their own responsibility in relation to this problem; instead, producers and retailers are blamed as those being the ones mainly responsible for this problem (Neubig et al. 2020). On the other hand, consumers might not be completely aware of the implications of potential mismanagement of food safety (Gallo et al., 2021), until an event triggers their attention and spoils their trust in the food supply chain, (e.g., mad cow disease or the horse meat scandal) (Cates et al., 2015).

Another element characterising the role of consumers is their level of openness towards technology. As reported by the National Retailer Federation (NFR) in the "Consumer View Summer (2019)", despite the fact that many of the technologies retailers are deploying are still in the early stages, initial consumer attitudes towards them seem to be positive. Focusing on the food sector, the seminal work by Rollin et al. (2011) explained that many factors could influence the consumers' acceptance of food technology innovations, and understanding them will be crucial to the realisation and success of technological advances, as posited also by McClements et al. (2021). The acceptance of specific technology can be driven by risk-benefit perceptions that a certain customer may have, as well as by socio-demographic and economic factors. At the same time, technology knowledge and trusted sources of information play a key role in consumer acceptance (Costa-Font et al., 2008; Hicks et al., 2009). The lack of knowledge regarding innovative and emerging food technologies can be a barrier to their acceptance since consumers can be suspicious of the least familiar technologies (Tongnamtiang and Leelasantitham, 2019). In contrast, a greater knowledge of the subject is mostly associated with positive attitudes about technology (Wunderlich and Gatto, 2016). In addition to this, it also seems that having consumers "educated" about new technologies can lead to ensuring that they will pay a premium price for being able to rely on technology to support their purchasing decisions, under the assumption that the adoption of technology and related availability of additional

information might increase a product's price (Costa-Font et al., 2008; Hicks et al., 2009). However, there is no unanimous consensus in the literature about this: some studies showed that consumers are willing to pay a premium price to have additional information on the origin, traceability, and quality of food products (Rousseau and Vranken, 2013; Desmet, 2016; Violino et al., 2019); on the contrary, other studies affirmed that even if consumers always want a larger amount of more reliable information about the safety and traceability of products, most of them are not willing to pay for it (Müller and Schmid, 2019).

OF the various types of SC 4.0 technologies that exist, which according to the literature are suitable for addressing the challenges of food waste and safety in the food supply chain (e.g., Internet of Things, Blockchain, Big Data Analytics and Cloud computing), some can enable the involvement of final consumers. Such technologies can play a key role in improving the transparency and traceability of the individual stages of the supply chain and the various actors involved, thus enhancing consumer trust and awareness. For instance, IoT-based tags embedded in the product, which records information on the entire process from production to distribution, enable consumers to access a huge amount of information that can lead them to a more aware purchase, with positive implications in terms of food waste reduction. On the supply side, IoT can enable intelligent packaging to track and monitor the conditions of packaged foods and to capture and provide data of a product's condition during storage and transportation (Chen et al., 2020), therefore providing food safety benefits. On the consumer side, it can enable interaction with consumers when they use, consume or dispose of food products. Smart tags combined with smart shelves might also facilitate variable pricing systems based on a product's expiry date (as per Wasteless, 2017; Gartner, 2019). With reference to food safety, Blockchain allows for tracking and authenticating the information throughout the entire food supply chain, and this becomes an important measure for identifying and addressing potential sources of contamination (Feng et al., 2020; Tse et al., 2017). QR codes for

traceability and information sharing based on Blockchain might also provide consumers with additional product features or history. Thanks to Big Data Analytics tools, algorithms that include consumer purchasing and inventory data can help predict food requirements at retail stores, resulting in adequate food delivery and decreased food waste. Likewise, predicting the shelf life of food products could become much more accurate, as data collected from supply chains could be used to more precisely determine when a food product will likely spoil (Astill et al., 2019). Finally, Cloud Computing can work as a powerful infrastructure in terms of storage and computational capacity, as it is able to manage the integration among multiple sources of data gathering, such as IoT and the transactions registered via Blockchain. Thanks to Big Data analytics tools, such as Machine Learning, this amount of data can be further exploited by conducting predictive analytics on consumer behaviour to further enhance food safety and food waste reduction (King et al., 2017).

2.1 Research gap and research questions

The literature review has shown the existence of some SC 4.0 technologies that can be used to improve the sustainability of the food supply chain through the involvement of the final consumers at the time of the purchase. It has also shown that consumer acceptance and willingness to use these technologies affects the success of their implementation in the supply chain for improved sustainability. However, we discovered that there is not sufficient knowledge about the characteristics driving consumer behaviour in this regard (e.g., socio-demographic factors) nor of the typology of consumers as grouped according to their sustainability preferences and openness to technology. In addition, if the adoption of SC 4.0 technologies means that there will be an additional cost for the consumers, we found contrasting opinions about consumer willingness to pay a premium price to obtain information about the safety and traceability of the food products.

Consequently, given the identified research gaps, to achieve the objective of the research as described in the introduction, we will provide an answer to the following research questions (RQs):

- RQ1: How does consumer openness to SC4.0 technologies for sustainability in the food supply chain vary depending on consumer characteristics and attitudes?
- RQ2: What are the factors driving consumer willingness to pay a premium price (when required) to have more information about the products they are purchasing through SC 4.0 technologies?

3. Research methodology

Given the objective of the research and the nature of the research questions, we decided to rely on a quantitative research approach (Ellram, 1996). To take an exhaustive perspective on the topic, we adopted a combination of methods to answer the two research questions (Brannen 2005). More specifically, we approached the research questions sequentially, basing our investigation on a survey study (Forza, 2002). To provide an answer to RQ1, we decided to rely on group analysis and cluster analysis so that the characteristics of consumers could be classified according to common patterns (Flanagan and Priyadarshini, 2021). In this way, their relationship to consumer openness to SC 4.0 technologies for sustainability in the food supply chain could emerge. To provide an answer to RQ2, we conceptualised, in a model, the various factors driving consumer willingness to pay a premium price for using SC 4.0 technologies for better food supply chain sustainability, and we isolated the drivers through a partial least square structural equation modelling (PL-SEM) approach. This is a tool well suited to addressing issues related to sustainability and complex relationships among variables and factors affecting specific outcomes (Rehman Khan and Yu, 2021).

We relied on data collected from 632 Italian consumers, who, as mentioned in the introduction, constitute an important field of application for the topic. Besides, the purpose of focusing on a single country was to avoid deviations in the results related to elements such as culture, language, social and economic environment (Colicchia et al., 2019).

The methodological framework of this research is depicted in Figure 1.

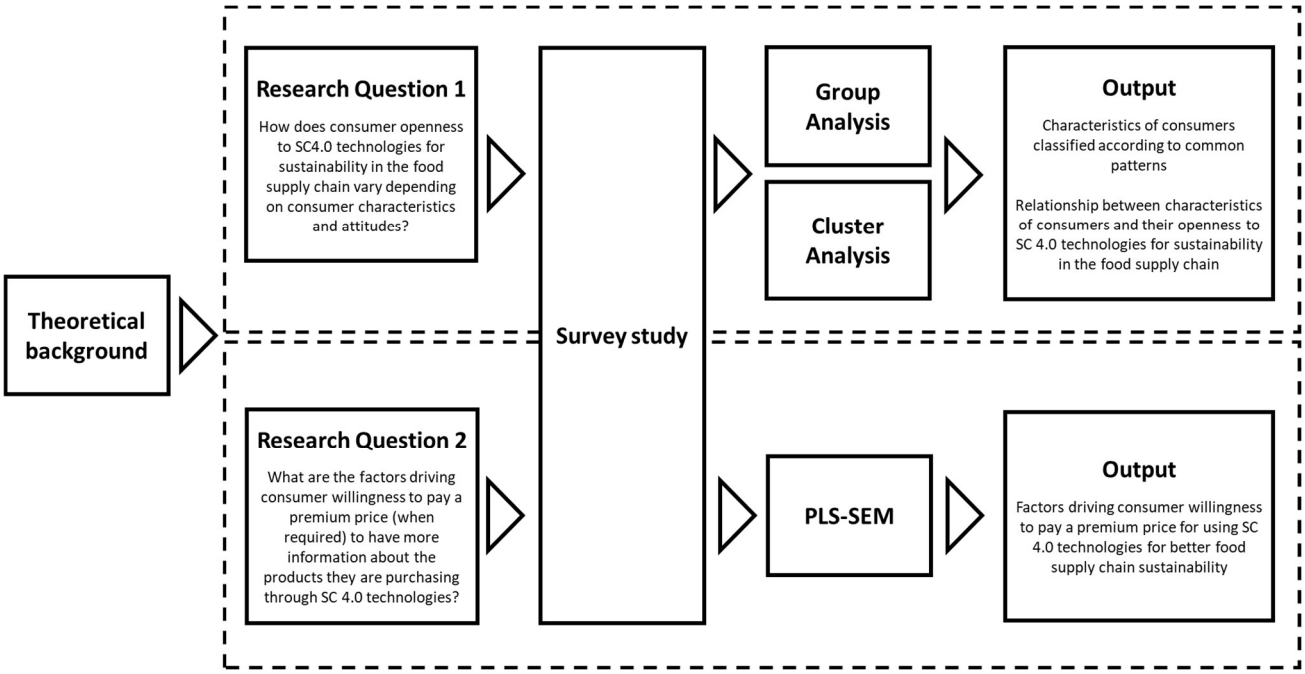

Figure 1 – Methodological framework

3.1 Survey instrument development

To build an appropriate measurement instrument, we identified the measurement scales from previous literature. Three academics and four practitioners reviewed the questionnaire items to ensure content validity. A five-point Likert scale was adopted to indicate, where applicable, the extent to which respondents agree or disagree with each question item, where 1 corresponds to strongly disagree, and 5 corresponds to strongly agree. The final questionnaire is reported in Appendix A. Because our target respondents

were Italian consumers, the questionnaire was translated into Italian and subsequently translated back into English by an external provider to make sure that the translated questions reflected the actual meaning of the original version (following the steps proposed by Brislin, 1980).

The first section of the questionnaire regards socio-demographic information. Section 2 includes questions related to the themes of sustainability, food waste and food safety. In the third section, respondents were asked to answer multiple-choice questions on consumer perception in relation to the role of organisations in the food supply chain as far as food waste and security liabilities are concerned. The subsequent sections address the consumers' buying behaviour and orientations and their level of openness to technological innovation.

3.2 Data collection

The survey was electronically administered to consumers through the Qualtrics™ platform. The link to the survey was circulated across social media platforms, such as Facebook, Instagram, WhatsApp, Telegram and LinkedIn. To reach a wider audience, the survey link was distributed to some Italian Facebook Groups focused on the topic of the research, such as "Rete Zero waste: il gruppo" (Zero Waste network: the group) and "Tecnologie e sicurezza degli alimenti" (Technology and Food safety). Concurrently, the link was shared among staff and students of the institutions the authors are affiliated with. Since the aim of this study was to reach a population of active consumers who have some spending power and the ability to express their preferences and orientations independently, we used as sampling criteria a minimum age of 18, the actual habit of doing some shopping, and residence in Italy. No other geographical or demographics constraints were added. This

choice was driven by the necessity to reach a wide and diverse population of Italian consumers without limiting their access to the survey.

In total, 648 survey questionnaires were received. However, only 632 responses were valid, as 16 of them were incomplete. Table 1 shows the information of the respondents.

Table 1 – Socio-demographic features of the sample of respondents

Metric	**No. of respondents**	**(%)**
Gender	Female: 423	67%
	Male: 209	33%
Age (years)	18-24: 208	33%
	25-34: 166	26%
	35-44: 99	16%
	45-54: 91	14%
	55 and over: 68	11%
Education	Secondary school: 38	6%
	High school: 233	37%
	University degree: 357	57%
Income	Student without personal income: 176	28%
	Below the national average: 154	25%
	Around the national average: 158	25%
	Above the national average: 140	22%
Shopping frequency	Less than once a week: 98	16%
	Once a week: 308	49%
	Twice a week: 149	24%
	Three or more times a week: 77	12%
Geographical location	Northern Italy	58%
	Central Italy	30%
	Southern Italy and main Islands	12%

The socio-demographics features of the sample of respondents show a good level of alignment with the average situation of the population living in Italy in the current years. Also, the geographical location of respondents is in line with the average national values, especially as far as the distribution of the spending and consumption is concerned (principally Northern Italy).

3.3 Definition of the variables

The literature review helped us in identifying the most important variables to be investigated. The survey questions related to these variables were combined to form the following constructs (see Table 2).

WPP (Willingness to Pay a Premium price by customers)

WPP was introduced to understand how much people are willing to pay more and then give an idea about the possible return on the investment to the interested companies, assuming that the willingness to pay more can be translated into higher prices set by the food manufacturers. It takes into consideration the willingness to pay more for several products. The discussion on whether customers are willing to pay more (i.e., premium price) or not for more food safety-related information has gained momentum in recent years (Astill et al., 2019). However, it is still quite unclear. According to Violino et al. (2019), consumers are ready to accept and be ready to spend more for the additional information if it is reliable. A different point of view is provided by Müller and Schmid (2019), who affirm that customers always want better quality and more information about products, but most are not willing to pay more for it. Only if they are well informed about the benefits they may obtain, might they be willing to spend more.

TO (Technology Openness)

TO measures how much the consumers are open to new technologies, taking into consideration the general interest in innovation, the level of adoption of new technologies and the ease of consumers to change their habits. This variable also relies on the fact that

educating customers about new technologies is critical to ensure that they will pay a premium price for products (Costa-Font et al., 2008; Hicks et al., 2009).

IT (Information Trust)

IT refers to the current level of trust consumers have regarding the information currently available on product labels; it measures consumers' opinions on the reliability and the effectiveness of the information. In fact, the literature shows that trust is one of the most critical factors in food production (Astill et al., 2019). Specifically, a 2016 study of consumer habits revealed that 94% of consumers find it important that food manufacturers are transparent about how food is made (Label Insight, 2016).

SB (Sustainable Behaviour)

SB measures if the final customers put sustainable behaviour and habits into practice, especially for what concerns food waste and how these consumers would behave facing a product that has already gone passed the suggested expiration date; expired food is a key driver in the generation of household food waste (Moreno et al., 2020). The literature indicates that this is an interesting aspect that needs to be delved into. In fact, as Neubig et al. (2020) claimed, consumer knowledge about general food waste and their food waste system is relatively poor. Even more surprisingly, it seems that consumers underestimate their own responsibility in relation to the food waste problem.

WUC (Willingness of the Consumer to Use technology)

WUC considers the willingness of the consumers to use technology to obtain more information and visualise several types of information about the product. As seen in the literature, innovative technologies are becoming a crucial factor in the buying process of final consumers. Especially, as reported by the National Retailer Federation (NFR) in the

"Consumer View Summer (2019)", 63% of the customer respondents to its survey say that shopping technologies and innovations improved their experience on their mobile devices.

PB (Presence of Barriers)

PB measures the presence of barriers that may prevent final consumers from using the technology and/or scanning the QR code. The main barriers considered are the habit of not looking at product information before purchasing it, the time required to use technology, and unconditional trust in the brand.

Rollin et al. (2011) explained that many factors could influence consumer acceptance of food technology innovations and understanding them will be crucial to the realisation and success of technological advances. According to the authors, barriers can be generated by risk-benefit perceptions that a certain customer may have, as well as by socio-demographic and economic factors.

Table 2 - Survey questions and related constructs

Item	N.	Question	Reference(s)
WPP	**25**	**For each of the following products, how much more likely would you be to pay more to make sure that what you are buying is tracked "from farm to fork", and also be able use a QR code to visualize the path with your smartphone?**	Astill et al., 2019, Violino et al. 2019, Müller and Schmid (2019)
WPP_1	25a	Meat and fish	
WPP_2	25b	Milk and cheese	
WPP_3	25c	Oil and wine	
WPP_4	25d	Fruit and vegetables	
WPP_5	25e	Sauces	
TO	**28**	**I am a person...**	Costa-Font et al., 2008; Hicks et al., 2009
TO_1	28a	…interested in innovations of any kind.	
TO_2	28b	…that easily uses new technologies.	
TO_3	28c	…that easily changes habits.	
IT		**I believe that...**	Bilyea and McInnes, (2018)
IT_1	12	…the information presented on the product's label is sufficient to ensure food safety	

IT_2	13	…the information presented on the product's label is reliable.	
IT_3	14	…food manufacturers should provide more information about the preservation and condition of food products	
SB	**20**	**I am about to eat a product and I notice that it has exceeded the expiry date for consumption so...**	Neubig et al. (2020)
SB_1	20a	…I immediately throw it away.	
SB_2	20b	...I try to figure out if it is edible.	
WUC	**23**	**When it is not possible to include additional information on the product label (in addition to the expiry date and nutritional values), I would use my smartphone, scanning a barcode /QR code to display...**	National Retailer Federation (NFR) in the "Consumer View Summer (2019)
WUC_1	23a	…information about the origin of the product.	
WUC_2	23b	… information about the path followed by the product.	
WUC_3	23c	…quality certificates.	
WUC_4	23d	…security certificates.	
WUC_5	23e	…storage conditions.	
WUC_6	23f	…possible uses of the product and waste.	
WUC_7	23g	…recipe suggestions.	
WUC_8	23h	…information about how to dispose of the package.	
PB	**24**	**I would not use my smartphone to scan a barcode/QR code because...**	
PB_1	24b	…it is not my custom to look at product information before purchasing.	
PB_2	24c	…it takes too much time.	
PB_3	24d	…I trust the brand.	

3.4 Data Analysis

3.4.1 Group Analysis and Cluster Analysis

Group Analysis

Through group analysis, we wanted to ascertain if statistically significant differences existed among various groups of respondents with respect to critical elements. We focused on questions related to consumer attitudes concerning innovation and buying behaviour preferences. Specifically, we took the following questions into consideration: 28a (I'm a person interested in innovations); 21 (I am interested in knowing more about the products I buy); 24a (I would not use my smartphone to scan a barcode/QR code because I do not

know what a QR code is); 8 (I always take actions to reduce food waste); 26 (I prefer buying products close to their expiry date at a discounted price.. To form the groups, we took as differentiating elements only those that allowed for satisfying the requirement of similar shape in the population distribution (Ruxton and Beauchamp, 2008): age, education, shopping frequency and income.

We checked if these differences were significant from a statistical point of view, considering the p-value. To do that, two steps were necessary: firstly, we checked if there was a significant difference between all groups, and secondly, to understand where the difference was, we carried out pairwise comparisons between couples of groups.

We performed the normality test through both the Kolmogorov-Smirnov and the Shapiro-Wilk tests to choose the most suitable analysis technique, and we discovered that none of the variables was normally distributed.

We then used the Kruskal-Wallis H test, which is non-parametric, to evaluate the significance of the differences between the group responses. In fact, the basic assumptions were respected, since the observations are independent, and we deal with ordinal scale dependent variables. For this test, the threshold for the p-value was set to the usual value of 0.05. Moreover, before each test, we checked if the groups had the same shape distribution by looking at the histograms and at the boxplot by using the same visual settings that allowed the evaluation of the shapes according to the same scales and parameters.

After that, if the difference among all the groups was significant, we looked for where this difference was, by comparing all the possible k groups combinations two by two through

the Mann-Whitney Test. Even in this case, we considered only the differences with a p-value lower than 0.05 to be significant.

Cluster Analysis

After performing the group analysis, we decided to carry out a cluster analysis to isolate clusters of respondents without segmenting them based on pre-determined groups. Rather, we wanted to discover clusters of respondents based on the responses given to the various questions that better describe the "position" of consumers concerning the studied phenomena.

We performed the cluster analysis on IBM SPSS, combining the hierarchical approach with the k-means approach. We first applied the hierarchical cluster analysis adopting the "between group linkage method". The hierarchical method allowed us to identify the correct number of clusters through the "elbow method" (Bholowalia and Kumar, 2014). Once the correct number of clusters had been identified, we performed the k-means cluster analysis by setting the number of cluster k equal to the result obtained through the "elbow method".

3.4.2 Conceptual model and PLS-SEM

We developed a conceptual model combining the previously described latent variables to ascertain the existence of relationships between the variables and isolate the factors affecting the willingness to pay when technology implies potential increases in the price of food products (i.e., the case of QR codes for enhancing food safety).

Based on the literature, we generated the hypotheses for our conceptual model.

H1: Technology Openness (TO) positively influences Willingness of the Consumer to Use technology (WUC)

H1 assumes that consumers who show high technology openness are typically more willing to use new technologies during grocery shopping.

Rollin et al. (2011) suggested that technology knowledge and trusted sources of information play a key role in consumer acceptance. The lack of knowledge regarding innovative and emerging food technologies can negatively influence the willingness of the consumers to use new technologies during grocery shopping since they are most suspicious of the least familiar technologies. In contrast, greater knowledge of the subject is mostly associated with positive attitudes about that technology.

H2: Willingness of the consumer to Use technology (WUC) positively influences Willingness to Pay a Premium price (WPP)

H2 is based on the fact that being able to visualise and interact with technology through IoT tools (i.e., QR code) can enhance customer willingness to pay a premium price. In fact, correctly implementing these technologies positively impacts consumer experience, as they potentially enhance consumer confidence about the origin and quality of their product (Chen and Huang, 2013). Industry 4.0 technologies allow for gathering, storing and sharing huge amounts of information and allows for making it reliable and secure, protecting the rights of consumers, too. This is essential to build confidence and trust among customers and establish consumer loyalty, improving the total customer experience (Qian et al. 2020; Feng et al. 2020; Violino et al. 2019).

H3: Information Trust (IT) negatively influences Willingness to Pay a Premium price (WPP)

H3 is based on the assumption that only the urgent need for secure and reliable information can push customers to pay more; so, if Information Trust is low, consumers consider information to be insufficient or not reliable enough. It is reasonable to assume that the willingness to pay a premium price to have more reliable information increases

(Desmet, 2016; Rousseau and Vranken, 2013). Violino et al. (2019) claimed that consumers are ready to pay a premium price for the additional information if the information is trustworthy, while Müller and Schmid (2019) affirmed that customers always want more reliable information about the products, though most of them are not willing to pay more for that.

H4: Sustainable Behaviour (SB) positively influences Willingness of the consumer to Use technology (WUC)

This is our assumption based on the fact that people who typically adopt a sustainable behaviour to reduce food waste might be more interested in using technology to visualise helpful information, such as details about how to preserve products. Furthermore, as reported by Butler (2018), it seems that customers are expecting companies to be committed to making an impact in terms of social and environmental sustainability. In this sense, consumers are more willing to purchase products granting social and environmental benefits, positively impacting the loyalty and trust towards the company producing those products. This results in potential opportunities to encourage people interested in sustainability to use innovative technologies in their grocery shopping (Wunderlich and Gatto, 2016).

H5: Presence of Barriers (PB) negatively influences Willingness of the consumer to Use technology (WUC)

The willingness of consumers to use technology can be affected by some barriers that prevent users from accepting technology and relying on devices to obtain benefits from innovations. Even if there is no specific literature dealing with the barriers to the adoption of technology to visualise information in the food supply chain, the extant body of

knowledge suggests that the presence of usage barriers and complexity of the usage processes can negatively impact the willingness and intention to adopt technology for digital services and other information-related activities (Tongnamtiang and Leelasantitham, 2019). In the case of this research, we extend the literature's hypothesis to the consumer's action of scanning the QR code to visualise information before purchasing food products. We posit that this activity is negatively affected by the usage barriers/complexity related to the time needed to scan the QR code and the habit of not reading the product information.

In Figure 2 the initial conceptual model based on the hypotheses generated from the literature is reported.

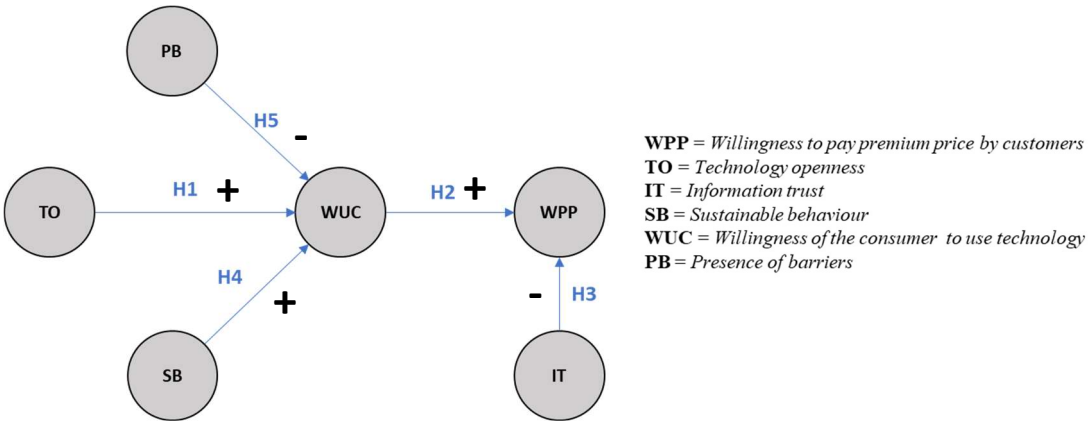

Figure 2 – Initial conceptual model

4. Results

4.1 General description of the survey results

Most of the respondents declared that they were familiar with the food waste problem. Only 10 % think that food waste is less than what it actually is, and 80% is aware of the fact that most of the food waste is originated downstream by retailers and final consumers.

However, only 36.2% knows that food safety is one of the main causes of food waste. Regarding consumer habits, only 12.2% of the people claim to do grocery shopping three or more times a week. Most people go to supermarkets/food retailers only once or maximum twice a week. The sample also provides interesting results about the factors that drive the consumers in their purchasing choice. As expected, price still plays a major role since 33% of the observations highlight the price as the most meaningful factor for consumer choice. The other significant drivers are brand (15.5%), visual quality (18.8 %) and expiry date (17.1%). For what concerns technology openness, on average, respondents declared that they are interested in innovations and can easily use new technologies: Figure 3 reports how the sample is distributed in relation to their knowledge of technologies, such as smart shelves or blockchain in the food supply chain, and in relation to their interest in visualising information about the product history, with specific reference to different product families. For oil (36.4%) and wine (18.4%), the interest is surprisingly low, considering the high value of these products and the role of the food chain in determining the quality of the final product. As we can see from Figure 4, the sample appears to be willing to pay a premium price, which is higher for meat and fish, for milk and dairy products and for fruits and vegetables. For all the analysed products, the price premium to be paid reaches, on average, 10% higher to have a greater amount of secure information. However, for meat and fish, and fruits and vegetables, more than half of the sample is willing to pay a premium price greater than 10% (even greater than 30% for 16% of the respondents for meat and fish, and 14% of the respondents for fruit and vegetables).

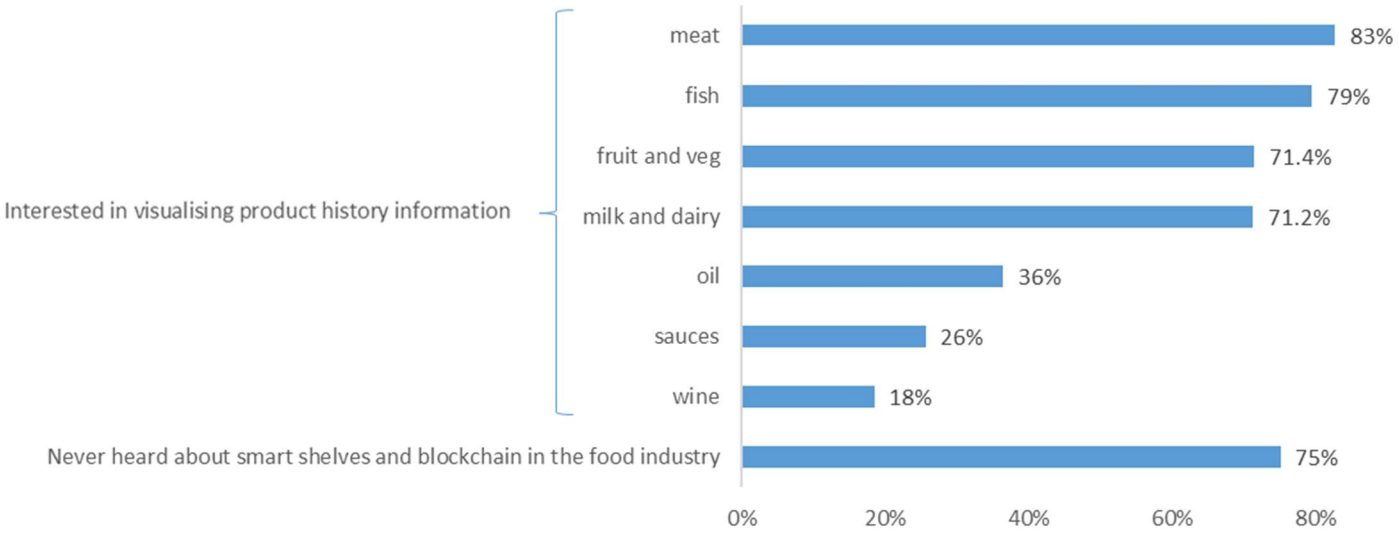

Figure 3 – Interest in visualising product information and familiarity with technology

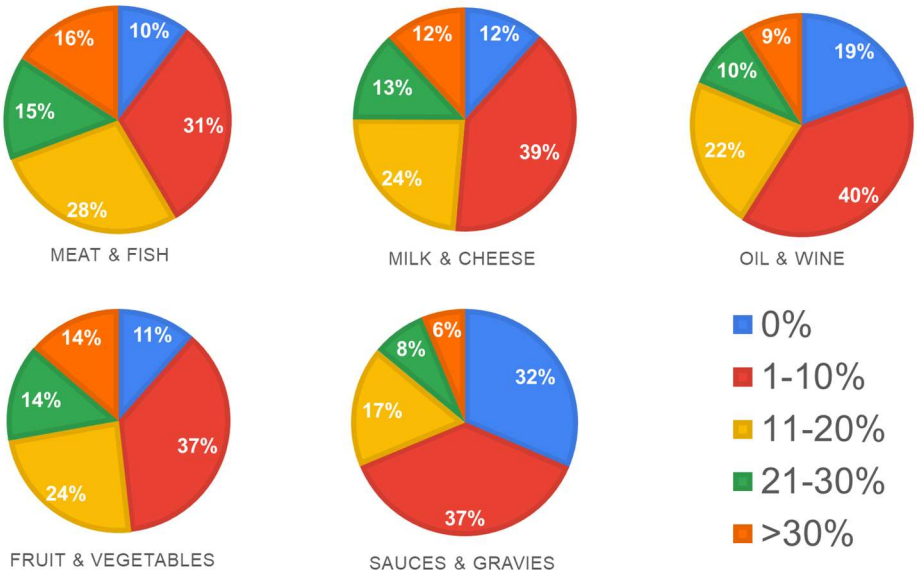

Figure 4 - Customer willingness to pay a premium price for each product category

Moreover, to verify the safety of the products, the final consumers typically look at brand (29.3%), certifications (53.1%) and origin (77%). However, 50% of the sample considers information on the label to be not enough to guarantee food safety, and 32% considers it unreliable. This seems to stress the importance of traceability in the food sector and the

need to make this information secure and reliable. This general sense of concern may have also been influenced by more recent food-related scandals, as confirmed by 50% of the sample. To evaluate technology usage, consumers were asked to assess their willingness to scan a QR code through their smartphone to visualise different kinds of information when it is not possible to print them directly on the labels. The results show that most of them would exploit this opportunity, especially to have more information about product origin (74% of respondents), path (68% of respondents) and certifications (69% of respondents). Also, 68% of respondents would adopt this technology to have more information on how to dismiss product packaging and re-use related product waste (58% of respondents). Recipe suggestions do not seem to be very important to them (44% of respondents). Consumers do not seem to perceive very strong barriers towards the use of smartphones to scan the QR code to obtain more information about the product, and the most perceived is represented by the fact that scanning the QR code could take too much time. However, this barrier is perceived as important only by 20% of the respondents. As for the willingness of the consumers to make a sustainable purchase, 20% of consumers would prefer to buy a product with a distant expiry date and at a higher price instead of a discounted product with a close expiry date. However, for the large majority of respondents (68%), having the possibility to choose among the same product at a different price, based on the expiry date, is considered to be a savings opportunity and not as another element that may create problems in the decision-making process (perceived by only 7% of the respondents).

4.2 Group analysis

The group analysis (see Table 3) revealed a statistically significant difference regarding the level of interest towards innovation and technology with respect to age (Question 26a, i.e., "I am a person interested in innovations of any kind"). In particular, the respondents in group 18-24 showed to be more interested in innovations than the others, with a

statistically significant difference between them and the 35-44 group (p-value = 0,001). At the same time, it seems that the level of education does not constitute a significant element of differentiation (p-value = 0,068). This result is supported by the detected significant difference in the knowledge of the QR code technology among different age groups (Question 24a, i.e. "I would not use my smartphone for obtaining more information about the product because I do not know what a QR code is"). In fact, young people are confident to use this new technology, while older people tend to know less about this technology (with mean scores equal to 1.09, 1.11, 1.26, 1.36, 1.73 respectively for age groups 18-24, 25-34, 35-44, 45-54, 55 and over). Besides, people with a lower level of education are generally less aware of the existence of QR code technology compared to those who have a higher one (with mean values equal to 1.76, 1.32, 1.10 respectively for education groups Secondary school, High school, University degree). Surprisingly, with reference to Question 21 (i.e., "I am interested in knowing more about the products I buy through visualising the origin and the whole path followed before reaching the shelf of the supermarket"), it seems that younger generations are less interested than older people in having more transparency on the product and its path before arriving at supermarket shelves (with mean scores equal to 3.99, 4.39, 4.69, 4.31, 4.42 respectively for age groups 18-24, 25-34, 35-44, 45-54, 55 and over). At the same time, the level of education isn't a significant differentiation factor (with mean values equal to 4.24, 4.20, 4.36 respectively for education groups secondary school, high school, university degree).

With respect to food waste issues, respondents aged 55 or more declared to behave in a more sustainable way (mean value = 4.55) compared to the younger generations, with a significant difference among them and the 18-24 age group (mean value = 4.10, p-value < 0.001) as well as with the 25-34 age group (mean value = 4.24, p-value = 0.001), in contrast with the expectations that younger generations behave more sustainably. It also seems that shopping frequency is a differentiation factor: people who rarely go to the supermarket are generally less interested in behaving in a sustainable way (mean value = 4.01) compared to

people who frequently visit supermarkets (mean values equal to 4.31, 4.31, 4.14 respectively for groups Once a week, Twice a week, Three or more times a week). In this case, we can assume that people who are buying food more often are also more willing to practice sustainable actions, like avoiding food waste, because they feel more responsible for the products they purchased and because they have a higher sense of money being needlessly wasted. On the other hand, results suggest that education does not constitute a differentiation factor (p-value = 0.964).

However, while choosing whether to buy products with a shorter expiration date at a lower price or products with a more extended expiration date but at a higher price, we can notice that younger people are more willing to purchase products with a shorter expiration date compared to the older generation (p-value = 0,000). The level of education and the shopping frequency are not differentiation factors. Given that question 26 (i.e., "If you had the chance to choose, would you buy a product close to its expiry date at a discounted price, or a product with a distant expiry date at full price") explicitly mentions the price of the products, we thought it could be interested to see if income, in this case, could be an element to explain differences among groups of respondents. We found that there is a statistically significant difference based on income levels (p-value = 0.034). However, if on the one hand, this is undoubtedly a way to save money, on the other hand, the economic availability seems to be an influencing factor in the choice of the final consumer only when respondents declaring no income or income below the average value are concerned: these respondents, in fact, show a moderately stronger preference for reduced prices compared to respondents with income around or above the average. No significant difference is recorded between those who have average income and income above the average.

Table 3 - P-values resulting from Kruskal Wallis test

	Age	**Education**	**Shopping frequency**	**Income**
28a – I'm a person interested in innovations	*0.002*	*0.068*	-	-
21 – I am interested in knowing more about the products I buy	***[1]	*0.181*	-	-
24a – I would not use my smartphone for obtaining more information about the product because I do not know what a QR code is	***[1]	***[1]	-	-
8 – I always take actions to reduce food waste	***[1]	*0.964*	*0.006*	-
26 - I prefer buying products close to their expiry date at a discounted price	***[1]	*0.086*	*0.727*	*0.034*

[1] *P-value equal to zero*

4.3 Cluster analysis

In line with the objectives stated above for the cluster analysis, we took into consideration elements such as consumer willingness to use technology for better sustainability and their willingness to pay for having technology at their disposal, along with age as an additional clustering variable. This choice was made because the group analysis results showed that age is the demographic characteristic that recorded the largest number of significant differences across the sample. The *elbow method* helped determine that the correct number of clusters to consider was three. We then performed the k-means cluster analysis by setting the number of clusters k equal to three and we obtained the following clusters. We ran an ANOVA test on the clusters to check their statistical significance. The obtained results indicated a p-value equal to 0.000 for all clustering variables, proving the statistical significance of the generated clusters.

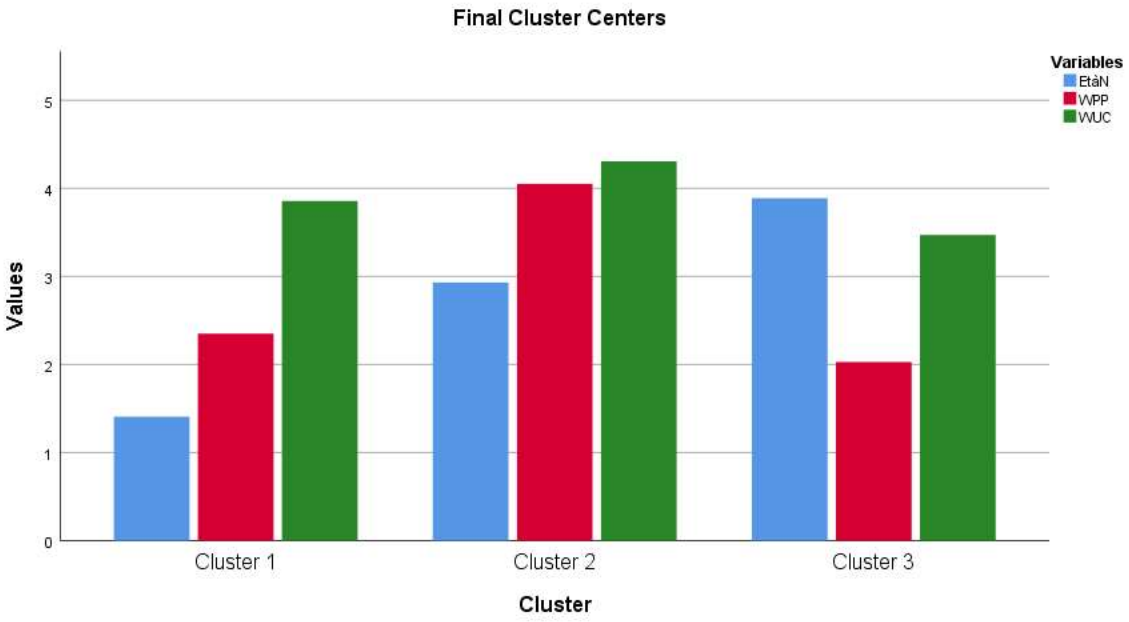

Figure 5 – K-means cluster analysis with k=3

As we can notice from Figure 5:

- Cluster 1 represents young people who have a very high willingness to use technology and quite a low willingness to pay a premium price;
- Cluster 2 represents people aged around 35 to 45, who have the highest willingness to use technology and the highest willingness to pay a premium price;
- Cluster 3 represents older people who are characterised by the lowest willingness to adopt new technologies and the lowest willingness to pay a premium price.

According to the performed analysis, it appears that Cluster 2 is the group of consumers that can be defined as "early adopters". Early adopters appear to be people in their thirties/forties who, compared to the younger ones, have greater spending power than younger people and that, compared to the older people, have greater familiarity with technology. Differently from what one could expect, younger people do not seem to represent the "early adopters", even though, from the results of the group analysis above reported, they appear to be more interested and open to technology than the others. Still, they might be hindered by limited spending capacity even if they show values similar to those of "WUC" as early adopters. Moreover, crossing these results with the outcomes of

the group analysis, early adopters are those people who tend to check information about products before purchasing them more than the other groups of respondents, and it is the group of consumers interested the most in having more transparency about product information.

4.4 Hypotheses testing

Model validation – validity and reliability of the measurement model

In this study, the common method bias may exist, as all the measures use five-point Likert scales and responses are from a single consumer (Podsakoff, 2003, Doty and Click, 1998). To assess the common method bias, we carried out a full collinearity test for the concurrent assessment of vertical and lateral collinearity (Kock and Lynn, 2012). We generated the Variance Inflation Factors (VIFs) and related coefficients for all constructs composing our model. The VIFs obtained for each construct are well below the critical threshold of 3.3, meaning that common method bias is not an issue in this research. We first checked the indicator reliability, assessing the value of the loadings, which should be equal to 0.7 or higher (Hair et al., 2014). Table 4 reports the results of the assessment, which show that some of the indicators do not satisfy the threshold value. For this reason, we decided to review the measurement model by removing those indicators whose loadings were below the value of 0.7 (in accordance with Hair et al., 2014).

Table 4 – Validation of the initial conceptual model

Constructs	Loadings	Mean	Standard Deviation
IT			
it1	0.752	3,374	1,065
it2	-0.517*	2,598	1,028
it3	-0.462*	3,039	1,009

it4	0.691	3,901	1,125
SB			
sb1	0.120*	2,009	1,264
sb2	0.784	4,088	1,203
sb3	0.331*	2,553	1,180
WUC			
wuc1	0.862	4,070	1,127
wuc2	0.832	3,962	1,146
wuc3	0.876	3,916	1,150
wuc4	0.875	3,948	1,147
wuc5	0.832	3,946	1,162
wuc6	0.709	3,750	1,244
wuc7	0.484*	3,231	1,372
wuc8	0.747	4,005	1,234
PB			
pb1	0.314*	1,221	0.680
pb2	0.766	1,754	1,085
pb3	0.812	2,300	1,308
pb4	0.709	1,804	1,055
WPP			
wpp1	0.822	2,947	1,227
wpp2	0.892	2,737	1,185
wpp3	0.879	2,494	1,172
wpp4	0.881	2,819	1,219
wpp5	0.834	2,200	1,147
TO			
to1	0.854	4,000	0.977
to2	0.855	3,974	0.991
to3	0.757	3,563	1,016

** Below the acceptable threshold value*

The validity and reliability of the resulting revised model has been assessed taking into account Internal consistency reliability (through Composite Reliability - CR), Convergent validity (through Average Variance Extracted – AVE) and Discriminant validity (through the Fornell Larcker criterion analysis and Heterotrait-Monotrait ratio of correlations - HTMT) (Hair et al., 2019). Table 5 reports the results of the tests carried out, along with the values of the new loadings that satisfy the quality requirements.

Table 5 – Validation of the revised conceptual model

Constructs	Loadings	Mean	Standard Deviation	CR	AVE
IT				0.774	0.635
it1	0.885	3,374	1,065		
it4	0.698	3,901	1,125		
SB				1,000	1,000
sb2	1,000	4,088	1,203		
WUC				0.936	0.678
wuc1	0.876	4,070	1,127		
wuc2	0.839	3,962	1,146		
wuc3	0.887	3,916	1,150		
wuc4	0.886	3,948	1,147		
wuc5	0.832	3,946	1,162		
wuc6	0.679	3,750	1,244		
wuc8	0.741	4,005	1,234		
PB				0.810	0.588
pb2	0.767	1,754	1,085		
pb3	0.818	2,300	1,308		
pb4	0.712	1,804	1,055		
WPP				0.936	0.744
wpp1	0.824	2,947	1,227		

wpp2	0.893	2,737	1,185		
wpp3	0.878	2,494	1,172		
wpp4	0.885	2,819	1,219		
wpp5	0.830	2,200	1,147		
TO				0.863	0.678
to1	0.852	4,000	0.977		
to2	0.854	3,974	0.991		
to3	0.760	3,563	1,016		

Results show the good validity and reliability of the measurement model, i.e., loadings > 0.7 (or very close to this threshold); CR > 0.70; AVE > 0.5. Besides, the Fornell-Larcker criterion analysis shows that the square roots of AVE are higher than any correlation between the constructs, and the HTMT ratios range from a minimum value equal to 0.091 to a maximum value equal to 0.481. None of these values exceeds the threshold of 0.85 for conceptually different constructs (Hair et al., 2019).

PLS Path model

The structural model's quality was measured by assessing collinearity issues and overall fit and the model's explanatory power. The obtained VIF values did not indicate any collinearity problem, remaining under the critical value of 5 (ranging from 1.017 to 1.095). We used the standardised root mean square residuals (SRMR) and root mean square residual covariance (RMStheta) to assess the overall fit of the model in terms of estimation error and misspecification of the model (Cepeda-Carrion et al., 2019; Hair et al., 2014). The value of SRMR equal to 0.070 is below the critical value of 0.08, and the value of RMStheta

equal to 0.167 is slightly over the threshold of 0.12. These results indicate no substantial issues in the overall fit of the model.

The model's explanatory power was assessed through the measurement of the variance explained by an endogenous variable (R2). For endogenous variables, WUC and WPP, the values of R2 were respectively equal to 0.254 and 0.034, which indicates a sufficient level of explanatory power. Besides, we assessed the predictive relevance of the model, measuring the value of Q2 for each endogenous variable through the Blindfolding procedure with omission distance equal to the suggested value of 7 (Hair et al., 2014). We found positive values of Q2. In particular, we obtained a value equal to 0.168 for WUC and equal to 0.041 for WPP, indicating sufficient levels of predictive relevance.

To evaluate the main effects of the model and test the hypotheses, we assessed the path significances through the PLS algorithm and the Bootstrapping procedure. The outputs are the p-values and the path coefficients for each relationship. We first ran the model using the PLS algorithm to compute the path coefficients. Then, we performed the Bootstrapping procedure with 5,000 random replications to test if these relations were significant from a statistical point of view. Considering the threshold for the p-value equal to 0.05, the results of the analysis are reported in Table 6.

Table 6 – Results of the SEM analysis

Hypothesis	Path	Path coefficient	P-value	Statistical Validity
H1	TO →WUC (+)	0.336	0.000	Supported
H2	WUC → WPP (+)	0.149	0.000	Supported
H3	IT → WPP (-)	0.073	0.092	Not supported
H4	SB → WUC (+)	0.108	0.006	Supported
H5	PB → WUC (-)	-0.321	0.000	Supported

We can see from Table 6 that four out of the five tested hypotheses are supported: H1, H2, H4 and H5.

H1: Technology Openness (TO) positively influences Willingness of the Consumer to Use technology (WUC)

As the positive path coefficient implies, the technology openness of the final consumers positively influences the willingness to use technology to visualise more information about the product. Moreover, the validation of this hypothesis confirms that technology knowledge plays a key role in consumer acceptance, as claimed by Rollin et al. (2011).

H2: Willingness of the consumer to Use technology (WUC) positively influences Willingness to Pay a Premium price (WPP)

The confirmation of hypothesis H2 highlights that, in general, the consumers' willingness to use technology to visualise more information can be moderately related to their willingness to pay a premium price. This implies that these technologies have a positive impact on consumer experience, as stated by Chen and Huang (2013), but also that this enhanced customer experience can be translated into a willingness to pay a premium price.

H3: Information Trust (IT) negatively influences Willingness to Pay a Premium price (WPP)

Besides showing a very low path coefficient value, which denotes a very weak relationship, the assumption that IT negatively influences WPP cannot be supported due to the high p-value. This reflects the contrasting point of views that emerged from the literature, and we are not able to support Violino et al. (2019), who claimed that consumers are ready to pay a premium price for the additional information if they are true and reliable, or Müller and Schmid (2019), who affirmed that consumers are not really willing to pay more for that.

H4: Sustainable Behaviour (SB) positively influences Willingness of the consumer to Use technology (WUC)

The data validates the assumption that people who usually behave in a sustainable way are more willing to use technology to have more information about the product they are buying. The positive path coefficient, which implies a (moderate) positive relationship between the two constructs, is supported by a very low p-value. This result confirms the idea that consumers are more willing to purchase products with social and environmental benefits, as claimed by Butler (2018), and suggests that sustainability awareness of the final consumers is a driver of their willingness to adopt new technologies in the grocery shopping process.

H5: Presence of Barriers (PB) negatively influences Willingness of the consumer to Use technology (WUC)

Our results show that the presence of barriers has a negative effect on consumer willingness to use technology – and the p-value equal to 0.000 supports the statistical significance of the relationship. The provided evidence supports the general mechanisms described in the literature, which states that the presence of barriers is an obstacle to the use of technology; these take the shape of a poor level of technology knowledge, or the perception that there will be complications in the use of technology in the buying process, or there being a lack of trust in the sources of information (Costa Font et al., 2008; Hicks et al., 2009).

5. Discussion of the findings

With reference to RQ1 (*How do consumers' characteristics relate to their openness to SC 4.0 technologies for sustainability in the food supply chain?*), from the analysis of the basic statistics, we discovered that the main factors taken into consideration by consumers in the purchasing choice are price, visual quality, expiry date and brand. It is clear that the relationship between price and expiry date can be an important driver, which has been

discussed in the existing literature in terms of consumer willingness to accept trade-offs between the remaining shelf-life of food products and price (Chung and Li, 2013). This seems to be perceived by the final consumers as an important opportunity that could be supported by the development of appropriate traceability systems that are able to collect and estimate the shelf life of products during various stages of the supply chain, as discussed in the literature (Gallo et al., 2021). In fact, the majority of the respondents consider dynamic pricing to be an opportunity to save money, and not another element that may create problems in the decision-making process. The possibility of saving some money can be considered an incentive to make a sustainable choice, i.e., buying food that would otherwise be discarded, in line with Adenso-Díaz et al. (2016) and Moustafa et al. (2018). Anyway, there are still some (about 20 % of the sample) that will keep buying with a long-term expiry date and at a higher price, instead of at a discounted product with a short-term due date. This seems to be the main problem of culture and habits based on the misperception that in the mind of some consumers, a longer expiration still means more freshness of the product, as has been discussed in the literature (Chung and Li, 2013). In this sense, companies are urged to put in place actions that could help consumers reconsider their choices when expiry dates are concerned. Consumers should be made (more) aware of the preservation of quality levels of food products, even when their expiry date is near. Consequently, the use of technology to convey "reassuring" information through data-driven and smart-device communication campaigns could potentially help reduce the amount of food wasted for the above-discussed reasons. This is something that companies could benefit from to not only reduce food waste and improve food safety, but also increase profitability, since this sort of initiative could reduce the number of unsold products and generate more value for them, too. Moving then from the results of the group analysis, with respect to the technological solution of the smart shelf, even if consumers are not supposed to use technology actively (but only to compare prices), younger people (approximately from 18 to 30 years old) appear to be the most interested ones. In fact,

younger people show a better willingness to purchase products with a shorter expiry date than the older generations. They also see the possibility of choosing between two products with a different price based on the expiry date as a greater savings opportunity compared to people in their 50s. This seems to be in line with the literature, which supports the view that younger consumers are more sensitive to price discounts and promotions (Anic et al., 2014). Interestingly, shopping frequency affects the profile of consumers: compared to those who go shopping only once a week, those who do their shopping twice a week show a tendency to see the purchase of products based on dynamic pricing as a complication in their decision-making process. This can be explained by the fact that increasing the shopping frequency means increasing the number of choices to be made. Consequently, this could lead to some complications in the purchasing process in the eyes of the consumer. However, this finding is somehow in contrast with the literature, which states that dynamic pricing is a benefit to a whole range of stakeholders, including retailers, customers, and society, besides being helpful for the environment (Moustafa et al., 2018). The possibility of saving money by buying discounted products seems to be attractive to final consumers with no or below average income, but not for people declaring average or above average income. While, on the one hand, savings opportunities are positively seen by those categories of consumers with limited spending capabilities, on the other it appears that discounted prices are not a driver of choice for those people who are better off: companies should leverage other factors to attract the interest of these consumers, such as effective information regarding the quality of products and, especially, the possibility to avoid waste of "still good" food, which again relates to the possibility to reduce the amount of unsold products for the benefit of company profits, too. The literature discusses this aspect, suggesting that marketing and sales strategies can heavily influence the waste behaviour of individuals (Mondéjar-Jiménez et al., 2016). Hence, the critical role of manufacturers and retailers in preventing the generation of food waste is highlighted. For example, a multi-period dynamic pricing strategy empowered by technologies and

information on the product's quality can have a different impact on customer willingness to accept the trade-off between price and shelf life and customer satisfaction, especially for perishable and fresh food (Chung and Li, 2013). Another interesting note is that education does not seem to play a role as an element of differentiation. The only significant difference is recorded when consumers are asked about their level of knowledge about technology and the related intention to use it for obtaining more information about products. In this case, people with more education seem more willing to rely on technology. However, the existing literature supports the view that a more educated consumer emphasises sustainability in general and is more open to technology, as stated by Costa-Font et al. (2008) and Hicks et al. (2009).

The cluster analysis somehow confirms the outcomes of the group analysis, but on top of that, it lets the category of "early adopter" consumers emerge. Interestingly, the youngest members studied do not make up this group. Instead, “early adopters” are those people aged 35-44, who tend to have good spending power and are open to technology and (crossing with the outcomes of the group analysis) checking information about products before purchasing them, doing so more than the group of young people (18-24) and the group of older people (>55). The 35-44 group is also the cluster of consumers interested the most in having more transparency about product information. This cluster is a potentially interesting one from the perspective of retailers and food product manufacturers, as "early adopters" may be the most receptive ones to using technology for sustainability to avoid food waste and increase food safety. Organisations should leverage these consumers to attract the interest of the other clusters of consumers in order to target the "soft spots" of reluctant customers regarding critical variables, such as openness to technology and willingness to use it. This could happen, for example, through adequate communication campaigns and tests of systems offered to consumers, including "early adopters" as leaders of this awareness campaign regarding the ways to use technology to improve sustainability.

As far as RQ2 ("*What are the factors driving consumer willingness to pay a premium price - when required - to have more information about the products they are purchasing through SC 4.0 technologies?*) is concerned, two areas for discussion arise. First, from the overview of the basic statistics on the survey results, it appears that consumers are, on average, ready to pay a premium price to have more information about the products they are purchasing. The sample of the survey points out a general and shared opinion for what concerns the willingness to have more transparency of the products, with consumers interested in having the opportunity to visualise product history and path before the goods arrive at the supermarket. In this sense, companies are invited to put actions into place that could push consumers to ask for more information. For example, organizations could provide evidence of transparency and details about product history without always requiring consumers to put in an effort to obtain more information. So, companies can make consumer life "easier" by providing simple and straightforward visualization systems.

Second, as seen from the PLS-SEM analysis, it seems that the willingness to pay is positively influenced by the willingness to use technology, and not by Information Trust, which does not arise as a driver of it (our data do not support the related hypothesis). This is interesting evidence, and it is supported by the finding that the information on the label does not suffice to guarantee food safety but can also be perceived as unreliable. In this sense, consumers seem to be more interested in having the opportunity to visualise the tracked path of products. In turn, the willingness to use technology seems to be positively affected by Technology Openness and Sustainable Behaviour and contrasted by the Presence of Barriers. As a consequence, on the one hand, retailers should put into action initiatives to help consumers to understand technology and its value, as well as to help them learn about the potential of those technologies to reduce food waste and improve food safety. This is something that is also consistent with the findings of the group and cluster analyses. Given that "Presence of Barriers" is an element contrasting the willingness

to pay, companies need to identify those actions that could remove the technological barriers perceived by consumers, for example, by improving the ease of use of technology and the solutions presented on the shelf. This would help to "educate" consumers about how well technologies can support sustainability. It would also make consumers more familiar with innovation and help them to perceive it in a more open way, as indicated by the literature (McClements et al., 2021). In line with the discussion presented above, other initiatives to reduce the barriers perceived by consumers should be put in place by retailers. For example, the latter can promote user-friendly and straightforward processes for the use of technological solutions during the grocery shopping experience. These solutions should reduce the time that consumers must spend to complete the process, as this was highlighted as the main item loading on the Presence of Barriers construct. Along these lines, a sort of progressive introduction of technology on the shop floor could be devised: as “Presence of Barriers” depends on how difficult and how time-consuming consumers see the use of technology, companies could first implement and run technological solutions that do not require any specific effort on the part of consumers and that provide an immediate indication of the intended output (such as smart shelves) to let them get familiar with the idea of doing their shopping in a more technological way. Then, solutions with more engagement needed from the side of consumers could be introduced and made available to consumers. Inviting consumers to “test” technology themselves through actions such as promotional activities, on-field experiences on the shop floor, loyalty programs and other direct engagement actions could help organizations to leverage the drivers of willingness to use technology and willingness to pay.

On the other hand (through the supported hypothesis about the effect of sustainable behaviour on the willingness to use technology), our analysis suggests that retailers should take actions to increase the awareness of consumers about the latter’s role in the generation of food waste. Retailers should also increase the overall safety of food in the food supply chain by demanding that more information be captured and shared in the

community of consumers for the benefit of the whole society. Since our data show that the (sole) antecedent of the willingness to pay is the willingness to use technology and that the strongest antecedent of the willingness to use technology is 'technology openness', it would be relevant for retailers to engage consumers in adopting these new technologies, focusing on the technological maturity of consumers and devising ways to invite more consumers to use technology without necessarily having to be technologically savvy from day one. In this sense, engaging the "early adopters" would allow for devising ways to reach the above-mentioned awareness target.

In conclusion, technological maturity and the removal of personal barriers to technology in the purchasing process, together with consumer awareness of sustainability issues, represent an opportunity for companies to customise products and services to positively influence consumers towards making more sustainable choices. Differently from what was reported by Verdouw et al. (2016) and Astill et al. (2019), consumer acceptance does not seem to be a barrier to investing in this direction. This might be because there are different categories of products that seem to make consumers more sensitive to food waste and food safety issues. In fact, consumers seem to be more interested in having the opportunity to visualise the tracked path of fresh products, as shown by the statistics of the sample, and organisations might want to start from these product categories to sensitise consumers about the issue of sustainability in the food supply chain.

The main research outcomes and insights are summarised in Table 7.

Table 7 – Main outcomes and insights of the research

Type of data analysis	**Main outcome/insight**	**Engagement with existing literature**
Basic statistics	Main factors taken into consideration by consumers in the purchasing choice are price, visual quality, expiry date and brand.	Novel insight
	Consumers should be made aware of the preservation of quality of food products. Technology to convey "reassuring"	In line with the literature (Chung and Li, 2013)

	information could help reduce the amount of food waste – about 20 % of the sample will keep buying with a long-term expiry date and at a higher price (due to misperceptions about food quality preservation over time).	
	Consumers are, on average, ready to pay a premium price to have more information about the products they are purchasing.	Novel insight
Group analysis	Younger people seem the most interested in the smart shelf technology for choosing products with a shorter expiry date and low prices.	In line with the literature (younger consumers are more sensitive to price discounts - Anic et al., 2014)
	Consumers doing their shopping more frequently tend to see dynamic pricing as a complication, since it increases the number of choices and the complexity of the buying process	Partially in contrast with the literature (dynamic pricing is beneficial to a whole range of stakeholders – Moustafa et al., 2018)
	Discounted prices are not a driver of choice for better off people: companies should attract these consumers through effective information on the quality of products and its preservation over time to avoid waste of "still good" food.	Novel insight, partially discussed in the literature (Mondéjar-Jiménez et al., 2016)
	Education does not seem to be an element of differentiation, except for the case of knowledge about technology and related intention to use it for obtaining more information	In contrast with the literature (more educated consumers emphasise sustainability and are more open to technology - Costa-Font et al., 2008; Hicks et al., 2009)
Cluster analysis	The “Early Adopters” cluster emerges: people aged 35-44, with good spending power, open to technology and checking information about products before purchasing them, interested in having transparency about product information, may be the most receptive ones to using technology for sustainability.	Novel insight
PLS-SEM	Willingness to pay is positively influenced by the Willingness to use technology, and not by Information Trust (information on the label does not suffice to guarantee food safety but can also be perceived as unreliable). Consumers seem to be more	Novel insight, neither supporting or contrasting Violino et al. (2019) (consumers are ready to pay if information is reliable) nor Müller and

	interested in having the opportunity to visualise the tracked path of products.	Schmid (2019) (consumers are not willing to pay for any sort of information)
	Technological maturity and the removal of personal barriers to technology in the purchasing process, together with consumer awareness of sustainability issues, represent an opportunity for companies to customise products and services to influence consumers towards making more sustainable choices.	In contrast with the literature (low consumer acceptance is a barrier to investing in technology for better sustainability - Verdouw et al., 2016; Astill et al., 2019)
	Retailers should propose initiatives to help consumers to understand technology and its value and remove barriers through user-friendly and effortless solutions, leveraging "Early Adopters" to engage other consumers in adopting new technologies, raising their awareness.	Novel insight

6. Conclusions

The work carried out has both theoretical and practical implications. In terms of theoretical implications, this study contributes to theory by exploring the role of consumers in relation to sustainability and supply chain 4.0 and contributes to the debate about consumer acceptance. By connecting consumer acceptance and attitudes towards sustainability in the food supply chain, this work proposes to the academic community an original perspective that combines these two essential constructs. In this sense, our work advances knowledge by taking into consideration the downstream side of the food supply chain as an enabling factor for improving its level of sustainability. Moreover, our work offers some insights that question existing research, especially in those “grey areas” discussed in the literature review: for example, our findings point to the direction that dynamic pricing is attractive only to some groups of consumers, so we posit that more research on consumer profiling could be needed. We also found that education does not seem to play a role as an element of differentiation, while the literature suggests that it does. In this case, we invite researchers and companies to scrutinize other socio-demographic features that can affect

consumer behaviour. This also applies to the case of consumer acceptance of technology, which we found does not seem to be a barrier to companies investing in technology. In contrast, the literature suggests the opposite is true in some cases. So, we stimulate the debate to consider the link between acceptance and product features in relation to food safety and waste. In this sense, our work discusses the limitations of current research that point to consumer technology maturity and acceptance as barriers, while in our work we isolate some areas that can be used as leverage for organisations to foster the adoption of technology for better sustainability.

This can also represent the first practical implication of our research. Our study provides the industrial community with knowledge and insights on consumer behaviour. From our findings, companies learn that consumers can be ready to embrace technology and even be willing to pay a premium price to access information for their safety and to reduce waste. This is true under some circumstances, such as for investing in technology for fresh products like meat and fish, milk and dairy products, and also for fruits and vegetables, since consumers appear to be more interested in visualising the path of these products. To do this, companies need to work on the right advertisement to spread knowledge about QR usage and to overcome any age barriers. This will help retailers to reduce waste since less food will be unsold and disposed of.

Finally, a few limitations of this study need to be acknowledged. First, our study takes into account food waste and safety from the perspective of the downstream side of the supply chain, i.e., at the retailing stage where consumers make their purchases with the aid of technology. The upstream side of the supply chain was not investigated. Therefore, only a limited set of SC 4.0 technologies was examined. The survey was carried out only in Italy and with a sample of the population representative of the Italian society, showing good alignment with the average national values in relation to the main socio-economic features and geographical distribution of the population - and consequently limited bias. It is true, instead, that results might be influenced by the level of technological maturity and attitude

towards sustainability of Italian consumers. Other future endeavours could also replicate this study in other countries or geographical contexts so that it would be possible to understand how consumer behaviour and perceptions may vary. Variations in consumer preferences and behaviour can also depend on the regional differences within a single country, especially in those areas where pronounced differences exist (e.g., United States, Northern and Southern Italy). Hence, further investigation on how regional differences can affect the level of sustainability within the food supply chain through the actions of consumers could yield interesting outcomes on how retailers could approach consumers across a specific country. Lastly, an interesting development of this work could be represented by the investigation of the perspective of manufacturers and retailers towards the adoption of technology in the food supply chain, and the implementation of technological solutions at the points of sale. In this way, their point of view can be matched against the consumers' perspectives and ways could be devised in which the level of food supply chain sustainability could be improved by leveraging the convergence of consumer attitudes and company actions. This could also be a steppingstone for future investigations looking at the introduction of technology across the whole food supply chain in an integrated fashion that includes manufacturers, retailers and consumers. Further study would also require researching a type of progressive pathway, setting priorities and preference levels for initiatives aimed at the digitalisation and technological empowerment of the food supply chain following a holistic view.

Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Compliance with Ethical Standards

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No funding was received for conducting this study.

Disclosure of potential conflicts of interest

All the authors declare that they have no conflicts of interest.

Research involving human participants and/or animals.

All procedures performed in this study were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent

Informed consent was obtained from all individual participants included in this study.

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APPENDIX A – SURVEY QUESTIONNAIRE

Section 1 – Demographics

1. Gender:
    a. Female
    b. Male

2. Age (years):
    a. 18-24
    b. 25-34
    c. 35-44
    d. 45-54
    e. 55 and over

3. Education
    a. Secondary school
    b. High school
    c. University degree

4. Income
    a. Student without personal income
    b. Below the national average
    c. Around the national average
    d. Above the national average

Section 2 – Sustainability, food waste and safety (adapted from Neubig et al., 2020 and Bilyea & McInnes, 2018)

5. What's the percent of food wasted in the world?
    a. 10%
    b. 20%
    c. 30%
    d. 40%
    e. 50%

6. Where does most food go to waste in the supply chain?
    f. Farms
    g. Transportation
    h. Processing
    i. Supermarkets and restaurants
    j. At home

7. Did you know that contaminated food is one of the most relevant causes of food waste?
    k. Yes

l. No

Please indicate the degree to which you agree with the following statements (from 1 = totally disagree to 5 = totally agree):

8. I always take actions to reduce food waste
9. I feel responsible for the generation of food waste
10. The recent food-related scandals (e.g. mad cow, horse meat, tampered eggs) have affected my behaviour and pushed me to pay more attention to food security

11. To verify the safety of the food you buy, what factors do you pay attention to?
    a. Brand
    b. Origin
    c. Certifications
    d. Nothing
    e. Other (please specify)

Please indicate the degree to which you agree with the following statements (from 1 = totally disagree to 5 = totally agree):

12. The information presented on the product's label is sufficient to ensure food safety
13. The information presented on the products' label is reliable
14. Food manufacturers should provide more information about the preservation and condition of food products

Section 3 – Consumer buying behaviour (adapted from Neubig et al., 2020)

15. How often do you go shopping?
    a. Less than once a week
    b. Once a week
    c. Twice a week
    d. Three or more times a week

Please indicate how often you… (from 1 = never to 5 = always):

16. Scan with your smartphone the QR code of the food products you buy at the supermarket
17. Buy at the supermarkets products close to their expiry date
18. Check the label of products to check the origin of food products

19. What's the most important thing for you when you buy a food product?
    a. Price
    b. Brand

c. Visual quality
d. Expiry date
e. Other (please specify)

20. I am about to eat a product and I notice that it has exceeded the expiry date for consumption so...
    a. …I will immediately throw it away.
    b. ...I try to figure out if it is edible.

Section 4 – Consumers' willingness to obtain information about food products (adapted from National Retailer Federation NFR in the "Consumer View Summer, 2019)

21. I am interested in knowing more about the products I buy through visualising the origin and the whole path followed before reaching the shelf of the supermarket
    a. Totally disagree
    b.
    c.
    d.
    e. Totally agree

22. Of what product families you would like to know more about the whole path followed before reaching the shelf of the supermarket?
    a. Meat and fish
    b. Oil and wine
    c. Dairy products
    d. Fruit and vegetables
    e. Sauces
    f. None
    g. Other (please specify)

23. When it is not possible to include additional information on the product label (in addition to the expiry date and nutritional values) I would use my smartphone, scanning a barcode /QR code to display...
    a. information about the origin of the product
    b. information about the path followed by the product
    c. quality certificates
    d. security certificates
    e. storage conditions
    f. possible uses of the product and waste
    g. recipe suggestions
    h. information about how to dispose of the package

24. I would not use my smartphone to scan a barcode/QR code because...
    a. I do not know what a QR code is
    b. it is not my custom to look at product information before purchasing
    c. it takes too much time

d. I trust the brand

Section 5 – Consumers' willingness to pay (adapted from Astill et al., 2019; Violino et al. 2019; Müller et al., 2019)

25. For each of the following products, how much more likely would you be to pay more to make sure that what you are buying is tracked "from farm to fork", and also be able use a QR code to visualize the path with your smartphone?
    a. Meat and fish
    b. Dairy products
    c. Oil and wine
    d. Fruit and vegetables
    e. Sauces

26. If you had the chance to choose, would you buy…
    a. A product close to its expiry date at a discounted price
    b. A product with a distant expiry date at full price

27. The potential choice about the closer expiry date and discounted price versus distant expiry date and full price is:
    a. a saving opportunity
    b. an additional complication in your choices

Section 6 – Consumers' technology openness (adapted from Costa-Font et al., 2008; Hicks et al., 2009)

28. I am a person...
    a. interested in innovations of any kind.
    b. that easily uses new technologies.
    c. that easily changes habits

29. Have you ever heard about smart shelves?
    a. Yes
    b. No

30. Have you ever heard about blockchain applied to the food supply chain?
    a. Yes
    b. No

APPENDIX B

List of acronyms

AVE	Average Variance Extracted
CR	Composite Reliability
FAO	Food and Agriculture Organization of the United Nations
G7	Group of Seven, i.e. an inter-governmental political forum consisting of Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States
IT	Information Trust
NFR	National Retailer Federation
PB	Presence of Barriers
SB	Sustainable Behaviour
SC 4.0	Supply Chain 4.0
SDGs	Sustainable Development Goals
TO	Technology Openness
VIFs	Variance Inflation Factors
WHO	World Health Organization
WPP	Willingness to Pay a Premium price
WUC	Willingness of the Consumer to Use technology