Barriers and Drivers to adoption of IoT-Enhanced Smart Packaging in the Food Supply Chain

by

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Abstract

This study investigates the adoption of Internet of Things-enhanced Smart Packaging within the Food Supply Chain (FSC) to combat food waste and enhance operational efficiency. With global challenges like food waste and operational efficiency persisting, innovative technologies can advance the FSC. By examining the drivers and barriers influencing IoT-enhanced Smart Packaging adoption, this exploratory research provides a general understanding of its potential impact. Semi-structured interviews were conducted with experts spanning companies from producers to grocers, as well as packaging manufacturers. Thematic analysis of these interviews uncovers crucial insights. Key drivers, including consumer requirements, food quality monitoring, efficiency, and sustainability emerged alongside barriers such as cost, consumer perception, technological complexities, and regulatory uncertainties. The findings highlight the potential to reduce food waste and enhance efficiency and visibility through IoT-enhanced Smart Packaging. Additionally, they highlight the need for stakeholder collaboration, governmental support, and effective education to expedite adoption and achieve sustainable outcomes within the FSC. This research offers a unique perspective on the evolving landscape of IoT-enhanced Smart Packaging adoption, its transformative potential, and the challenges it aims to address.

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Chapter 1 - Introduction

The United Nations [UN] (n.d.a) estimations consider that the 8.0 billion mark for the global population was virtually reached in the last weeks of 2022, one of the multiple challenges that come from this amount of people is the requirement of resources to effectively feed them. On the bright side, it is estimated that the current level of food production matches the needs, but the distribution methods must be improved to place food at the right location for consumption (Tóth & Zachár, 2021). Unfortunately, the reality is different since many regions in the globe suffer from hunger due to different reasons creating the condition of food insecurity, which is the lack of "adequate physical, social or economic access to food" (FAO, 2003, p. 29). Hunger and malnutrition are found among the reasons preventing families of getting higher income and, thus, a better quality of life. Both are also recognized as barriers to sustainable development (UN, n.d.b). Following the data of this source, 690 million people were catalogued as undernourished in 2019, most of them living in Africa and Asia; a warning is shared in the form of a somber forecast: if this condition is not fixed, 840 million people would be in this situation by 2030.

On the flip side, global wellbeing is also affected by the seemingly opposite problem of Food Loss and Waste (FLW). It was estimated that the total food wastage in our planet reached one third of the food produced per year (FAO, 2011). Another way to picture this problem is through the weight of the discarded food per annum, 1.3 million tons (de Oliveira et al., 2021). Additionally, the resources involved in the production and distribution, unfortunately most of them not renewable, are to be considered due to the socioeconomic cost and the impact on the environment (Beretta et al., 2013). Sharma (2021) depicts the situation sharing that the equivalent of fertile land is 1.4 ha, which represents 28% of the total area used for the agricultural activity, the total CO_2 expelled to the atmosphere is 3.3 billion tons, and the amount

of money poorly spent is USD 936 billion. The total effect is difficult to measure since the consequences reach many dimensions beyond generation and social classes; as a result, it is seen as a moral problem (Flanagan & Priyadarshini, 2021; Lohnes & Wilson, 2018).

Beretta et al. (2013) consider the Food Supply Chain (FSC) as a key player to alleviate the negative effect of this phenomenon on the society and the planet since the resources consumed in the production, processing, and distribution activities can be reduced through different initiatives. Two major venues to reach this goal are the collaborations among all the entities involved in the FSC (Kwak et al., 2018) and technologies oriented to raise the efficiency and visibility of the shared processes (Poyatos-Racionero et al., 2018). Two of the most promising technologies in the FSC are smart packaging and the Internet of Things (IoT). The former extends the basic function of traditional packaging of containing and protecting through incorporating the possibility to sense the condition of food and performing actions over it (Marsh & Bugusu, 2007). Knowing the freshness, concentration of gasses inside the package, presence of pathogens, leakages, excess temperature, and pH levels allows the FSC players to react and avoid health risks and spoilage (Schaefer & Cheung, 2018). The IoT upgrades the visibility, traceability, and other dynamic capabilities of Supply Chains (SC) in general terms, particularly enhancing the benefits of smart packaging (Bouzembrak et al., 2019). The contribution of IoT to FLW reduction stems directly from its ability to monitor food quality, enabling prompt action when food approaches the end of its shelf-life, improving category management and inventory management (Chauhan et al., 2021). The combination of both technologies, called in this document IoT-enhanced Smart Packaging, uncovers new benefits and applications (Schaefer & Cheung, 2018) that are currently being explored.

The implementation of technology typically creates and boosts competitive advantages for companies since it allows innovation (Benner & Tripsas, 2012) in different areas. Despite its benefits, the adoption of smart packaging in the FSC is still in the introductory phase (Armstrong et al., 2018), with the IoT-enhanced Smart Packaging even behind that phase. This is a common situation faced by innovative technologies since, according to Mitchell (2007), these types of technologies create uncertainty on the stakeholders delaying dissemination and the obtention of the promised benefits. In this sense, to understand what is preventing and supporting the integration of this disruptive technology to the food industry, two research questions are driving this study: What are the drivers to adoption of the IoT-enhanced Smart Packaging in the FSC? And what are the barriers to adoption of the IoT-enhanced Smart Packaging in the FSC?

A semi-structured interview was designed to gather informed opinions from the field of FSC and the packaging industry. Given the current status of dissemination of the technology, expert sampling was considered as the most suitable way to get access to deep knowledge on this matter (Bhattacherjee, 2012b). To have a thorough scope on the IoT-enhanced Smart Packaging acceptance and its future, professionals from the food, grocery retail, and packaging industries were included in the sample. The opinions expressed were discussed to draw conclusions that help understand the phenomenon of IoT-enhanced Smart Packaging.

The remaining sections of this document are organized as follows: Literature Review: This section provides an overview of global food issues, the role of technological innovations in competitiveness development, and an exploration of IoT-enhanced Smart Packaging. Methods: Here, the research design used to address the questions is described. This section also offers insights into the suitability of this particular methodology. Results: Detailed information regarding the data obtained from each interview is presented in this section. Discussion: This

section delves into the evaluation of key drivers, barriers, and other related concepts that merged from the opinions of the experts. Conclusions: Summarizing the main findings, this chapter also addresses limitations and offers recommendations for future research. Finally, Appendix: The questionnaire used as a script for the semi-structured interviews is presented.

Chapter 2 - Literature Review

2.1- The food problem

Our problems with food are, unfortunately, not new. In 1974, as part of the efforts to ensure the access to food for all the inhabitants of our world, the Committee on World Food Security (CFS) was created (CFS, n.d.). This entity generates policies considered as recommendations only, intended to contribute to food security and nutrition improvement. To fulfill the condition of security, people must have "access to sufficient, safe, and nutritious food which meets their dietary needs and food preferences for an active and healthy life" (FAO, 2003, p. 29). The opposite side of the food issue, food wastage, also generates big problems. In terms of money, the estimated total cost per annum is USD 2.6 trillion, this amount is calculated by 0.7 trillion from societal cost, 1 trillion from economic and production issues, and 0.9 trillion from the general wellbeing (FAO, 2014). After noticing the lack of common concepts and definitions in this topic and to properly orient its measurement, the State of Food and Agriculture Report 2019 set out the understanding of FLW as "the decrease of food quality and quantity along the food supply chain" (FAO, 2019, p. xii), with a clear boundary for the notion of Food Loss and Food Waste. The concept of food loss pertains to the loss or wastage that happens from the initial stages of the food supply chain process, extending up to but excluding the retail level; in

contrast, food waste encompasses wastage occurring at the retail and household stages (FAO, 2019).

Two of the UN's 17 Sustainable Development Goals are oriented to find solutions; Goal 2 is devoted to end hunger with its Target 2.1 setting the year 2030 to complete the task (UN, n.d.c). Goal 12 is focused on consumption and production, its Target 12.3 tackles FLW with the objective of reducing it by one half by 2030 (UN, n.d.d). Despite the efforts of the UN and governments regarding the Sustainable Development Goals launched at the beginning of 2016 (UN, n.d.e), the results displayed in the 2021 Report Progress toward the Sustainable Development Goals are not positive (UN, 2021). From the FSC trench, solutions to the problem of FLW are more feasible than the hunger related ones since problems coming from the deterioration of food can be found integrating the operational and tactical levels through new technologies to improve traceability along the full chain of processes (Chen et al., 2020). This study is oriented to the food waste problem only. Food companies must recognize the impact of food loss on society and the environment, especially now that consumers are making choices based on the efforts of companies towards the protection of the planet (Grazzini et al., 2021).

Since the term FLW and the separate definitions for Food Loss and Food Waste are not widely used in the industry, during the study, the term "food waste" was employed to encompass both types of waste, simplifying communication. Throughout the remainder of this document, only "food waste" will be utilized.

2.2- Technological innovation and competitive advantage in the Food Supply Chain

To solve problems and to stay competitive, companies must continually adapt to the dynamic environments that prevent them from endlessly getting benefits from their resources and

capabilities (Li & Liu, 2014). The response comes through Supply Chain Innovation (SCI) which facilitates the development of competitive capabilities and advances the performance of the full FSC (Wu & Tsai, 2018). According to the Resource-Based View (RBV), organizations obtain advantage by developing scarce, valuable, and non-substitutable resources, e.g., knowledge, technical know-how, and organizational skills (Barney, 1991). Since the RBV has a static perspective, companies need to develop dynamic capabilities to create new configurations of their resources to generate innovative solutions and to adapt to new conditions in their markets (Eisenhardt & Martin, 2000). When technology is part of the resource base, it becomes a key component of innovation (Benner & Tripsas, 2012), which is a dynamic capability known as a contributor of the development of competitive advantages (Palazzeschi et al., 2018). The way the RBV and the dynamic capabilities complement each other is not enough for the FSC since it is integrated by more than one company. The missing point of view is provided by the Relational Theory which remarks the need for collaboration among companies to share and develop complementary capabilities (Mesquita et al., 2008) obtaining supernormal gains from the committed resources such as people, knowledge, time, and funds (Azadegan, 2011).

Nowadays, the quest for solutions to food waste in the FSC are oriented to food packaging, information-driven integration, and big data, the first is tackled with smart packaging, and for the other two the IoT is the tool at place (Cappellesso & Thomé, 2019). The combination of these technologies expands the benefits not only in the FSC but also in households with the foreseeable integration of home appliances to the created network (Liegeard & Manning, 2020).

2.3- Smart Packaging

In the food business, the core functions of traditional packaging are protection and preservation of food, containment to facilitate transportation, convenience for handling and

disposal, and marketing to share information with consumers (Schaefer & Cheung, 2018). Yam et al. (2005) considered the pressure on the food industry to reduce the use of preservatives, observe regulations, offer traceability and clear information, and provide a good experience to customers as generators of secondary functions. Some of the secondary functions are traceability, tamper indication to reduce the risk of manipulation and adulteration, and other functionalities such as inclusion of gifts, coupons, and additional products (Marsh & Bugusu, 2007).

Conventional packaging was enhanced in three main ways:

1) *Intelligent packaging*, to monitor food quality assisting in better decision making. It senses, detects, traces, records, and shares data using time-temperature indicators, freshness indicators, time recorders, gas detectors, humidity sensors, RFID tags, and data carriers (Ghaani et al., 2016; Kerry et al., 2006; Soltani Firouz et al., 2021).

2) *Active packaging*, which is capable of dispensing or absorbing substances on the contained food to keep or improve quality while ultimately extending the shelf life (Ahmed et al., 2017). The most common used chemicals are scavengers for oxygen and ethylene, absorbers, releasers, anti-microbials, and antioxidants (Soltani Firouz et al., 2021).

3) *Connected packaging* is used to share additional content or promotions with consumers through printed codes like bar codes and QR codes. The first contains static information and the second is used for richer information, usually including promotional contents or extended uses displayed on web sites (Vanderroost et al., 2017). The concept of smart packaging integrates the benefits of the mentioned evolutions of packaging (Kerry et al., 2006) and is properly applied to any type of packaging that makes more than just containing a product. The FSC improves its performance and profit through smart packaging (Pacquit et al.,

2007). While information regarding origin, destination, location, and physical conditions in transportation and storage phases improves logistics operations efficiency, information for customers (usually regulated) can support waste reduction at households (Poyatos-Racionero et al., 2018). Moreover, the added value is appreciated by consumers (Schaefer & Cheung, 2018) thanks to the enhanced customer experience involving digital marketing and physical shopping (Lydekaityte & Tambo, 2020).

Full economic viability of smart packaging has not been reached due to some high costs (Ghaani et al., 2016) originated by the continuous development of sensitivity, selectivity, robustness, and materials transference in the case of sensors (Mustafa & Andreescu, 2018). Marketability of smart packaging is not easy due to the unfinished features, impact on the price of food, and the perception of packaging as a pollution generator (Soltani Firouz et al., 2021).

2.4- IoT-Enhanced Smart Packaging

The IoT is based on the idea of connected services with currently implemented networks including GPS devices, smartphones, cloud computing, analytics, and social networks (Ben-Daya et al., 2019). It has been applied to the FSC to trace products (Chen, 2015), monitor food quality (Bouzembrak et al., 2019), and predict perishability (Talavera et al., 2017). Brous et al. (2020) highlights the possibility to immediately enable information to make decisions, analyze data, plan, and reduce costs. IoT can be integrated with smart packaging since sensors usually have a power source and a memory or RFID antenna to share data, this antenna can be connected to an IoT network transforming a food package into a cyber-physical object (Wang et al., 2019). With most possibilities still remaining to be explored, some IoT-enhanced Smart Packaging developments are now available allowing multi-sensor devices to monitor chemical composition of food sharing data in real time (Bouzembrak et al., 2019). Dynamic re-routing applied at the

individual package level is allowed to match the shelf life requested at delivery points and the First-Expired-First-Out management is simplified or even automated to reduce food waste (Bogataj et al., 2017). Overall information and higher efficiency can be directed to reduce the resources consumed to produce and process food (Kalpana et al., 2019; Soltani Firouz et al., 2021). Integrated with cloud computing, mobile devices, and data analytics, IoT-enhanced Smart Packaging offers seamless end-to-end visibility which exploitation depends on the capabilities, alignment, and strategy of the FSC (de Oliveira & Handfield, 2019).

Considering that some sensors are still in the developing and improvement phases, it is not expected to obtain from them all the promised functionalities at the moment (Mustafa & Andreescu, 2018). Even with the relatively easy integration of the IoT and smart packaging enabled by the antennae and the availability of batteries (Wang et al., 2019), the unification of smart packaging is still not finished for all the possible combinations. Additionally, RFID is the main wireless element to connect smart packaging into an IoT network, which presents issues. Some of the difficulties are the reader and tag collision (Pal, 2019), the general readability in the logistical processes including indoor and outdoor operations, as well as the interference of some materials such as metals and liquids (Lach et al., 2021).

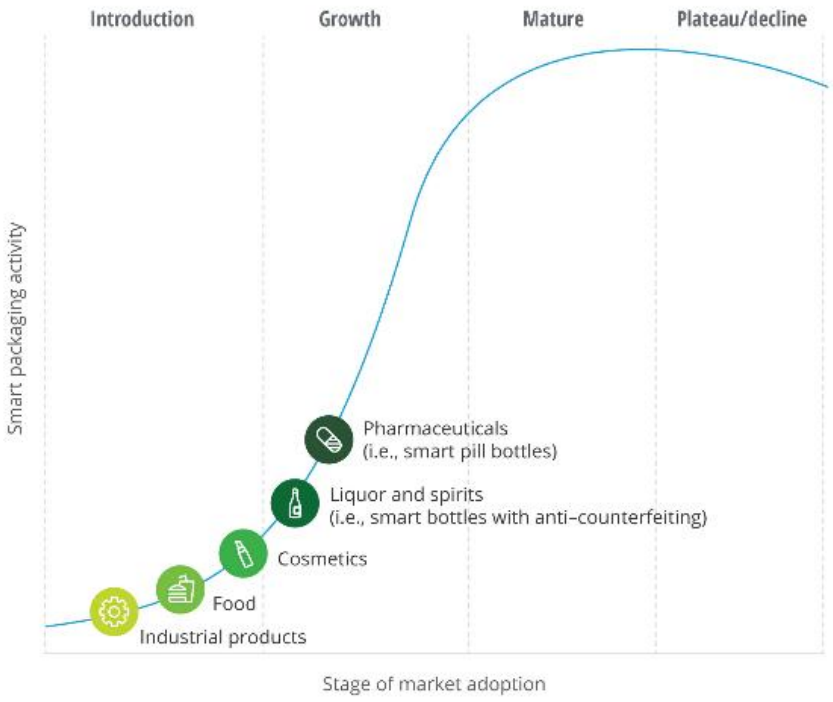
From the consumer's point of view, good results from the adoption of emerging technologies such as big data, artificial intelligence, robotics, and others in the SC are expected during this age (Merlino & Sproge, 2017). According to these authors, the digitalization of the SC and other technologies are here as a response to the rapid changes in the environment and to build sustainable operations. The attention of consumers to engage in efforts to protect the planet is influencing their buying decisions (Grazzini et al., 2021), and companies are becoming aware

of this pressure in the form of concerns with food quality, safety, fraudulent food, and mislabeling (Vu et al., 2021).

2.5- Adoption of IoT-Enhanced Smart Packaging

The introduction time of technological innovations is subject to its diffusion process, which is the adoption approach followed by users (Taalbi, 2019). The IoT-enhanced Smart Packaging creates uncertainty because the potential benefits have not been proved yet and there can be some unexpected and undesirable uses. Additionally, ambiguity exists due to the interpretation that different stakeholders would make of the technology and its benefits (Mitchell, 2007; Stirling, 2007). Beyond the mentioned attitudes of consumers towards cost and sustainability, there are still favourable and unfavourable opinions about smart packaging applications in the food industry, creating the need for education about benefits and clarification of misconceptions (Thirupathi Vasuki et al., 2023). Overall, individual consumers and companies involved in the FSC dictate the current status of the adoption process of smart packaging which is in the initial stages, as shown in Figure 1, with IoT-enhanced version results immersed but not clearly segmented. The reasons behind this market introduction status, specifically for the IoT-enhanced Smart Packaging, drive the posed research questions.

Figure 1- Smart packaging market introduction.
Source: (Armstrong et al., 2018)



Chapter 3 – Methods

As stated before, the technologies integrated to shape the innovative offerings of IoT-enhanced smart packaging are in the introductory phase to the target market. Previous research in this specific topic is, as a consequence, scarce. The present study is intended to gain insights into the adoption decision in the FSC to exploit the benefits in order to gain competitive advantage, support the reduction of food waste, etc. This objective fits in the second of the typical goals of an exploratory study described by Bhattacherjee (2012a), which is expressed as the first attempts taken to gain understanding about a phenomenon. Therefore, this study is considered as a piece of exploratory research. This lack of information to answer the research question makes qualitative methods more suitable than quantitative methods.

3.1- Instrument

Since the goal is to get informed opinions and perspectives about the barriers and drivers to adoption of the IoT-enhanced Smart Packaging in the FSC, the chosen method is qualitative interview. According to Creswell (2014), this method allows the researcher to reach this objective through interviews with people possessing the required knowledge. These interactions could be in person or using other means, one-on-one or in group. Additionally, the guiding questions are few in number, and the attitudes towards the topic can be obtained and understood (Gray, 2014). This study will offer the interviewees the possibility to choose from in-person, online, or telephone according to their preference or the limitations of distance and resources. The specific type of interview that has been selected is the semi-structured interview, the main reasons for this decision are the possibility of adding or removing some questions, the flexibility in changing the order according to the perceived relevance during the interview, and the opportunity for respondents to expand on answers (Gray, 2014).

The design of the guiding questions for the semi-structured interview includes three sections, it can be found in the Appendix 1 - Interview guiding questions. The first phase is aimed to know the background of the respondent and the company. The second section was designed for the subjects to share their knowledge, opinions, and experience with IoT-enhanced Smart Packaging. The final section provides opportunity to the interviewee to share insights on the future of the studied technology and the possibility to refer to other experts. Instructions for the interviewer are included in the form.

The application of the interview was done according to the guidelines created by Creswell (2014) in his interview protocol to ask and record the provided answers. This protocol comprises several essential components, starting with a header containing information about the

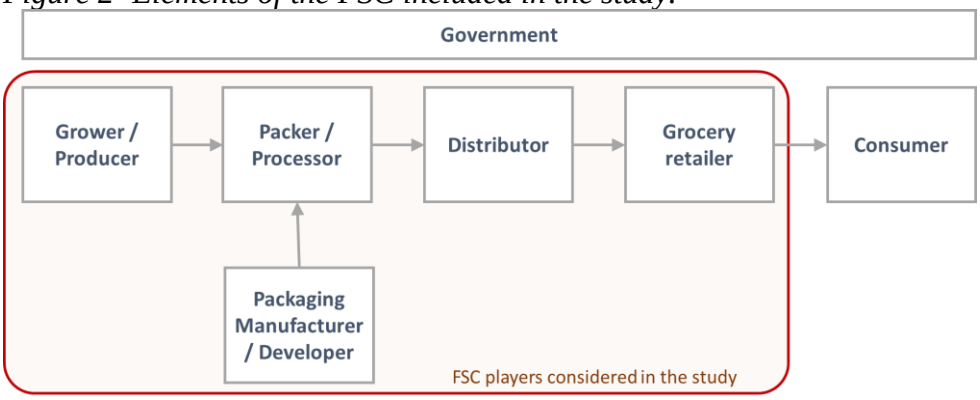
place and date, along with the names of the subject and the interviewer. It also provides clear instructions to ensure the proper application of the protocol. Moreover, the protocol offers the opportunity to record the answers provided by the subject, concluding with a final expression of gratitude.

3.2- Sampling

Due to the novel nature of the IoT-enhanced Smart Packaging, knowledge about it is not widely available in many companies. Therefore, non-probabilistic sampling was more adequate to focus the research on professionals who possess the required expertise. The selected type of non-probabilistic sampling was expert sampling, a type of purposive/judgement sampling designed to consider only people with knowledge on the studied phenomenon (Bhattacherjee, 2012b). Interviewing experts from both buyers and sellers of this technology was intended to support the possibility to find if the barriers and drivers on each side are different, as well as the relative importance perceived by each industry. To be considered as an expert, a professional on the buyers' side must hold a decision-making position in the supply chain or packaging departments or be part the technical area related to technology and process of a company that has conducted an IoT-enhanced Smart Packaging implementation project within the FSC disregarding the final adoption decision. On the sellers' side, the expert is a professional possessing knowledge about the technical details and benefits, with direct contact with companies in the FSC.

In total, three types of companies in the FSC were considered, food-related companies because they make the adoption decision, grocery retailers since they have a direct influence on this resolution, and technology developers or sellers because they are on the other side of the commercial relationship. Figure 2 depicts the scope of this study.

Figure 2- Elements of the FSC included in the study.



Other stakeholders such as governments, scholars, environmentalists, and final consumers were not included at this stage. The rationale for the exclusion was that the lack of dissemination of the benefits and nature of the technology would have created the need to educate the interviewees before conducting the actual interviews, increasing the required time and economic resources. Third party logistics companies (mainly related to transportation and warehousing) are not considered because the IoT-enhanced Smart Packaging is focused on individual product packaging. The implementation of IoT in their operations currently offers similar benefits at container or pallet level, namely information available in real time, faster decision making, inventory control, and lower operational costs (Brous et al., 2020). Even though the benefits in the FSC can be enjoyed by all the players, considering only the mentioned groups of companies seems more appropriate at this point.

The source to select the packaging companies offering the technology were associations such as PAC Global, which describes itself as a non-profit organization to connect, collaborate, and innovate (PAC Global, n.d.), and Canadian Packaging. Including suppliers of different types of technology would strengthen the scope of the study. To gather the buyers, the board of directors of associations of the food and grocery industries were consulted. Some of the considered associations are Retail Council of Canada, Dairy Processors Association of Canada,

American Association of Meat Processors, Canadian Meat Council, Canadian Produce Marketing Association, and Alberta Food Processors Association. As an additional source, online publications on specialized websites were consulted to find experts, resulting in the inclusion of an author, and editor, and two employees of packaging companies. The initial list of prospects consisted of 24 experts from six different sectors (Table 1) and four countries (Table 2). All of them were contacted via email, telephone, or the professional social network LinkedIn, depending on the available information.

Table 1-Initial list of prospects by Industry Sector

Sector	**Total**	**%**
Grocery Retail	7	29.2%
Packaging Industry	4	16.7%
Meat	4	16.7%
Food processor	3	12.5%
Produce	3	12.5%
Dairy products	3	12.5%
Total	24	100.0%

Table 2- Initial list of prospects by Country

Country	**Total**	**%**
Canada	18	75.0%
USA	4	16.7%
UK	1	4.2%
Switzerland	1	4.2%
Total	24	100.0%

3.3- Validity and Reliability

According to Drucker-Godard et al. (2020), internal validity in qualitative research is obtained through precautions taken in the design phase rather than specific actions. The diversity of companies in the sample and the consideration of both sides of the buyer-seller dyad would fulfill this recommendation. Following the ideas of the authors, reliability in qualitative research rests mainly on the provided description of the methodology of the research provided by the researcher. The condensation and analysis of data is also emphasized, which would be done once the final report is written. Additionally, research reliability is supported by the reliability of the instrument to collect data, which was assessed following the directions given by Drucker-Godard et al. (2020). These authors state that to gain reliability in unstructured interviews transcription is needed to later focus on analysis. For interviewer-driven interviews, it must be assured that questions are understood in the same way by all the interviewees through pre-testing. To fulfill this requirement, the instrument was pre-tested interviewing two students at the Asper School of Business on Zoom videoconferencing software, the audio of the interviews was recorded following the protocol using the proper function of the application. Modifications to improve the clarity of some questions and its contribution to the data were applied.

3.4- Data Collection, Coding, and Thematic Analysis

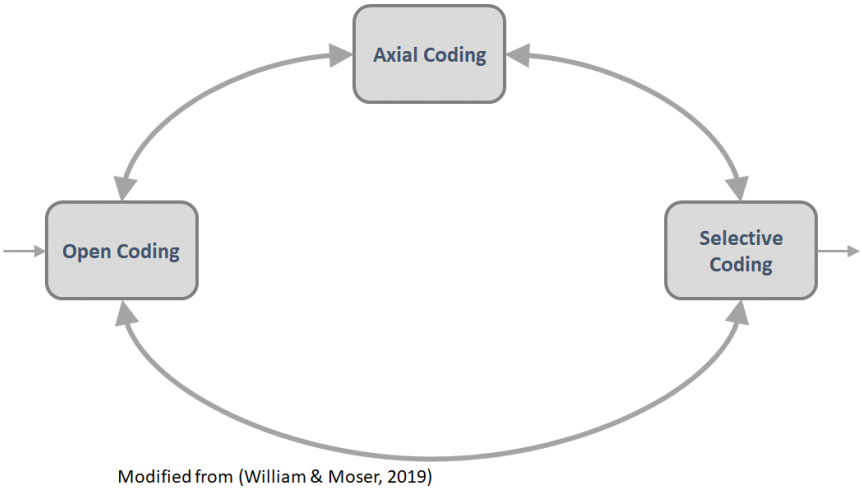
All interviews were performed online using Zoom and Microsoft Teams videoconferencing software, scheduling each session at a convenient time for each subject. Interviews were audio recorded and then transcribed. A summary of the main points was sent by email to each participant for validation.

Thematic analysis (Clarke & Braun, 2017) was selected because it is a qualitative research technique employed to recognize, examine, and make sense of patterns of significance (themes) within qualitative data. It is a flexible approach not coupled to a specific theoretical framework. It involves generating codes (small units of analysis capturing interesting data features) and then building themes (more extensive patterns of significance) directed by a central guiding principle. This methodology emphasizes rigorous analysis and offers quality procedures like a two-stage review process. Its flexibility makes it suitable for various research questions, sample sizes, data collection methods, and research paradigms. The steps followed to perform thematic analysis were:

1) *Data Familiarization:* This step was completed by listening the audio-recordings and reading transcriptions multiple times to gain understanding of its content and context.

2) *Data Coding:* Coding was applied to each interview transcription following the guidelines given by William and Moser (2019). According to them, coding in qualitative research is an inductive approach focused on generating meaning from collected data through activities like interviews and observations, involving an ongoing interaction between the researcher and the data. The coding process includes open coding (identifying concepts and themes), axial coding (refining and categorizing themes), and selective coding (integrating categories into cohesive expressions). These three levels of coding were applied in a linear way, as shown in Figure 3. The small number of interviews allowed manual coding, so no coding software was needed for this study.

Figure 3. Coding: Non-linear process for qualitative research



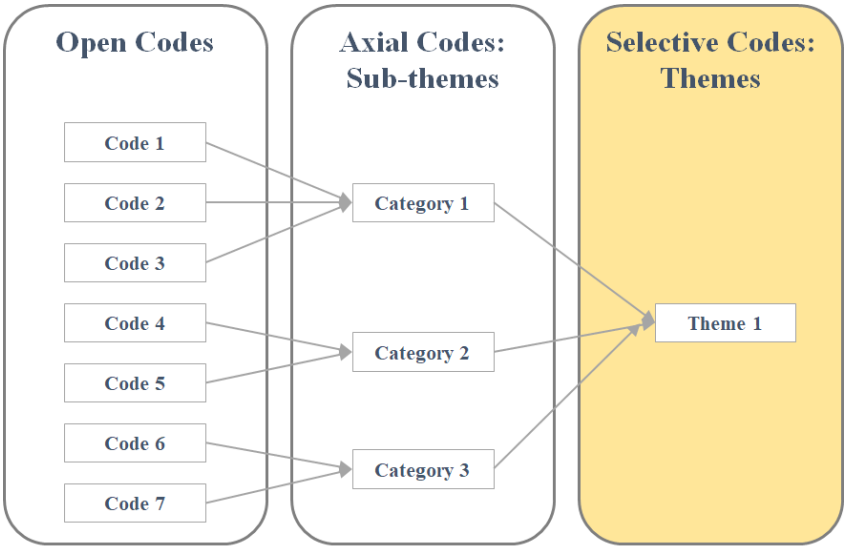
3) *Generating Initial Themes:* Themes or broader ideas that capture the essence of the coded content were created using the sequence of three steps described in the previous point.

4) *Reviewing and Defining Themes:* Initial themes were reviewed and refined by considering how they relate to the interview as a whole.

5) *Theme Naming and Definition:* A clear name was assigned to each theme, as well as a description enclosing the main aspects to briefly explain what it represents.

Steps 3), 4), and 5) were done following the sequence created by William and Moser (2019) and depicted in Figure 4.

Figure 4. From Open Codes to Selective Themes



Modified from (William & Moser, 2019)

6) Mapping and Reporting: This step is integrated by three sub-sections:

   a. A **mapping structure** was created for each interview to denote the particular point of view of the FSC stage represented by the expert.

   b. An **individual report** was written for each interview using a narrative style to ease the understanding of how the interaction developed and to capture the individual profile of each subject. These reports were created from the resulting thematic analysis but some of the themes were grouped to provide meaning while clearly identifying and understanding the opinion regarding the main themes such as drivers, barriers, types of smart packaging implemented/known, IoT, sustainability, food waste, cost, benefits, challenges, company size, innovation, integration, regulations, etc. This was needed as during a single interview some themes were mentioned by the interviewee multiple times when answering different questions and some

questions were not actually asked as the response was embedded in previous comments.

c. An **overall mapping structure** integrating the individual mapping structures was created (Table 8) to concentrate the relevant concepts provided by the experts. This sequence of main themes and subthemes was followed in Chapter 5 - Discussion to follow a coherent sequence.

7) Data Validation: Thematic analysis is typically an iterative process where validation of findings and interpretations must be assured. The input of the thesis committee members was the source of this validation.

3.5- Ethics of the Study

Confidentiality of participants and companies was maintained during all the study, with identifiable data, recordings, and transcriptions properly secured and destroyed according to the protocol submitted and approved by the Research Ethics Board 1 (Appendix 2 – Research Ethics and Compliance Approval). The anonymization of companies was done following the FSC players included in Figure 2- Elements of the FSC included in the study. The list of options is shown in Table 3, in the case of having two or more companies pertaining to the same code, a numerical sequence was applied, e.g. Grower 1 and Grower 2. Individual reports for each interview were created; the sequence of presentation in this thesis is following the downstream order. The experts were anonymized following their appearance in this document, using the codes Expert 1, Expert 2, etc.

Table 3- Company Anonymization Code

Company Anonymization Code

Grower
Producer
Packer
Processor
Distributor
Grocery Retailer
Packaging Manufacturer

Chapter 4 - Results

All the prospective subjects were contacted by email or LinkedIn, depending on information availability. From this list, only two prospects replied to the initial contact message. One professional working for a produce packing and distribution company accepted the invitation but due to agenda issues did not participate, but he referred a suitable expert within his employer. The other prospect asked for additional information about the study but after receiving it stopped communication. Table 4 illustrates these outcomes across industry sectors. Referrals emerged as the primary source for participating subjects, with details presented in Table 5.

Table 4- Results of Initial list of Prospects

Sector	Prospects	Responded initial message	%	Accepted invitation	%	Remarks
Grocery Retail	7	0	0.0%	0	0.0%	
Packaging Industry	4	0	0.0%	0	0.0%	
Meat	4	0	0.0%	0	0.0%	
Food processor	3	1	33.3%	0	0.0%	Asked for additional details but interrupted communication
Produce	3	1	33.3%	1*	33.3%	Agenda issues. Referred a suitable professional within his employer
Dairy products	3	0	0.0%	0	0.0%	
Total	24	2	8.3%	1	4.2%	

* Accepted but unavailable within study timeline

Table 5- Results of Referrals

Sector	Referral	Replied initial message	%	Accepted invitation	%
Packaging Industry	4	4	100.0%	3	75.0%
Produce	1	1	100.0%	1	100.0%
Packer & Distributor	1	1	100.0%	1	100.0%
Grocery Retail	1	1	100.0%	1	100.0%
Total	7	7	100.0%	6	85.7%

The final sample is composed by one producer, one packer and distributor, one retailer, and two packaging companies (Table 6). This provides a complete scope of the FSC as intended in the initial design. The companies operate mainly in more than one country, but the participants are based in two countries, Canada and the USA (Table 7). A report was written for each interview, showing the main points shared by subjects.

Table 6- Final Sample by Industry Sector

Sector	Total	%
Packaging Industry	3	50.0%
Produce	1	16.7%
Packer & Distributor	1	16.7%
Grocery Retail	1	16.7%
Total	6	100.0%

Table 7- Final Sample by Country

Country	Total	%
Canada	5	83.3%
USA	1	16.7%
Total	6	100.0%

4.1- Interview Report 1: Producer

The initial link of the FSC was covered in the interview with Expert 1, who is the owner and operator of the Producer. Expert 1 is a second-generation farmer overseeing an 18-acre greenhouse farm situated in BC, which specializes in cultivating tomatoes and strawberries. Given their shelf life of three to four days, strawberries are distributed in Western Canada, while the 3-week shelf life of tomatoes allows shipments to the Pacific Northwest and Ontario within Canada, with occasional shipments to the Southwest US and, in the past, to Asia.

The Impact of Government Regulations: Government regulations were found to significantly impact the agriculture sector. The BC Vegetable Marketing Commission was identified as a regulatory authority governing greenhouse construction through a quota system. As detailed by Expert 1, this organization does not regulate prices but controls the construction of greenhouses and offers protection by preventing the access of large foreign companies to the market. Additionally, regulated marketing agencies play a crucial role in the sale of produce, wherein farmers, including the Producer, are required to go through these agencies to sell their products. In BC, there are only six of these marketing agencies, a condition that limits the options for the commercialization of products. Expert 1 feels that the government's heart is in the right place but disparities in support for different agricultural sectors exist. There are concerns about the fairness of carbon tax policies and how the costs of packaging innovations are often pushed onto the farmers.

Smart packaging within the Producer: The packaging practices in the company consist of plastic shell containers that allow airflow to maintain the produce's freshness. Expert 1 revealed that the Producer had already adopted some aspects of this concept. In the past, packages that change the atmosphere inside to reduce levels of CO_2 or other gases have been employed for the purpose of retarding the ripening process and extending the duration of shelf life. If required by the customer, monitoring of temperature at truck level is applied. As usually a single truck collects orders from various farmers to make a full load, it is at the last loading point where a temp tale device is placed.

Adoption of smart packaging: According to the interviewee, in the farmers' sector, smart packaging is implemented based on customer requirements and is usually determined by the marketing group or end customer. They usually work together to determine packaging specifications such as the size of the pack, the materials, the inner arrangement, and the technology used. He stated that regarding smart packaging "a lot of it is out of our control. It's not something that we drive from the farm". The sequence of defining actors starts with the end customers, usually large companies, then the regulated marketing group, and finally the farmer receiving directions. Expert 1 sees a disconnection between the consumer's requirements and the actual solution implemented, as an example it was mentioned the common claim for less plastic in food packages. A potential benefit of smart packaging is the solution of disputes when product is rejected as the reasons presented by the customer are not always perceived as valid by farmers. Upon previous agreement of the rules, the information made available by technology and sensors could be used to confirm the produce specifications at delivery. It was also mentioned that smart packaging can enhance the efficiency of the supply chain, particularly in tracking and tracing products, dynamically monitoring temperature and humidity levels, and employing IoT

technology for data transmission. Unfortunately, farmers do not have deeper impact as most supply chain operations are coordinated by other companies.

Challenges in implementing smart packaging: Expert 1 acknowledged that the adoption of smart packaging innovations is often associated with increased costs, raising concerns about financial feasibility not only for small-scale farmers but for almost the full sector. When he said "one of my frustrations as a farmer is it seems like a lot of the costs of all these initiatives end up being pushed on the farmer", his idea was clearly stated. Despite asking for new types of packaging materials end consumers are not willing to pay more for his products. Innovative packaging solutions proposed by the marketing company have been discarded since the cost was three times higher. Packaging material is a special concern as it is farmers' second biggest cost after labor. He finally expanded this consideration to determine that additional costs developed in the supply chain are pushed down expecting farmers to bear them. A massive challenge as they are price takers, a situation created by the disparity in numbers: thousands of farmers and a handful of main customers in Canada. Availability of technology is considered a potential problem as packaging is a basic element, it must be there consistently. Additionally, the skill level required to implement and maintain the technology can be a challenge for some frontline workers and shippers in the agricultural sector.

Competitive Advantage: Larger greenhouse companies with vertically integrated operations were observed to be more inclined to invest in sophisticated smart packaging technologies. As they incorporate marketing and distribution arranging the logistics and transportation to directly sell to customers, could initiate the adoption of technology to create a competitive advantage. Their extended influence on the supply chain could report benefits to them, especially by the reduction of food waste. In general terms, potential economic benefits for

the big picture are considered feasible despite the cost increase, but there must be a fair distribution within the supply chain. Regarding the improved image of the brand, there is no direct impact on the Producer since the product does not go with its name but with the marketing agency's. This intermediary dictates what is included in the labels and in the currently added QR codes.

The Sustainability and Food Waste factor: Sustainability emerged as a prominent theme during the interview, with Expert 1 showcasing a 99% yield in his greenhouse. He attributed this high yield to the consistent, high-quality produce that greenhouses can provide compared to traditional field farming. When weather is not favourable, field farming waste levels are around 20% to 30%. However, downstream food waste was acknowledged, especially during transportation, distribution, and retail stages, where products are prone to overbuying and mishandling. Specifically, on the customer end, C & D type customers have a higher level of waste (50%) compared to those of the A type which have a tighter control of their supply chain. As a result, the margin obtained by the Producer is better when selling to type A customers.

Expert 1 expressed interest in leveraging smart packaging to share sustainability efforts, recognizing the importance of communicating a company's commitment to reducing waste and greenhouse gas emissions to build a positive image among consumers.

4.2- Interview Report 2: Packer & Distributor

Expert 2, a Packaging Manager, was the subject for the second and third links of the scope of the study in Figure 2. This expert works for a leading Packer & Distributor of fruits and vegetables serving customers such as restaurant and hospital chains as well as retailers in Western Canada and the US. The supplier network of growers and distributors developed by the

Packer & Distributor covers Canada, Mexico, US, South America, Africa, Australia, and New Zealand. Since each country has different requirements for packaging, the company repacks and grades the imported products to meet Canadian standards.

Smart packaging at the Packer & Distributor: Expert 2 revealed that some smart packaging solutions, such as temperature and humidity monitoring using temp tales during transportation, were already in place in the company. This is applied only at the truck level, with the intention of obtaining data of the conditions when product is transported.

Drivers and demand for smart packaging: The interview highlighted food processors and growers as the main drivers behind the adoption of smart packaging. Their primary goals were to ensure product quality, avoid rejected shipments, enhance shelf life, and reduce food waste. Grocers and consumers drive the information they require from upstream companies. Particularly, what is being more used is connected packaging with interactive QR codes for accessing recipes or additional marketing-related information. This disparity in the origin of demand of added functionalities emphasized the need for customized and tailored smart packaging solutions to satisfy the diverse requirements of various stakeholders along the FSC. Regarding competition, what others are doing is not forcing the Packer & Distributor to follow the same path.

Benefits of smart packaging: Smart packaging in the food industry demonstrated several significant benefits. Expert 2 underscored the importance of analytical data generated through smart packaging to track the product's journey, identify potential issues, and optimize quality control. By providing crucial insights into product integrity and supply chain efficiency, smart packaging can contribute to sustainability efforts within the industry. Moreover, it can assist in determining liability in case of disputes and damages to protect themselves; as “unfortunately, a

lot of grocery stores do abuse product". Better traceability supports recalls in the case of potential bacterial infection, but also alleviates the financial impact of it. Enhanced traceability also allows for better waste reduction strategies, but it will not come as a direct benefit since information alone cannot materialize the reduction of food waste and resource optimization. It is needed to take direct action using the available information to benefit both customers and growers financially.

Challenges and Barriers: The interviewee highlighted various challenges associated with implementing smart packaging in the food industry. The main barrier was the high upfront costs required to integrate smart technologies into packaging materials. While connected packaging, which transfers information, may have a comparable cost, environmentally friendly packaging currently remains 5 to 10 times more expensive, particularly for active packaging, and lacks volume in the market. Consumers are not willing to pay a premium for new packaging solutions, so retailers do not perceive value in spending more in these options. According to Expert 2, smart packaging can add around 10% to the overall cost of a product. Additionally, the lack of communication and synchronization within the FSC hindered the integration of smart packaging solutions. This was compounded by the need for greater consumer education and awareness about the benefits of sustainable packaging practices. Furthermore, the complexity of adopting innovative packaging materials, discrepancies in manufacturing requirements, and varying legal regulations across different countries posed additional challenges.

Market Influence and Stakeholder Collaboration: The interviewee noted the substantial influence of large retail chains on market trends and packaging requirements. The decision-making process for adopting smart packaging was often driven by customer demands and retailer preferences. Consequently, collaborative efforts among growers, packaging manufacturers,

distributors, and retailers were deemed critical to driving sustainable packaging practices and effectively implementing smart packaging solutions. To achieve sustainable outcomes, stakeholders must work together to align their goals and implement cohesive strategies that benefit the entire FSC.

Sustainability Impact: While analytical data generated through smart packaging can provide better information about product quality and shelf life, it is unclear whether it will directly reduce food waste and resource optimization or simply notify retailers when products are close to expiration. Its overall impact on food waste reduction may be contingent on various factors beyond packaging technology. Supply chain management practices, consumer behavior, and other systemic considerations also influence the extent of food waste reduction achieved. The interview emphasized the importance of adopting a holistic approach to sustainability, encompassing various aspects of the food industry beyond just packaging. A special concern disclosed was “the sheer quantity of falsely labeled enviro-friendly products that are basically a greenwash pretending to be enviro-friendly but actually aren’t”.

Government support and education: The government should support recycling companies to create a market for their recycled products as there are not enough opportunities for them to sell their products. Additionally, there is a need for education to the general population about the benefits and drawbacks of different packaging materials to promote sustainable choices.

4.3- Interview Report 3: Grocery Retailer

Expert 3 is a supply chain engineer at the Grocery Retailer, a California-based grocery business reaching consumers with its network of above 400 stores across the West Coast of the United States. Approximately 30% of the total items are perishables such as produce, dairy, and

meats. The expansion to the East Coast has been initiated with selling points in New Jersey and Philadelphia. He outlined his role in the company, which involves ensuring smooth supply chain operations, facilitating expansion plans of the company, and innovating the logistical operations to increase overall efficiency.

Smart packaging technologies at the Grocery Retailer: Currently, what the Grocery Retailer has implemented is “these labels on the packaging of the product so that you can scan with your phone and get additional information from them.” Expert 3 mentioned that they have not seen much on sensors as they mainly rely on barcodes, with information for consumption dates like the best by or expiry dates included. The best differentiator for the company is not technology but the business model developed.

Benefits and drivers to adoption of IoT-enhanced Smart Packaging: Expert 3 recognizes the high potential benefits of adopting IoT-enabled packaging within the FSC, highlighting improved traceability, real-time condition monitoring, and the potential reduction of food waste as key advantages. However, he acknowledges that the technology is still in its nascent stages and may primarily cater to trend-setting consumers willing to pay a premium for enhanced transparency and freshness assurance. He sees more benefits for the consumer as the information availability for expiry dates management and marketing messages could be appreciated by them. As a result, Expert 3 believes that the main driver for the adoption is the end costumer with a chain reaction upstream.

Barriers and Challenges to Adoption: Expert 3 identifies cost as a pivotal factor, encompassing both the initial investment in hardware and software and the potential increase in product cost due to the integration of smart packaging features. He also raises concerns about the compatibility and integration of these technologies within existing supply chain infrastructures,

particularly in regions with inadequate internet connectivity. For him, a major concern is the integration of IoT-enhanced Smart Packaging into the current systems of the company such as the ERP and WMS. Information flowing within different systems must be properly defined and homogenized; overall, it must be valuable and not currently provided by the means in place. In his words: “I think that to really fully exploit and get the benefits, first we have to understand what we will be getting from there. Because if it is just expiry date, it's already printed into barcode… I can get it already if I just scan a product or maybe I can get it online if I get EDI connection, or if I get an ASN. …So, what is the plus to get? What is the extra that it is giving me to get this technology so that it's worth making the investment?” He added that implementation in a warehouse seems costly as well since the reading devices must be installed in large buildings.

Expert 3's insights underscore the importance of balancing the added value of smart packaging for manufacturers and end customers against the associated costs. He considers as a pivotal point the need for a robust business case to justify the adoption of these technologies in an industry characterized by tight profit margins. For him, the return on investment makes adoption projects a hard problem for his company. On the consumer’s side, Expert 3 considers it difficult for most of them to pay the price difference resulting from the added functionality. For the cumulative increase they could acquire other items.

Regulatory Implications: For Expert 3, the regulations are there, and his employer is currently complying, so he suggests that simplified compliance processes and enhanced traceability requirements could encourage the integration of IoT-enhanced Smart Packaging devices to meet the standards effectively. By aligning regulatory objectives with the potential

benefits of smart packaging, Expert 3 emphasizes the potential dual role of regulations in improving both product quality and environmental sustainability.

Supply Chain Integration: A higher integration of the FSC is not perceived by Expert 3 as a result of IoT-enhanced Smart Packaging adoption. The main reason is that the FSC already has communication protocols like EDI and ASN, so basing new connectivity on current standards would be enough and cheaper because not everything must be reinvented.

Significance and Sustainability of Packaging in the Grocery Industry: Expert 3 underscored the multifaceted role of packaging saying it extends beyond mere containment to encompass protection during transportation, presentation on store shelves, and even environmental considerations. He highlights the potential environmental benefits of optimized packaging that reduces waste and spoilage in the supply chain, aligning with broader industry trends toward sustainability and reduced ecological footprint. For his industry, the disposal of packaging discarded at the distribution centre and store levels must be alleviated by the use of more sustainable materials.

4.4- Interview Report 4: Packaging Manufacturer 1

Expert 4 and Expert 5 were interviewed to gather valuable insights from professionals within the packaging industry. Both work for a company pertaining to a global packaging manufacturing group focused on protection of perishable food and other products. With facilities in North America and in close relationship with a European packaging manufacturer, Packaging Manufacturer 1 specializes in the manufacture and distribution of flexible packaging, rigid packaging, lidding, and packaging machinery. Expert 5 is a R&D manager with previous experience in the plastics industry. On the other hand, Expert 4 is the corporate vice president of

supply chain and procurement for North America with close cooperation with the European companies of the group.

Smart packaging at Packaging Manufacturer 1: Both Expert 4 and Expert 5 demonstrated a concise understanding of smart packaging, emphasizing its active nature, which is the main type manufactured by Packaging Manufacturer 1. Expert 4 sees more contribution from the company in the protein and dairy markets where it aims to add an extra day or two to extend the shelf life. They are focused on multilayer co-extruded materials but also are doing modified atmosphere packaging and oxygen scavengers to control the gas composition within the package preventing oxidation and spoilage. For Expert 4, “where things are going in the future is the active side of things” as well as “the ability to track that package from cradle to cradle because grave doesn't exist anymore”. Additionally, they explore various intelligent options, such as color code indicators and QR codes, to help consumers and their customers know if the package has been compromised or violated during its journey in the supply chain.

Designing solutions: Food processors do not find it challenging to determine the most suitable smart packaging solution for their specific needs. They just give The Packaging Manufacturer 1 mandates and expectations, and the company provides the solution which accomplishes the required functionalities.

Drivers for smart packaging adoption: One of the primary drivers mentioned by Expert 5 is the consumer demand for high-quality, fresh, and safe food products. As lifestyles become more fast-paced and centralized, consumers seek convenience without compromising product integrity. Smart packaging addresses this need by extending shelf life and reducing food waste, which aligns with sustainable consumer choices. For Expert 4, regulatory requirements and food safety standards have become more stringent, prompting food manufacturers to explore

innovative packaging solutions. They remarked that the smart packaging technologies they use offer enhanced preservation capabilities, ensuring compliance with safety regulations.

Applications and benefits of smart packaging: During the interview, the experts discussed various applications of smart packaging in the FSC and highlighted the associated benefits. One notable application is in the preservation of fresh meat products. Expert 4 and Expert 5 explained that smart packaging can maintain the color and appearance of fresh meat, which is crucial for consumer appeal and acceptance. Additionally, by reducing spoilage and food waste, smart packaging contributes to cost savings and improved supply chain efficiency. They also mentioned as another significant benefit of smart packaging its potential to enable traceability and transparency in the FSC. By integrating Internet of Things (IoT) technologies, smart packaging facilitates data exchange and real-time tracking of products from production to recycling facilities. In this sense, Packaging Manufacturer 1 is in discussions with some companies to implement a blockchain-based technology, which aims to support not only data exchange but also to ensure that materials are effectively recycled, thus minimizing waste. This traceability enhances supply chain visibility, helping to identify and address potential issues promptly. To improve the purchasing experience and ease to track physical flows, they are working with a printing company to include barcodes invisible to human eye on flexible packaging.

Challenges to adoption of smart packaging: Cost and infrastructure were identified as the main barriers to the widespread use of smart packaging. Expert 4 and Expert 5 agreed that the initial investment required for smart packaging solutions may be higher compared to conventional packaging methods. As a result, some companies might be hesitant to embrace these innovations, as not all consumers may be willing to pay higher prices for products with

smart packaging features. Additionally, the lack of proper infrastructure, especially for chemical recycling and handling of post-consumer waste, poses a significant challenge to the effective implementation of smart packaging solutions. Despite the positive impact, the plastics industry faces challenges in promoting the benefits of smart packaging effectively, given the prevailing negative perception of plastics and the need for better communication and education on the matter. The government must participate in the education process and avoid negative messages towards plastic.

They acknowledged the need for integration to extend beyond the traditional boundaries of the supply chain and include recycling companies and grocery store chains. Upstream integration involves working closely with suppliers and joint development to guarantee that the packaging complies with the necessary functionality and regulatory standards. Downstream integration encompasses collaboration with stakeholders like recycling companies and grocery store chains to create a comprehensive loop that promotes circularity and sustainability. They highlighted the challenge of managing contamination in recycling processes, where residues from food products can compromise the quality of recycled materials.

Impact on Sustainability: The experts underscored the positive impact of smart packaging on sustainability and reducing food waste. They emphasized that smart packaging is essential in addressing food waste issues and minimizing greenhouse gas emissions resulting from food decay. On the distribution side, it was acknowledged that it reduces the frequency of replenishment and, consequently, the carbon footprint associated with transportation. Moreover, the incorporation of materials with higher barrier properties and the exploration of biodegradable or bio-renewable packaging elements align with the broader sustainability goals of the industry. Both experts are proud of the efforts of Packaging Manufacturer 1 towards sustainability, which

are properly undisclosed to the general public and are central to find ways to recycle or repurpose the packaging materials once their initial function is complete. However, Expert 4 also pointed out that to fully realize the environmental benefits of smart packaging, improvements in recycling processes are necessary, especially concerning flexible packaging materials. Enhancing recycling capabilities will ensure that smart packaging materials are appropriately managed at the end of their lifecycle, minimizing their impact on the environment.

Influence of Big Corporates: Expert 4 highlighted that the consolidation of the food industry has led to more centralized processing and distribution. As a result, the need for effective packaging solutions, like smart packaging, to maintain product quality and freshness during transportation and storage has intensified. Expert 5 also mentioned that the influence of big corporations can drive innovations in packaging technology. As these corporations invest in research and development, they pave the way for smaller businesses to adopt and implement smart packaging solutions, thereby benefiting the entire industry.

4.5- Interview Report 5: Packaging Manufacturer 2

Expert 6, a sales account manager at Packaging Manufacturer 2, who possesses over 20 years of experience in the packaging industry, provided his comments specifically from the perspective of the label and lidding sector of the packaging industry. Packaging Manufacturer 2 is a company based in BC offering high-quality printing and packaging products and solutions to clients over Canada and US and down to Peru and Brazil with third party packers. The organization has expanded its operations from labels to include lidding films and bags.

Trends and drivers to adoption of smart packaging: Expert 6 defines smart packaging as a system employing QR codes to track the journey of a product from the production site to the

hands of consumers, “including all the way to the recycle bin if you really want to go that far”. According to him, QR codes facilitate tracing the origin, growth conditions, and unique product attributes, providing consumers with valuable information. The responsibility of integrating QR codes into packaging lies with the product manufacturers, not with the Packaging Manufacturer 2 as they only support the requirements defined by their clients. Consumers can access traceability information and unique features by scanning the QR code if interested. This interest is the driver to adoption that Expert 6 identifies as he considers that the most benefited stakeholder is the consumer rather than food producers. A second driver is the facilitation of marketing information to consumers regarding what is unique about the product. However, he observes a decline in the use of QR codes for smart packaging. Economic challenges modifying consumer priorities and the impact of the pandemic have led to decreased interest in traceability information. For Expert 6, despite the packaging image, labels are not negatively perceived due to the need for basic information to be communicated to consumers. Additionally, it was mentioned that the company is researching about software linked to the IoT to measure and improve production efficiencies, to reduce waste levels, and to set ink reorder points based on production trends. Expert 6 considers that this is expected to keep going forward in the near future.

Link between IoT and smart packaging: For Expert 6, the integration of neuro-linked fridges and other devices with smart packaging was once envisioned as a way to streamline the entire supply chain process. However, the practical implementation of such integration has not materialized as expected leaving the industry questioning its feasibility. In his words, “the QR code has never really taken off and that is really the key for everything to integrate that has just not happened”. RFID tags were briefly mentioned as a technology used by some clients, but it is

Expert 6's opinion that their usage has also seen a decline and is not as prevalent as initially expected.

Sustainability and Innovation within Packaging Manufacturer 2: The potential of smart packaging to impact sustainability by reducing food waste and carbon footprint was acknowledged. However, consumer demand for such features fluctuates with economic conditions, limiting its adoption. Expert 6 shared some of the ways they are following to address sustainability concerns. Packaging Manufacturer 2 is focused on R&D efforts, such as developing paper-based alternatives to plastic lidding films. Also, the label sector of the industry has developed the so-called flake technology. With this innovation, once the label is off the package, it can be recycled by a bath method of separating and raising it above the water. The clients of Packaging Manufacturer 2 have not shown interest in this technology either. Moreover, IoT technologies are also being explored for process efficiencies without success at the company. They have not reached the point to integrate everything as a smart packaging proposal.

Challenges in Adoption: Despite potential benefits, consumer interest in traceability and sustainability information through QR codes remains low leading to little motivation for producers to invest in these technologies. Expert 6 does not see an increased interest coming since "at this point, people are more concerned about interest rates than they are about where the origin of their food is". The additional cost, which is not significantly higher due to the nature of printing, is enough to discourage manufacturers to implement smart packaging. In a broader sense, it was mentioned that during economic downturns, the focus on sustainability and green initiatives tends to decrease as companies prioritize survival and cost-cutting measures.

Table 8 concentrates the main concepts provided by the experts.

Table 8- Summary of relevant concepts provided by the experts

	Producer	Packer & Distributor	Grocery Retailer	Packaging Manufacturer 1	Packaging Manufacturer 2
Use of Smart Packaging					
Smart packaging in the company	•Intelligent: Temperature tracking at truck level •Active packaging: modified atmosphere (CO2 and other gases) •Connected packaging: QR codes for recipes and marketing information	•Intelligent packaging: temperature and humidity tracking at truck level •Connected packaging: QR codes for recipes and marketing information	•Connected packaging: QR codes for product codes, expiry dates, and additional marketing information	•Intelligent packaging: exploring various color indicators •Active packaging: modified atmosphere, oxygen scavengers, •Connected packaging: QR codes	•Connected packaging: QR codes
Intensity of use	•Low use	•Low use	•Low use	•Low use	•Use in decline
Use of Internet of Things					
	•QR accessed information only	•QR accessed information only	•QR accessed information only	•Not used in the company developed solutions •Useful to track products in real time up to the recycling stage •Researching to integrate blockchain technology	•Integration of IoT and smart packaging with other devices (e.g. fridges) was a promise that did not fully materialize •Oriented to increase efficiency in the manufacturing process of their own products •RFID tags show the same negative trend
Smart Packaging sensors connected to the Internet of Things					
	•No real-time connection for intelligent and active packaging	•No real-time connection for intelligent packaging	•Not implemented at the company	•Not currently developed. •Blockchain technology is the closest approach	•Not developed as a product offered by the company
Initiator / requestor					

	Producer	Packer & Distributor	Grocery Retailer	Packaging Manufacturer 1	Packaging Manufacturer 2
	•Regulated marketing agency or end customer (retailer)	•Customer demand •Retailer	•Consumers	•Their customer, a food processor or packer •The customer defines requirements and expectations and the Packaging Manufacturer 1 develops solutions	•Consumers •Customers of the company
Drivers to adoption					
Consumer requirements				•Consumer demand for high quality, fresh, and safe food products	•Consumer interest in additional information about origin and growth conditions
Food quality monitoring and preservation		•Quality control optimization •Product integrity verification •Assurance of product quality	•Real-time condition monitoring	•Preservation of appealing characteristics for customer acceptance	
Food waste reduction		•Food waste reduction •Shelf-life enhancement	•Food waste reduction	•Food waste reduction •Cost savings by reduction of spoilage	
Improved efficiency	•FSC efficiency through tracking and tracing	•FSC efficiency		•Improved SC efficiency	
Information availability		•Information availability	•Information availability (expiry dates and marketing)		•Marketing information about unique attributes of product
Improved logistical operations	•Disputes solution when product is rejected •Information availability of delivery conditions	•Potential issues identification and liability determination •Avoidance of rejected shipments			

		Producer	Packer & Distributor	Grocery Retailer	Packaging Manufacturer 1	Packaging Manufacturer 2
	Regulations compliance				•Governmental regulatory requirements •Stringent food safety standards	
	Better tracking and Tracing		•Tracking of product •Recalls support through enhanced traceability	•Improved traceability	•Traceability and transparency	
Barriers to adoption						
	Lack of perceived value	•Disconnection between consumer requirements and implemented solutions •Consumers do not want to pay more	•Consumers do not want to pay a premium for added functionalities •Lack of consumer education and awareness of the benefits	•Only a section of the market is interested in this technology •and want to pay more for the product •Most of the consumers do not want to pay more	•Customers are not willing to pay for smart packaging features •Negative perception of plastic •Lack of consumer education about benefits of plastic and smart packaging	•Consumers are not interested in the additional information shared through QR codes
	High cost	•High cost pushed onto farmers •Second biggest after labor	•Active Packaging: High upfront cost to integrate technology into packaging (5 to 10 times more expensive) •Connected Packaging: No significative cost difference for connected packaging	•High cost due to nascent technologies •High initial investment	•High initial investment	•Cost is not substantially different to traditional labeling •Challenging economic conditions shift the consumers priorities

		Producer	Packer & Distributor	Grocery Retailer	Packaging Manufacturer 1	Packaging Manufacturer 2
	Low Demand		•Low demand for this technology due to lack of perceived value	•No demand if not requested by consumers		•The Covid pandemic has reduced the interest in traceability information •Low demand not motivating investments in IoT-enhanced Smart Packaging
	Poor FSC integration		•Lack of communication and synchronization of FSC			
	Changing Regulations		•Varying legal regulations complicate adoption			
	Lack of technical skills	•Skills for implementation not available at small producers/shippers				
	Technological uncertainties	•Technology availability	•Discrepant manufacturing requirements	•Lack of compatibility with current infrastructure •Connectivity and network availability •Systems integration (ERP, WMS, etc.)	•Lack of infrastructure for production and recycling	
FSC Integration						

	Producer	Packer & Distributor	Grocery Retailer	Packaging Manufacturer 1	Packaging Manufacturer 2
	•Disparity, many farmers - few main customer companies •Fair distribution of costs and benefits is required	•Lack of integration hinders the adoption •Goals must be aligned •Cohesive strategies to benefit full FSC	•Upstream reaction to requirements •Added value and cost for each entity must be balanced •Current integration level would not be improved	•Extend integration of the FSC to include recycling companies and include circularity •Upstream integration must be reinforced to better define requirements	
Company size effect					
	•Large companies with vertical integration can implement IoT-enhanced Smart Packaging	•Large companies influence packaging requirements		•Large corporates drive packaging innovation though investments in R&D	
Development of competitive advantages					
	•Possible •Reflected in the reduction of food waste	•No concerned •What others do is not forcing the company to do the same	•Competitiveness based on the business model not on technology		
Impact on brand image					
	•Neutral as products are not commercialized under the Producer's brand		•Marketing advantages		•Labels do not affect negatively brand image •Information about unique attributes supports image improvement
Influence of Government					
	•High impact of regulation •Must sell through regulated marketing agencies	•Educate general population to promote sustainable options •Create market for recycled products	•Regulation compliance is not an issue as they currently comply •Simplification of the task and alignment with other goals would benefit the adoption	•Must participate educating consumers •Share proper comments on benefits of plastic as a packaging material	

	Producer	Packer & Distributor	Grocery Retailer	Packaging Manufacturer 1	Packaging Manufacturer 2
Impact on Sustainability					
	•Positive impact on non efficient stages of the FSC (traditional farming and retailing) •Reduction of greenhouse gas emissions	•Positive impact but not through packaging initiatives only	•Potential for waste, spoilage, and carbon footprint reduction •More sustainable packaging material would alleviate the final disposal	•Food residues can compromise the quality of recycled materials •Reduction of transportation footprint •Use of higher barrier materials, bio-degradable bio-renewable elements fosters the sustainability results	•Tracing can be extended up to the recycle bin •Potential to reduce carbon footprint Trying to collaborate with other environment-friendly initiatives
Food Waste Reduction					
	•Support of food waste reduction	•Possible, but not only by availability of information •FSC practices, consumer behaviour, and other systemic issues must be considered	•Potential for food waste reduction	•Effective reduction of food waste •and the minimization of greenhouse gas emissions	•Potential to reduce food waste

Chapter 5 - Discussion

As an innovative technology, the adoption of IoT-enhanced Smart Packaging in the FSC is influenced by multiple variables. This study has explored the barriers and drivers and other aspects surrounding the current situation in the food industry. The FSC has been represented by at least one expert for each of the main blocks up to the retailing point, with a couple of companies representing the packaging manufacturing sector. By delving into these insights, stakeholders can gain a deeper understanding of how smart packaging alone or integrated with the IoT can enhance the FSC and drive positive change.

5.1- Use of Smart Packaging, Internet of Things, and its combination.

As expected for a novel technology combination, expertise availability was limited, complicating the identification of prospects and their participation. The situation is no different for companies; the three food industry companies participating in the study exhibit low usage of smart packaging, with connected packaging present in all of them. Intelligent packaging is used only at the truck level, which implies that conditions tracking and other functionalities are not covering the shelves and the initial stages of the FSC. Active packaging has an even more limited presence, only at the producer level. The integration with IoT is applied only at a basic information sharing level through QR codes, while the other implemented smart packaging devices are not connected, thus online availability has not been unlocked. The consequence of not utilizing IoT is the exclusion of opportunities like the mentioned dynamic routing and warehousing functionalities. One of the packaging manufacturers exclusively focuses on QR codes, while the other encompasses more types but is not leading the development; it mainly reacts to customer demands. Although all experts recognize the potential of IoT and smart

packaging integration, most of them acknowledge that its realization lies in the future. Notably, one expert mentioned that this technology is in decline and his company doesn't heavily focus on it. This highlights a lack of consensus in the industry regarding trend identification and interpretation, as others perceive new QR code applications, such as supporting enhanced interaction through augmented reality (Fernandez et al., 2022).

5.2- Drivers to adoption

Despite the expected benefits focused on food waste reduction and increased efficiency, the starter of the adoption process is not on the producers and processors side. The FSC companies viewed the initiator on the downstream side. The Producer pointed out the marketing agencies and retailers, the Packager & Distributor, the customer and retailers, and the Retailer signaled the consumers. The Packaging Manufacturers opted for their customers and the final food consumer. In short, the motivators for each end are different, the upstream companies (growers and processors) try to ensure product quality, avoid rejected shipments, enhance shelf life, and reduce food waste, while the downstream section (grocers and consumers) value information to improve their operations and decisions.

Although none of the drivers identified in the responses was mentioned by all the experts, there is a consensus in the overall perception. Only regulations compliance was also considered as a barrier, but as different aspects of it are included on each side, it is kept on both for further validation.

The drivers below and in Table 8 are arranged in alphabetical order since their relative relevance was not tested.

A) **Consumer requirements.** Consumers request high-quality, fresh, and safe products, and are interested in information about what they are buying.

B) **Food quality monitoring and preservation.** FSC players value quality control optimization, integrity verification, and real time monitoring of food conditions to preserve conditions that match consumer preferences.

C) **Food waste reduction.** This is recognized as a source of savings and reduction of negative impact on sustainability.

D) **Improved efficiency.** Reached mainly through enhanced tracking and tracing and reflected in several processes.

E) **Information availability.** Details of different parts of the shared supply chain process and product-related data useful for consumers.

F) **Improved logistical operations.** This is centered on the reduction of rejected shipments, conditions at delivery, and liability determination.

G) **Regulations compliance.** In general, the need to comply requirements and the stringent food standards requires technology for better solutions.

H) **Better tracking and tracing.** Improved traceability and transparency for the full process, as well as the possibility to track products and support recalls reducing negative impacts.

5.3- Barriers to adoption

A) **Lack of perceived value.** Unanimity was reached regarding the lack of will of consumers to pay for IoT-enhanced Smart Packaging features but it seems linked to poor

awareness of its benefits. The need for education was constantly mentioned. In this sense, there should be initiatives aimed at educating consumers about the advantages of smart packaging. Raising awareness among consumers can drive demand for smart packaging features and encourage manufacturers to invest in these technologies.

B) **High cost.** High cost is another constant on the barriers' side. There are two elements, the initial investment for infrastructure and the unit cost for packaging. The required investment for the related projects is an element that must be deeply evaluated because the cost of smart packaging sensors is still high (Ghaani et al., 2016) as well as the implementation of IoT networks (Brous et al., 2020). For connected packaging there is not significant difference, but for active packaging the increase is huge. Some experts expect a cost decline in the future as the technology mature and the demand increases.

C) **Low demand of IoT-Enhanced Smart Packaging.** Low demand is the consequence of lack of perceived value and no interest in additional information, with the influence of economic conditions creating fluctuations.

D) **Poor FSC integration.** Poor communication and synchronization withing the FSC block the adoption of this technology.

E) **Changing regulations.** The negative effect of regulations is generated by the common modifications and updates applied to them.

F) **Lack of technical skills.** Some small companies such as producers and shippers do not have the required skill for implementation.

G) **Technological uncertainties.** Availability of technology to ensure continuous supply and the different manufacturing processes are considered as risks that could increase the cost. Additionally, compatibility of infrastructure and systems is not assured.

5.4- Development of competitive advantages and Supply Chain Innovation

There is no homogeneity in opinions regarding the creation of competitive advantages. For some companies, the adoption of IoT-enhanced Smart Packaging could generate competitive advantages, while for others it is not a concern as they base their strengths on different aspects. The establishment of competitive capabilities seems not solely linked to the adoption of innovative technology within the selected sample. Additionally, the strategies of other companies are not taken into account when defining action paths, at least within this segment of the organizations. The leadership in supply chain innovation is not clearly defined; for instance, the Producer responds to requirements and trends, the Packer & Distributor maintains communication with retailers but does not initiate the innovation process, the Grocery Retailer is restricted by tight margins, and Packaging Manufacturers propose suggestions and engage in R&D projects, however the final adoption decision does not rest solely with them.

5.5- Impact on brand image

In terms of brand image, the Producer's brand is not displayed on the sales floor, resulting in decreased interest. The Grocery Retailer identifies marketing advantages that favor the preferred brand. Some experts acknowledged concerns about the overall packaging image but also recognized the positive facets of its inherent marketing functions. The adoption of IoT-enhanced Smart Packaging could gain from tailored strategies aimed at emphasizing the environmental benefits, thus guiding consumer perception (Lydekaityte & Tambo, 2020).

Strategies centered on information about the eco-friendliness of packaging materials and the overall impact on reducing waste could be included in marketing and labeling strategies.

5.6- Impact on Sustainability

By minimizing food waste, enhancing supply chain efficiency, and promoting better recycling practices, IoT-enhanced Smart Packaging is expected to contribute to improve the sustainability aspect of the food industry. To fully unlock the potential of sustainability, all the involved variables must be addressed collectively. Consumer education emerged as a crucial piece of this puzzle, with a recognized responsibility of governments. Educating consumers about the positive impact of reducing food waste and enhancing sustainability can drive increased demand for these technologies. To maximize impact, attention should be directed towards the weakest links within the FSC that generate the highest waste volumes. The recycling stages, often ignored, must be integrated into the scope of the solution. Positive results are anticipated on the reduction of greenhouse gas emissions as well.

5.7- Food waste reduction

The potential to reduce food waste at all levels was mentioned by the experts. It is clear that this cannot be reached only through technology and information availability, other factors such as consumer behavior, supply chain practices, and consumer education play a significant role. It's important to note that during the interviews the experts did not explicitly reference the UN’s Sustainability Goals as a foundation for their policies aimed at reducing food waste.

5.8- Supply Chain Integration

The current level of integration does not favour the absorption of the studied technological innovation. Power imbalances between producers and customers, misalignment of

goals, not fairly shared costs and benefits, suboptimal communication, and some parties not properly included in the chain are considered as some of the non-solved issues. Cohesive strategies intended to benefit the full FSC are required to satisfy the needs of all the companies, meanwhile the supernormal gains promised by the Relational Theory (Azadegan, 2011) are not being created. To reach this objective, industry stakeholders should collaborate closely to align goals, share insights, and jointly develop solutions that cover the needs of the entire food supply chain.

5.9- The effect of company size

In concordance with Lin (2009), who proved that the firm size influences the adoption of technology, large companies were indicated by the interviewees as the adoption leaders, with three basic reasons identified. 1) They have more capabilities resulting from vertical integration. 2) They can influence the definition of packaging requirements and 3) they can create innovation trends through investments in R&D.

Chapter 6 - Conclusions

This integrated analysis of IoT-enhanced Smart Packaging adoption within the FSC provides comprehensive insights into the complex dynamics that drive and impede its implementation. Across various sectors of the FSC, perspectives of experts converge on both the potential benefits and the intricate challenges associated with this transformative technology.

Sustainability emerges as a potent driver, aligning with heightened consumer demands for environmentally conscious practices. Efficiency gains, improved traceability, and potential cost savings stand out as additional drivers that could reshape the FSC. However, the path to adoption poses multiple obstacles. The high initial costs of implementation, coupled with

technological difficulties and a negative perception of packaging come first. Regulatory concerns and standards ambiguity further contribute to the complexity of adoption decisions.

Notably, the study underlines the significance of collaborative efforts among stakeholders to overcome these barriers. A balanced evaluation of the value-added by smart packaging against its costs is crucial, especially within the segments of industry marked by slim profit margins like producers and grocers. Seamless integration, spanning from packaging manufacturers to end consumers and recycling facilities, requires collective commitment.

Governmental support and educational initiatives emerge as pivotal in driving sustainable packaging practices and enhancing consumer awareness. While the promise of this combined technology is evident, its fruition needs meticulous analysis of the economic, technological, and regulatory aspects. The findings emphasize the importance of research and collaboration, particularly given the lack of consensus on trends and motivators for each FSC stage. The fusion of sustainability, brand image, and supply chain complexities further shapes the adoption landscape. Large corporations, enjoying the benefits of vertical integration and R&D budgets, emerge as enablers of adoption. To fully capitalize on the potential of IoT-enhanced Smart Packaging, cohesive strategies must be devised to navigate the obstacles and foster synergies into the FSC. This study uncovers the significance of an integrated approach, involving various stakeholders, to accelerate the realization of IoT-enhanced Smart Packaging's promise within the FSC.

6.1- Limitations and Future Research

This exploratory study has several limitations that need to be acknowledged. Firstly, the sample size of interviewees may not fully represent the diversity of perspectives within the FSC.

The findings might be influenced by the specific backgrounds and experiences of the interviewed stakeholders. Additionally, the focus on North American companies, coupled with the reliance on qualitative data may limit the generalizability of the conclusions to other regions with different economic, cultural, and regulatory dynamics. Moreover, this study concentrates on current conditions without projecting long-term trends. Consequently, the rapidly evolving nature of technology and consumer preferences implies that the insights presented could become outdated as new developments emerge. Therefore, further research encompassing a larger and more diverse sample of stakeholders across different regions and industries is necessary to validate and extend the findings presented here.

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Appendices

Appendix 1 - Interview guiding questions.

Barriers and Drivers to adoption of IoT-Enhanced Smart Packaging in the Food Supply Chain

Semi-Structured Interview Guideline

This guideline is used to interview experts in Internet-of-Things-Enhanced Smart Packaging in the food and packaging industries. The interviewer will not provide this questionnaire to the interviewee for written response. Annotations must be done in this format and will not replace the audio/transcript recording. The ultimate intention is to know the drivers and barriers to adoption of this technology by food companies. The questions are oriented to get general information about the respondents and the companies they represent (Section 1), knowledge, opinions, and experience with IoT-enhanced Smart Packaging (Section 2), and insights about the future of this technology in the food supply chain (Section 3). The audio of this interview must be recorded to be transcribed and properly analyzed. All the information provided will be safely kept and managed. This physical copies of this format with notes must be destroyed once the thesis is published or by November 31, 2023, whichever happens first.

Interviewee's name: _____ Date & time: _____
Location: _____
Place: _____

Interviewer's name: _____

Section 1 – General information and introductions

Instructions.

- The interviewer must introduce himself and provide a brief explanation of the study.
- Ask the following guiding questions.
- Use the empty boxes under the guiding questions to take notes.

1- Could you please introduce yourself?

2- Please briefly describe what your company does and your experience and position there.

Section 2 – Considerations about IoT-Enhanced Smart Packaging and its adoption.

3- In your experience, what is Smart Packaging? What are its features?

4- What is the role of IoT in Smart Packaging?

5- Have you developed/implemented Smart Packaging? Why or why not? Are you aware of it?

6- If yes, please describe.

7- What are the drivers of Smart Packaging in your industry sector? And in the other sectors of the food industry (food processing, packaging, distribution, grocery retail)?

8- What are the benefits of Smart Packaging integrated with IoT?

9- What are the barriers and drivers to its implementation?

10- Would IoT-enhanced Smart Packaging increase the cost of products?

11- Would this combined technology have an impact on sustainability, e. g. reduce food waste?

Section 3 – Insights on the future of the IoT-Enhanced Smart Packaging

12- What is your vision about the future of this technology in the food industry and its supply chains?

Appendix 2 – Research Ethics and Compliance Approval

University of Manitoba | Research Ethics and Compliance

Human Ethics - Fort Garry
208-194 Dafoe Road
Winnipeg, MB R3T 2N2
T: 204 474 8872
humanethics@umanitoba.ca

PROTOCOL APPROVAL

Effective: July 18, 2023 Expiry: July 17, 2024

Principal Investigator:	Dax Yair Trejo Beltran
Advisor(s):	Paul Larson
Protocol Number:	HE2023-0127
Protocol Title:	*Barriers and Drivers to adoption of IoT-Enhanced Smart Packaging in the Food Supply Chain*

Natalie Riediger, Acting Chair, REB1

Research Ethics Board 1 has reviewed and approved the above research. The Human Ethics Office (HEO) is constituted and operates in accordance with the current *Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans*- TCPS 2 (2022).

This approval is subject to the following conditions:

i. Approval is granted for the research and purposes described in the protocol only.

ii. Any changes to the protocol or research materials must be approved by the HEO before implementation.

iii. Any deviations to the research or adverse events must be reported to the HEO immediately through an REB Event.

iv. This approval is valid for one year only. A Renewal Request must be submitted and approved prior to the above expiry date.

v. A Protocol Closure must be submitted to the HEO when the research is complete or if the research is terminated.

vi. The University of Manitoba may request to audit your research documentation to confirm compliance with this approved protocol, and with the UM *Ethics of Research Involving Humans*Ethics of Research Involving Humans policies and procedures.