POLITECNICO
MILANO 1863

SCUOLA DI INGEGNERIA INDUSTRIALE
E DELL'INFORMAZIONE

Communicative packaging for food waste reduction: barriers and drivers to the adoption along the agri-food supply chain

MASTER THESIS IN FOOD ENGINEERING

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Academic Year:	2020-2021

Abstract

The phenomenon of food waste has taken on great significance in recent years. According to a study conducted by the FAO in 2011, the amount of food wasted each year is about a third of the total amount produced, equal to about 1.3 billion tonnes, 80% of which is still consumable. It is in this context that the Research aims to find solutions to reduce surplus and wasted food along the supply chain. Communicative packaging plays a key role in terms of sustainability. Its communicative function enables food packaging to provide information about the product it contains, the packaging itself or its value chain, both to end consumers and to the actors in the food chain. The research focuses on the latter, investigating the point of view of actors developing and selling communicative packaging technologies, and of actors adopting them, from the post-harvest and processing stage to distribution. The work aims to identify the barriers to the adoption of communicative packaging technologies and the possible drivers that push for their diffusion. Through the systematisation of the scientific literature, it was possible to propose two conceptual frameworks, validated and refined thanks to the comparison with the results of a case study. The dialogue with different actors involved in the implementation of these innovations was necessary to refine the frameworks. The results of the Research can be used to understand what criticalities are encountered along the food supply chain during the adoption of communicative packaging, to understand what are the priorities to be addressed and to study ad hoc solutions to facilitate its diffusion.

Keywords: food waste, sustainability, supply chain, barriers, drivers, communicative packaging

Abstract in lingua italiana

Il fenomeno dello spreco alimentare ha assunto negli ultimi anni una grandissima rilevanza. Secondo uno studio condotto dalla FAO nel 2011, la quantità di cibo sprecata ogni anno è circa un terzo della quantità totale prodotta, pari a circa 1.3 miliardi di tonnellate, di cui l'80% è ancora consumabile.
In questo contesto si inserisce la Ricerca che, una volta identificato il problema della generazione delle eccedenze e degli sprechi alimentari lungo la filiera, si pone l'obiettivo di trovare delle soluzioni per contrastarlo. Il packaging parlante ha un ruolo chiave in termini di sostenibilità. La sua funzione comunicativa consente al packaging alimentare di fornire informazioni sul prodotto contenuto, sull'imballaggio stesso o sulla sua catena del valore, sia ai consumatori finali che agli attori della filiera agroalimentare. La Ricerca si focalizza proprio su questi ultimi, approfondendo il punto di vista di chi sviluppa e vende tecnologie di packaging parlante, e di chi le adotta, dallo stadio di post-raccolta e trasformazione, fino alla distribuzione. Il lavoro si pone l'obiettivo di identificare le barriere ostacolano l'adozione di tecnologie di packaging parlante ed i possibili drivers che ne consentirebbero la diffusione. Attraverso la sistematizzazione della letteratura scientifica è stato possibile proporre due framework concettuali, validati e rifiniti grazie al confronto con i risultati dello studio di caso sviluppato. Il dialogo con diverse figure professionali direttamente coinvolte nell'implementazione di queste innovazioni è stato necessario per approfondire l'esperienza diretta all'adozione di queste tecnologie. I risultati della Ricerca possono essere utilizzati per comprendere quali siano le criticità riscontrate lungo la filiera alimentare durante l'adozione di packaging parlante, capire quali siano le priorità da affrontare e studiare delle soluzioni ad hoc per facilitarne la diffusione.

Parole chiave: spreco alimentare, eccedenze, sostenibilità, supply chain, barriere, drivers, packaging parlante

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Executive summary of the thesis:

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1. Introduction

Food packaging is defined as a system "that serves the functions of containing and protecting the product, as well as providing convenience and communicating to the user" (Zepf, 2009). The present Research investigates food packaging technology and specifically its communication function and sustainability implications. In fact, the Thesis analyses the main communicative packaging technologies that can be used along the food supply chain to reduce surplus food and food waste generated at different stages of the supply chain (SC). According to a study conducted by FAO in 2011, the amount of food wasted each year is about a third of the total amount produced, equal to about 1.3 billion tonnes, 80% of which is still consumable. It is in this context that this Research wants to find solutions to reduce food waste. To prevent and reduce it, is not enough to understand how much food is wasted, but it is necessary to deeply investigate the problem: understanding the critical points for the generation of surplus food, which are the root causes that lead to its generation, and which are the currently adopted strategies that allow to prevent the transformation of surplus food into food waste (FAO, 2019). Communicative packaging has a key role in this perspective. It is defined by the Food Sustainability Observatory of Politecnico di Milano as a package able to make the product "talk". This means increasing, with respect to the traditional solutions, the quantity and the typology of information conveyed to the user. In fact, some of these systems make it possible to track all the movements made by the product at each stage of the SC and other ones allow the optimization of planning and inventory management, limiting food waste along the SC. The starting point for this analysis was a previous Research Thesis (Facchini, 2020) that led to the elaboration of a framework that put in correlation communicative packaging technologies with information conveyed. The only technologies selected for this Research are the ones able to convey the information categories relevant for our purpose of reduction of food waste along the SC. Relevant information comprehends both dynamic information, as instant status of food and variations of internal properties, and static information, as critical dates. The communicative packaging technologies selected were therefore chromogenic inks, sensors, barcodes and RFID. These technologies have already been developed for several years, but have not adequately spread, despite their known benefits. For this reason, this Thesis does not focus on the development of these technologies, but on their adoption along the agri-food supply chain. They are critical to reduce food waste, but they require significant effort within the single company and also in the interface with other SC actors. This Research investigates difficulties arising at this level, namely barriers to adoption and it aims also to find possible drivers to push their diffusion on a large scale.

2. Literature review

Literature analysis has been performed using Scopus as a literature research platform and consulting scientific journals of a selected list. In addition to academic literature also grey literature has been analyzed, and the search engine used was Google Search. To find the articles to be analyzed, a rigorous analysis of the journals was carried out, considering subject area, year and topics which has led to a list of 11 journals. Appropriate queries were chosen to better identify the problem and at the end of this process 14 articles were selected for the analysis. The literature review has been conducted with the aim of investigating the state-of-the-art of the scientific knowledge on the topic of communicative packaging technologies and its sustainability implications. The reduction and management of surplus food and food waste is one of the main challenges for achieving a sustainable ecosystem, as highlighted by the 12th Sustainable Development Goal introduced by United Nations. In greater detail, Target 12.3 aims to "*Halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses, by 2030*" (United Nations, 2015). For example, thanks to the correct use of packaging and thanks to the information that it could convey, it is possible to optimize all the stages in the supply chain in order to reduce any food losses along production and supply chain. In this Thesis, the analyzed communicative packaging technologies that can be implemented along the food supply chain and shared by all stages of the supply chain are the following:

- **Chromogenic inks:**
  They are used to characterize indicators by different features with respect to the variable they measure. The working principles of chromogenic inks are the spread of a dye along a path or the change of color due to chemical or biochemical reactions. The inks can reversibly undergo color change within a defined temperature range.

- **Sensors:**
  The working principle of this technology is made of three steps: to sense the physical or the chemical properties and convert them to an electric signal; to amplify, linearize and scale the signal; to convey the signal to users through an adapter, a simple mechanical connector or a wireless device.

- **Barcodes:**
  The barcode is a sequence of characters and numbers placed on products. The data stored in barcodes are read by an optical scanner and are sent to a central system. One-dimensional barcodes are ordinarily created as wide or narrow black vertical bars printed on white background and the distance between those bars is also either wide or narrow. Two-dimension barcodes are able to arrange spaces, dots and lines in an array or matrix, and Quick Response (QR codes) barcodes are able to store higher amount of data. They can be also integrated with chromogenic inks and sensors to become dynamic codes, i. e, they do not remain the same in time, but they communicate different information about the product status and related information.

- **RFID:**
  RFID (Radio Frequency Identification) technology uses electromagnetic field to monitor different parameters and can communicate the readings through a reader that emits radio frequency waves to capture the data stored on the chip with the use of antenna in the RFID.

According to the literature, the most advanced version of these technologies has not yet reached a mass market and the purpose of this Research is to understand which barriers prevent the adoption of these technologies and what can be the drivers to overcome them. The barriers that emerged from the literature concern different aspects. The economic-financial barrier related to costs was certainly found. It must be noticed that it is not only a matter of costs related to the purchase of these innovative technologies, but it is also a matter of costs related to adapting or changing current production processes after introducing these systems. Another factor to consider is the legislative and regulatory aspect. The lack of an adequate regulatory framework in the EU for intelligent packaging systems until 2004 hindered the diffusion of new packaging solutions into the market. Moreover, since these technologies need to be integrated along the supply chain and used by various actors, a great deal of collaborative effort is required from all stakeholders and there are many organizational issues to consider and a high degree of trust to be achieved. Then, literature has identified a cultural gap that needs to be filled. There is the strong need to educate stakeholders on the extra benefits arising from intelligent systems. Once understood the potential of these technologies, they can really spread on a large scale. The last part of the literature analysis focused on possible drivers to overcome adoption barriers previously identified. Drivers reported by the literature were the following:

- Regulatory support,
- R&D activities,
- Internal development,
- Collaboration and networking,
- Marketing and promotion.

3. Research gaps and RQs formulation

In literature review, most of the discarded articles concerned the barriers perceived by the final consumers rather than by the supply chain actors, and the number of publications that looked at the topic of smart packaging adoption by SC actors point of view was limited. In addition, it was difficult to find articles regarding obstacles associated to adopting communicative packaging. These issues led to the formulation of the first Research Question (RQ 1) which had the objective to bring a clear classification of the barriers to the adoption perceived by SC actors.
Another substantial gap emerged regarding the possible drivers to overcome adoption barriers. This lack of information led to the formulation of the second Research Question (RQ 2). The two research questions derived from the gaps are:

- **RQ 1**: *Which are the barriers to adoption of communicative packaging technologies perceived by the actors of the supply chain?*
- **RQ 2**: *Which are possible drivers to overcome barriers to adoption of communicative packaging technologies?*

4. Methodology

The methodology used to answer RQs included:

- the analysis and re-elaboration of academic and grey literature, which allowed to produce two conceptual frameworks;
- a multiple case study to adapt and refine frameworks.

To have a punctual picture of which SC actor perceives the barriers, literature findings have been schematized in a proper way: each barrier emerged has been referred to the actor who has to face it along the supply chain. Secondly, to have a punctual picture of barriers perceived with respect to the single technology adoption, barriers have been referred to the specific technology. After this, a prioritization of barriers, based on the mentions in the selected articles, has been done. Then, an empirical refinement of the frameworks through the development of a multiple case study was conducted, that allowed to validate and corroborate them. In this part, the data collection was conducted through semi-structured interviews. The type of case study in this thesis is explanatory, that means to study the reflection of hypothesis in real cases and make a contribution to theory. A sample of nine interviews of the duration of approximately one hour was held by video call between July and October 2021. The units of analysis were the SC actors: technology provider, manufacturer, and retailer, with the exclusion of final customer. It was possible to collect information from a sample of 4 companies for the technology provider stage, a sample of 3 companies for the manufacturer stage and 1 company for the retailer stage. All the interviews were recorded and transcribed to facilitate their analysis and coding process. Two coding were performed for each interview: one for the barriers to adoption and one for the drivers to overcome those barriers. To make a detailed analysis of how barriers are perceived by the actors, the coding process was repeated individually for each stage of the SC. After the coding process, for each supply chain stage, an analysis and comparison of the results with respect to the conceptual frameworks derived from literature has been performed.

5. Conceptual frameworks

The first step in the review of the academic and grey literature was to identify the macro-categories of barriers in the adoption of communicative packaging. A research on supply chain innovations made by Gupta (2020) has been taken as a starting point to distinguish between macro-category barriers: *technological/ environmental, economic, regulatory, cultural, organizational, and market barriers*, To deepen the topic of barriers, papers have been analyzed in detail and sub-categories barriers have been labelled by the Author of this Thesis, to accurately describe all the barriers that relate to each specific macro-category. Literature results have been re-elaborated in two conceptual frameworks. The two summary frameworks (see *table 1* and *table 2*) have been elaborated to comprehensively present all the barriers to adoption that emerged from the articles in academic and grey literature. Summarizing the literature review, the barriers were divided into six macro-categories and twelve sub-categories. The framework barrier-actor (*table 1*) has been elaborated to clearly identify the barriers perceived by the single SC actor distinguishing between offer and demand side. The framework barrier-technology (*table 2*) allowed to schematize the barriers perceived by the SC actors referring to the single technology they developed or adopted.

6. Empirical refinements: case study

6.1 Primary information

Interviews with companies permitted to corroborate literature results with information derived from the real world. Thanks to the analysis of the transcribed text of the interviews, it has been possible to extract additional information, indicating the relevance of the barriers to the adoption of communicative packaging along the SC, according to the experience of the actors directly involved. Thanks to the codes it has been possible to see which barriers were the most mentioned in the interviews and the interpretation of the coding enabled to compare the results of the case study with the results from the literature and to see similarities and differences, to see which barriers mentioned in the literature are confirmed, and whether new ones emerge. The relevance of barriers highlighted by the actors interviewed has a big importance with respect to literature results, because this enables to have a point of view on the main barriers to adoption perceived by the actors directly involved based on their experience, going beyond the boundaries of academic and grey literature. To make a detailed analysis of how barriers are perceived by the different supply chain actors, the process of coding interpretation was repeated individually for each SC stage, analyzing experience with the four selected technologies. Case study enabled also to deepen the topic of drivers to overcome adoption barriers. The coding process followed for drivers was slightly different to that one used for the barriers. Firstly, the six macro-categories of barriers derived from literature have been identified in the transcribed interviews. Then, it has been possible to go into detail about possible drivers to overcome them, using the five labels derived from literature as codes. The interpretation of coding process both for strategies and drivers has been conducted stage by stage.

6.2 Discussion of results

First Research Question (RQ1)

From the evidence derived from the case study, the structure of the conceptual frameworks proved to be adaptable also to the case study. In fact, the same barriers and drivers deriving highlighted have been mentioned by the interviewees, with the only addition of the barrier *Difficulty in interpreting information conveyed by technology*. The barriers perceived by respondents were ranked according to the number of times they were mentioned in interviews. Then, this ranking related to case study was compared literature. *Table 3* shows the final comparison of barriers between literature results and case study ones. From the table it can be easily seen for each barrier if there is convergence of literature and case study or not, and which are the novelty elements that emerged. For example, two of the three barriers in red, i.e. the most frequently mentioned in the case study, confirmed the degree of relevance obtained from the literature: *Lack of mass market and affordable prices* and *Lack of adequate regulation.* On the other hand, the other barrier that is perceived to be of high importance by the case study, i.e. *Lack of long-term profitability perspective,* is a novelty compared to the literature. In fact, according to the theoretical results, it was considered of low importance. Then, *inertia toward new technology adoption*, shows convergence between case studies and literature. Some differences in degree of relevance appear with the barriers *Lack of trust in sharing information with other actors along the SC* and *Lack of collaborative processes along the SC*: they have been identified both by literature and case study, but interviews gave a higher relevance with respect to literature results. Moreover, other organizational, technological and market barriers, were found to be of secondary importance for both literature and case studies. In fact, thanks to the discussion with SC experts, it was possible to understand how these barriers are easier to overcome and come after to the economic, regulatory and cultural issues. Companies stated that there are already collaboration solutions that can be implemented, but the main problem is their cost. Finally, the last consideration concerns barriers which have been rejected by the case study: *Lack of recyclability for some smart packaging components, Lack of proper R&D activities, protocols and standard tests,* and *Lack of Best Practices.* This may be due to the fact that the technologies under consideration are developing a lot in recent years and many technological problems are being solved fast. A special attention must be given to the barrier which derives from case study, and that was not identified by literature: *Difficulty in interpreting information conveyed by technology.* It stands for a novelty that must be considered a warning about underestimated barriers to adoption of communicative packaging technologies.

Second Research Question (RQ2)

The information of the different stages was aggregated to see in an overall way which are the most relevant drivers according to the interviewees point of view. The result is shown in *Table 4*, where the drivers derived from literature are presented with different colors, according to the relevance given by case study. In the "mentions" column it is possible to see how many times in interviews the single drives has been mentioned by the actors. Three of the five drivers present in the literature have been confirmed in the interviews: *Marketing and promotion, Regulatory support* and *Collaboration and networking,* while the other two have been rejected by the case study. According to the interviewees, there are many ways of doing *marketing and promotion*, such as digital promotion, events, trade press (articles in editorials dedicated to large-scale retail), projects with academic world and research centers to raise awareness and spread the benefits of sustainable innovations. Experts stated that the economic barrier can only be overcome if companies will look for a result that is not immediate. Thus, the mission is to make companies aware that the advantage is achieved in the long term and that it is worth investing in technological sustainable innovations because they enable advantages such as reduction of food waste and traceability of the whole chain. Moreover, *regulatory support* comprehends incentives for companies to launch innovative projects, to test new technologies with a view to sustainability and to understand the substantial benefits they can gain from using these systems. In addition, it is necessary a precise legislation aimed at reducing food waste, because it could quickly push companies to change their way of acting and make them all conform to certain set standards, so that sustainability goals are understood and shared by the whole community. In the end, according to the interviewees a driver to overcome adoption barriers is *collaboration and networking*, which means involving very influential institutes sensible on aspects such as technology, innovation and sustainability, and being able to start with the scientific community and institutions innovative projects. The collaboration with the scientific community is fundamental to share new ideas and to give them resonance in certain contexts.

7. Conclusions

The aim of the Research is to try to answer the RQs in the most exhaustive way possible. Starting from the academic level, the conceptual frameworks are a comprehensive systematization of literature. However, the innovative point of the Research stands on the parallel evaluation of the subject at the theoretical and managerial levels, considering either the state of the art of the topic and solutions currently on the market, developed or adopted by the interviewed companies. At a managerial level, the results of this Thesis could serve as an instrument to analyze and visualize emerging technological breakthrough related to the adoption of communicative packaging solutions. Specifically, the evidence of the main barriers perceived by the different stages of the supply chain, could provide help for managers and decision makers operating within the agri-food supply chain in identifying the critical steps to be met when adopting communicative packaging technologies, and understand how to face them, to finally pursue the reduction of food waste along the supply chain. Due to the novelty of the subject under analysis and the way in which the Research was conducted, some limitations emerged. As far as the methodology is concerned, the case study did not cover all stages of the supply chain, but only three, not considering post-harvest and logistic operators. This may be related to the low interest in this type of innovation. Moreover, the number of companies interviewed for each stage was different. The retailer stage was less present (one company), so the results coming from the first two stages have a higher value than the last stage because the sample was larger. This limitation related to the different sample size must be remembered, but in spite of this, it can be concluded that the results obtained can cover the supply chain in a preliminary way, identifying barriers and drivers shared by the actors in the different stages. In the end, given the lack of specific literature, results on drivers could be less robust than those related to barriers. These limitations can be considered as a point to continue the study of this main subject. As regards the qualitative research focused on investigating the barriers to adoption and possible drivers to overcome them, the results could be further validated and enriched through other case studies including the stages not analyzed in this work, namely post-harvest and logistic operator. Moreover, also an enrichment of the sample size for the three analyzed stages could give an added value to the research and lead to more detailed conclusions based on a larger sample of analyses.
As emerged in this Thesis, integrating innovative communicative packaging technologies along the supply chain implies investments for companies. In this perspective, it would be interesting to better understand what the real opportunities for a company in the implementation of such solutions are. There is currently a relatively small diffusion for these technologies, so more specific analyses, such as cost-benefit analysis, should be done to ensure that the actors in the agri-food supply chain could implement these technologies overcoming economic barriers. Finally, remembering that the objective of this research was to reduce surplus food and food waste generated along the food chain, i.e. up to the final retailers, it is possible to think that further research can be carried out to understand how actors at the most advanced stages of the SC, who had direct experience with these technologies and are aware of their potential, can encourage other stages to adopt them, communicating the benefits that could be gained.

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Table.1: Framework barrier-actor: adoption barriers faced by each SC actor (Source: Author's elaboration)

	SUB-CATEGORY BARRIERS	OFFER TECHNOLOGY PROVIDER	DEMAND SUPPLY CHAN
TECHNOLOGICAL AND ENVIRONMENTAL BARRIERS	Lack of proper R&D activities, protocols and standard tests	X	
	Lack of recyclability for some smart packaging components	X	X
ECONOMIC AND FINANCIAL BARRIERS	Lack of mass market and affordable prices	X	X
	Lack of long-term profitability perspective		X
REGULATORY BARRIER	Lack of adequate regulation	X	
CULTURAL BARRIER	Inertia toward new technology adoption		X
ORGANIZATIONAL BARRIERS	Lack of collaborative processes along the SC	X	X
	Lack of Best Practices in the market to follow		X
	Lack of solutions for security, privacy, and data ownership issues	X	X
	Lack of a data management system for decision-making/ difficulty in identifying responsibility along the SC		X
	Lack of trust in sharing information with other actors along the SC		X
MARKET BARRIERS	Lack of smart technology market-competitiveness		X

LEGEND	
X	barrier perceived by the corresponding SC actor

Table.2: Framework barrier-technology: barriers perceived to the adoption of the single technology (Source: Author's elaboration)

	SUB-CATEGORY BARRIERS	CHROMOGENIC INKS	SENSORS	RFID	BARCODES
TECHNOLOGICAL AND ENVIRONMENTAL BARRIERS	Lack of proper R&D activities, protocols and standard tests	X	X		
	Lack of recyclability for some smart packaging components		X	X	
ECONOMIC AND FINANCIAL BARRIERS	Lack of mass market and affordable prices	X	X	X	X
	Lack of long-term profitability perspective	X	X	X	X
REGULATORY BARRIER	Lack of adequate regulation	X	X	X	X
CULTURAL BARRIER	Inertia toward new technology adoption	X	X	X	X
ORGANIZATIONAL BARRIERS	Lack of collaborative processes along the SC	X	X	X	X
	Lack of Best Practices in the market to follow	X	X	X	X
	Lack of solutions for security, privacy, and data ownership issues	X	X	X	X
	Lack of a data management system for decision-making/ difficulty in identifying responsibility along the SC	X	X	X	X
	Lack of trust in sharing information with other actors along the SC	X	X	X	X
MARKET BARRIERS	Lack of smart technology market-competitiveness	X	X	X	X

LEGEND	
X	barrier referred to the corresponding technology

Table.3: Comparisons between literature and case study results (Source: Author's elaboration)

SUB-CATEGORY BARRIERS	MACRO-CATEGORY BARRIERS	CONVERGENCE WITH LITERATURE	NOVELTY
Lack of mass market and affordable prices	Economic/Financial	Confirmed	NO
Lack of long-term profitability perspective	Economic/Financial	Rejected	**YES**
Lack of adequate regulation	Regulatory	Confirmed	NO
Inertia toward new technology adoption	Cultural	Confirmed	NO
Lack of collaborative processes along the SC	Organizational	Partially confirmed	NO
Lack of trust in sharing information with other actors along the SC	Organizational	Partially confirmed	NO
Difficulty in interpreting information conveyed by technology	New from literature	New	**YES**
Lack of recyclability for some smart packaging components	Technological/Environmental	Rejected	**YES**
Lack of smart technology market-competitiveness	Market	Confirmed	NO
Lack of solutions for security, privacy, and data ownership issues	Organizational	Confirmed	NO
Difficulty in identifying responsibility along the SC	Organizational	Partially rejected	NO
Lack of proper R&D activities, protocols and standard tests	Technological/Environmental	Rejected	**YES**
Lack of Best Practices in the market to follow	Organizational	Rejected	**YES**

LEGEND	
(red)	mentioned 7-10 times in interviews
(orange)	mentioned 4 times in interviews
(yellow)	mentioned 2-3 times in interviews
(light yellow)	mentioned 1 time in interviews
(white)	not mentioned in interviews

Table 4: Ranking of barriers according to case study findings (Source: Author's elaboration)

RELEVANCE	mentions
Marketing and promotion	5
Regulatory support	4
Collaboration and networking	2
Internal development	0
R&D activities	0

LEGEND	
(dark green)	mentioned 4-5 times in interviews
(light green)	mentioned 2 times in interviews
(white)	not mentioned in interviews

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List of acronyms

BB: Best Before

FLW: Food Loss and Waste

FWH: Food Waste Hierarchy

ID: Identification

LCA: Life Cycle Assessment

NFC: Near Field Communication

P&L: Profit and Loss

QR: Quick Response

R&D: Research and Development

RFID: Radio Frequency Identification

RSS: Reduced Space Symbology

SC: Supply Chain

SDGs: Sustainable Development Goals

TBL: Triple Bottom Line

TTIs: Time-Temperature Indicators

1. Introduction

Nowadays packaging has become a product itself. After starting out as a protective skin for food, it has turned into an interface for communication between producers and users. It captures the attention, and its visual elements appeal to consumers and sometimes re-direct to online content. Internet is omnipresent and some producers make use of this interface to continue the dialogue with users, especially in the case of small packaging without much room for visual or textual content. This is the best way to save space on the packaging without sacrificing the large amount of information that is required by the market. Moreover, this argument can also be extended to the supply chain level. In fact, there is an increasing use of the so-called "communicative packaging" to convey a great amount of information. Communicative packaging can be defined as a package able to make the product "talk". This means increasing, with respect to the traditional solutions, the quantity and the typology of information conveyed to the user thanks to the adoption of different technologies (Osservatorio Food Sustainability, 2019).

Packaging market is continuously evolving. In 2019 the global food packaging market was estimated to have a value of 303.26 B$, with an expected compound annual growth rate (CAGR) of 5.2% in the forecast period (Grand View Research, 2020). In this perspective, R&D arises as a basic department to guarantee organisations prosperity and progress. Innovation in food packaging is led by specific drivers mainly related to fast-changing social trends (Robertson, 2013): increase demand for convenience, claim for safety and need of extended awareness about the product and the environmental implications. The environment is becoming an increasingly important factor, but not the only one to consider when we deal with sustainability. To have a definition of sustainability, it is necessary to consider not only the environmental sphere, but also the social and economic spheres. In September 2015, 193 international leaders met at the United Nations to contribute to global development, to promote human well-being and protect the environment. The community approved the 2030 Agenda for Sustainable Development, the essential elements of which are the 17 Sustainable Development Goals (SDGs) and 169 sub-goals, which aim to end poverty, combat inequality and achieve social and economic development. (United Nations, 2015). Setting common goals encourages everyone - governments, companies, research centres and society as a whole - to act globally to achieve them by gathering and deploying a wide variety of strengths, knowledge and resources. This makes it possible to build alliances that are committed to for more prosperous, more just and more equitable societies. Below is reported a summary of the 17 Sustainable Development Goals (*figure 1.1*).

Figure 1.1:17 Sustainable Development Goals (Source: United Nations)

Sustainability objectives apply to all sector, but in this Thesis, dealing with food packaging, we will focus on sustainability only in the agri-food sector. A sustainable food system is a food system that delivers food security and nutrition for all, in such a way that the economic, social and environmental bases to generate food security and nutrition for future generations are not compromised (Ciccullo, 2020). This means that:

- it is profitable (economic sustainability);
- it has broad-based benefits for society (social sustainability);
- it has a positive or neutral impact on the natural environment (environmental sustainability).

In order to be sustainable, the development of the food system needs to generate positive value along three dimensions simultaneously: economic, social and environmental (FAO 2014). Any proposed measures to take advantage of a new opportunity (e.g. a new green technology or profitable market), will have to be assessed against all other dimensions of sustainability to ensure there are no undesirable impacts. (Ciccullo, 2020)

Food packaging, from this point of view, has a key role for sustainability. It is defined as a system "that serves the functions of containing and protecting the product, as well providing convenience and communicating to the user" (Zepf, 2009). Therefore, a good protection of the food contained in the packaging is important to avoid any food waste generation, so it is sustainable both from an environmental, economical and social point of view. Also communication is an enabling factor for achieving SDGs, for example the goal number 12 "*Responsible production and consumption",* because, thanks to the information conveyed by the packaging, it is possible to raise awareness among users and push responsible production and consumption. Another goal achievable thanks to the communicative function of packaging is SDG number 8 "*Decent work and economic growth*". This is because promoting, on the packaging, food origin, from local farming or disadvantaged communities, could have important implication in consumers' social responsibility attitude and ethical behaviour, increasing their willingness to pay for a specific product. Consumers become aware of the product origin and promote disadvantaged communities' development. This means, from a wider point of view, job creation and enlargement, work empowerment, health, gender quality and education. However, the most relevant goal concerning the use of food packaging is number 12. Specifically three targets are those that can be addressed: 12.3, 12.5 and 12.8.

- **Goal 12: *Responsible production and consumption***,

  Target 12.3: "By 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses"

  Target 12.5: "By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse."

  Target 12.8: By 2030, ensure that people everywhere have the relevant information and awareness for sustainable development and lifestyles in harmony with nature".

Target 12.3 indicates how, thanks to the correct use of packaging and thanks to the information that it could convey, it is possible to optimize all the stages in order to reduce any food losses along production and supply chains, including post-harvest.

Target 12.5 shows how packaging can be used to pursue some strategies of surplus food valorisation such as recycling and reuse, so that waste generation reduces.

In the end, target 12.8 refers to the ability of packaging to convey precious information to users. In this way it has a key role to raise awareness among costumers for sustainable development and lifestyles in harmony with the environment.

1.1 Communicative packaging technologies

This Master Thesis was conducted in collaboration with the *Food Sustainability Observatory*, a Research group of the School of Management of Politecnico di Milano launched in 2017. The goal of the group is to study the role of innovation and circular economy to achieve sustainability in the agri-food sector, to facilitate the transition towards more sustainable supply chain systems. The Observatory wants to give a concrete contribution to the sustainable transformation of the agri-food system through research, awareness and dissemination activities, which focus on the role of sustainable innovation. In the context of Research 2020-2021, the Observatory aims at mapping and in-depth analysis of innovative practices and business models for sustainability in the agri-food system. Regard to the circular economy, the Observatory seeks innovative practices and solutions for the prevention and management of surplus food to reduce any kind of food waste. It studies the enabling factors and barriers to the implementation of new practices, considering organizational structures and responsibilities involved. In addition, research is carried out on new materials for food contact and more sustainable food packaging. Particular importance is given to the field of packaging, because it has a big potential to food waste reduction. The Observatory defines the correlation between food packaging and food waste and studies the main thematic areas involved, which are packaging design, logistic and new technologies. Specifically, the Research group studies innovative technologies supporting food packaging to reduce food waste.

This Thesis is included in this field of Research. Specifically, it is focused on the main technologies of communicative packaging that can be adopted by different actors along the supply chain with the particular purpose to avoid the generation of surplus food and food waste along the supply chain. The main objective of the Research is to deeply understand which are barriers to the adoption of these technological solutions by the actors of the supply chain and which are possible drivers to push their diffusion on large scale. Even if communicative packaging technologies presented in this Thesis have been developed for several years, they have not adequately spread, despite their known benefits. For this reason, this Thesis does not focus on the development of these technologies, but on their adoption along the agri-food supply chain. Communicative packaging technologies are critical to reduce food waste generated along the SC, but they require significant effort within the single company and also in the interface with other SC stages. This Research investigates difficulties arising at this level, namely barriers to adoption, and it aims also to find possible drivers to facilitate their diffusion on a large scale.

As previously mentioned, communicative packaging is defined by the Observatory as a package able to make the product "talk". This means increasing, with respect to the traditional solutions, the quantity and the typology of information conveyed to the user thanks to the adoption of different technologies. Through the adoption of these packaging technologies, it is possible to control the environment in which the product is placed, to receive a guarantee on the origin of the food and on the state of the product, as it can be monitored along all the stages of the supply chain, guaranteeing the quality expected by the final user. Also from the environmental point of view, communicative packaging has many advantages. Through the adoption of these technologies, it is possible to minimize the environmental impact of the use of resources and limit the waste of the food contained in it. Moreover, it is possible to have a responsible management of the end of life and it is possible to start collaborative activities among the SC actors. In fact, some of these systems make it possible to track all the movements made by the product at each stage of the supply chain. Other ones allow the optimization of planning and inventory management based on the data provided, improving the processes of ordering, replenishment and return and limiting food waste along the supply chain. Finally, these technological solutions also have a social value. They allow to achieve a better accessibility to product information by making the labels more readable and interpretable and it is possible to achieve greater transparency on the origins of the product.

The starting point for this analysis was the Research conducted by Facchini in collaboration with the Food Sustainability Observatory in 2020, which was focalised on communicative function of food packaging solutions (Facchini, 2020). The Research led to the elaboration of a framework (*figure 1.2*) that put in correlation communicative packaging technologies with information conveyed. Each solution analysed aims to communicate specific information to the user. The range of information transmitted and gathered is wide. Some examples are the nutritional values, the real time status of the food product, the article lot number and its origin or how the food has been conserved along the value chain. The complete list of technologies identified by Facchini in her Research Thesis and the correspondent information categories are reported in *figure 1.2*.

That Thesis not only analysed literature, but also included a case study to see if what emerged from literature had a confirmation in reality. From *figure 1.2* it can be seen with letter "L" the information category related to each packaging solution which were found in literature. On the other hand, with color orange, it can be seen the information category related to each packaging solution, confirmed by the case study.

However, the current Research takes it a step further and, starting from the list of technologies analysed by Facchini, a narrow selection of communicative packaging technologies was done. According to the objective of this Research Thesis, which is to identify packaging technologies which can be adopted along the supply chain by all the different actors to reduce surplus food and food waste, only some technologies have been kept.

Specifically, technologies which convey dynamic information categories about the about the package system itself and about the food product contained inside have been selected.

				PACKAGING TECHNOLOGIES									
				Technologies that directly show the info to the user					Technologies that need a reader to convey the info				
				Chromogenic ink	Printed infographic	CMF packaging design	Embossed debossed material	Packaging shape	Barcode	RFID	NFC	Sensors	Tracers watermarks
INFORMATION CATEGORIES	STATIC	Food	Nutritional Content		L				L	L			
			Conservation Instructions		L				L	L			
			Cooking Instructions		L				L	L			
			Organoleptic Properties		L	L		L	L	L			
			Food Composition and Allergens		L		L		L	L			
			Critical Dates		L		L		L	L			
			Healthy Habits Suggestions		L				L	L			
			Social and Environmental Impact		L	L	L		L	L			
			Supply Chain		L	L	L	L	L	L	L		
		Packaging	Material Composition		L	L	L		L	L			
			Disposal Instructions		L	L			L	L			
			Convenience Features		L				L	L			
			Social and Environmental impact		L	L			L	L			
	DYNAMIC	Food	Nutritional Content Variation									L	
			Organoleptic Properties Variation	L								L	
			Realtime Cooking Instructions	L								L	
			Instant Status of the Product	L					L			L	
			Presence of Toxic Substances									L	
			Food Conservation along the Supply Chain	L						L	L	L	
		Packaging	Material Maintenance along the Supply Chain									L	
			Interior Conditions Variation	L						L		L	
		Supply Chain	Article ID		L				L	L	L		

LEGEND
- **L:** in literature the technology reported on the x-axis convey the information reported on the y-axis
- **orange**: commercialized technology reported on the x-axis convey the information reported on the y-axis

Figure 1.2: Technology-information matrix (Source: S. Facchini, 2020)

Referring to the analysis of Facchini, the dynamic information categories, relevant for our purpose are:

- *Material maintenance along the supply chain*
- *Interior conditions variation*
- *Nutritional content variation*
- *Organoleptic properties variation*
- *Instant status of the food*
- *Presence of toxic substances*
- *Food conservation along the supply chain*

All this information is dynamic because they regard something that can change over time. Therefore, the selected technologies are those able to monitor the change in the state of the product over time, in order to identify early the weak point of the supply chain where the problem occurred, going to act on the root cause to optimize the supply chain by decreasing any future surplus food waste.

These technologies are the ones able to detect, sense, record, track, and communicate to help make decisions, extend shelf life, increase safety, improve quality, and warn of possible problems. (Yam, et al., 2005). In addition to the dynamic information the only one static information relevant with a view to reducing waste along the supply chain, regards *critical dates*. This information is relevant not only for final customers, but also for supply chain actors, to properly manage stocks and minimize food waste generation. In fact, knowing the expiry date enables the correct managing of food products by all the actors in the different phases of the supply chain. All these information categories will be detailed next, in section 2.2.2. Starting from the framework elaborated by Facchini and looking only at the information categories previously mentioned, every technological solution that showed a correspondence between what emerged from literature and case study has been selected. Technologies useful to final customer, rather than SC actors, such as packaging design and embossed debossed material have been excluded. The resulting list of technologies, which convey the information categories relevant for the purpose of reduction of food waste along the SC is the following. All these technologies will be described in detail in section 2.3.1.

- **Chromogenic inks**
- **Barcodes**
- **RFID**
- **Sensors**

2. Literature review

This chapter aims to present the subject of food packaging and to introduce technologies of communicative packaging from a literary point of view. The first section contains the methodology followed for the literature review on Scopus and specialized websites. Then results from literature analysis have been reported.

In section 2.2 there is a presentation of food packaging and its several functions: containment, protection, preservation, convenience and communication.

Then, in section 2.3 there is a focus on technologies of communicative packaging that can be adopted along the supply chain by all the different actors in order to reduce surplus food and food waste.

In section 2.4 the topic of sustainability in agri-food sector has been deeply discussed to give a full overview on causes of generation of surplus food and the important role of food packaging to minimize food waste.

Moreover, the main objective of this literature research was to analyse, from an academic point of view, the main barriers to the adoption of a specific group of communicative packaging technologies, in particular those packaging solutions that can also be defined as "smart" or "intelligent", because they are able to monitor the current status of the food, increase safety and quality and warn of possible problems found inside the package. In section 2.5 barriers to adoption emerged from literature have been discussed.

In conclusion, in section 2.6 possible drivers to overcome adoption barriers have been reported.

What emerged from literature analysis is that the big advantages of intelligent packaging, with respect to traditional packaging, enable to have a high control on food along the supply chain, to identify causes of problems and to take proper actions in order to optimize supply chain management and minimize any kind of waste. In the following sections the state of the art of the academic research in food packaging field is reviewed, underlining how this technological breakthrough, occurred in the food sector, will represent a significant turning point for the market.

2.1 Literature review methodology

Once selected the main communicative packaging solutions from Facchini Thesis, a step forward has been taken. This Research in fact aims to understand which are the main barriers to adoption of these technologies from the point of view of the different players in the food supply chain: post-harvest, manufacturers, logistic operators and retailers on the demand side and technology providers on the offer side (*figure 2.1*). Each of them may have different needs and challenges to face, but all of them must pursue the same objective: decrease surplus food generation and minimize food waste along the agri-food supply chain.

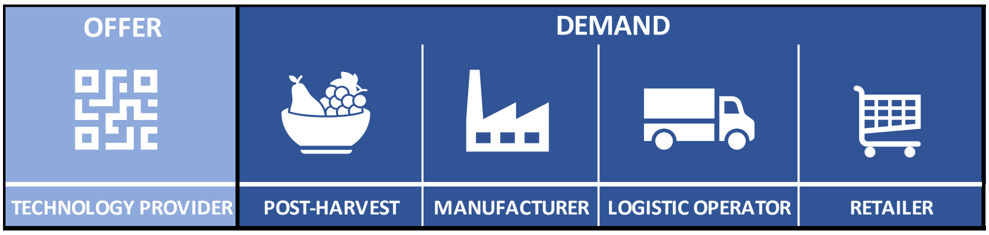

Figure 2.1:Actors in the supply chain (Source: Author's elaboration)

To have a broader understanding of this issue a literature review has been performed. The literature review has been focalized on the communicative packaging technologies previously mentioned, but also on the sustainability implications in terms of prevention of food waste and re-distribution of surplus food.

Then, the literature review has expanded to include the topics of barriers and obstacles to the adoption by supply chain actors and possible strategies to overcome these hurdles. The search has been conducted mainly in Scopus focusing on specific keywords and limiting the publication dates to a time range from 2012 to 2021. Moreover, to refine the search, subject area and journals have been properly selected following a snowball approach. Specifically, a generic search with keywords related to communicative packaging has been performed (see the first box of *figure 2.2*). Then, only the journals with at least 3 articles have been kept, in order to select only the journals most focused on our research topic of communicative packaging in food industry.

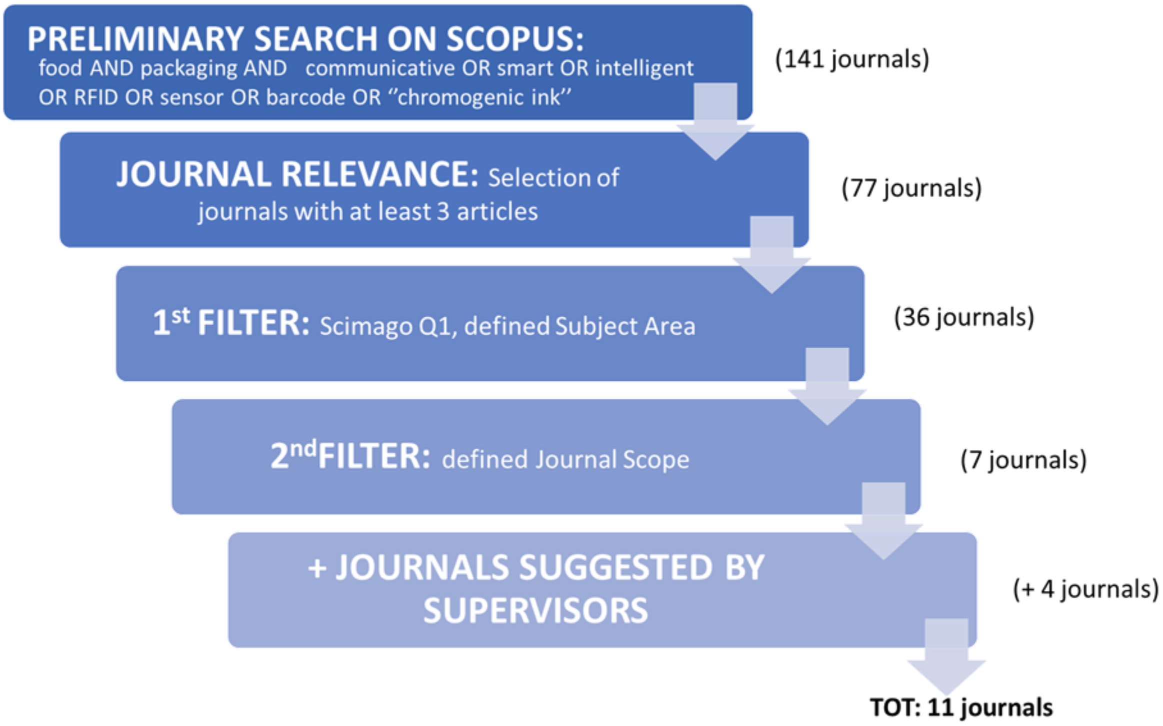

Figure 2.2: Methodology for journals selection (Source: Author's elaboration)

The first filter for journals selection was the subject area, which included:

- "Agricultural and biological science" with a focus on "Food Science",
- "Business, Management and Accounting",
- "Engineering",
- "Environmental Science".

The selection was done considering only these subject areas and the Scimago Q1 category, which means journals present in the first ranking quartile i.e. which have an SJR index (Scimago Journal Ranking) in the top 25% of journals for at least one of its classified subdisciplines. The SJR is a measure of scientific influence of scholarly journals, specifically it is an index of weighted citations per article over a period of three years. In addition, an analysis of journal scopes was done and only the ones dealing with reviews of existing technologies, technology trends, innovations, packaging applications and supply chain management have been kept, with a total sample of 11 journals, listed in *Table 2.1*.

Table 2.1: List of reference journals (Source: Author's elaboration)

1	*Industrial Marketing Management*
2	*Journal of Cleaner Production*
3	*Resources, Conservation and Recycling*
4	*Trends in Food Science and Technology*
5	*Food Research International*
6	*International Journal of Production Research*
7	*Food and Bioprocess Technology*
8	*LWT- Food Science and Technology*
9	*Annual review of Food Science and technology*
10	*Applied Sciences*
11	*Comprehensive Reviews in Food Science and Food Safety*

The complete methodology followed for selecting reference journals is reported in *figure 2.2*.

Given the extreme novelty of the topic, in order to have a full overview of all the possible barriers to adoption, a precise refinement work has been done on the query and a first analysis on the abstracts of resulting articles has been done. All the articles rejected were the ones:

- exclusively related to materials, technology or R&D;
- abstract and introduction not dealing with barriers to adoption;
- abstracts dealing with immature technologies not yet commercialized or ready to market.

After this selection, a total of 8 papers have been selected (*figure 2.3*)

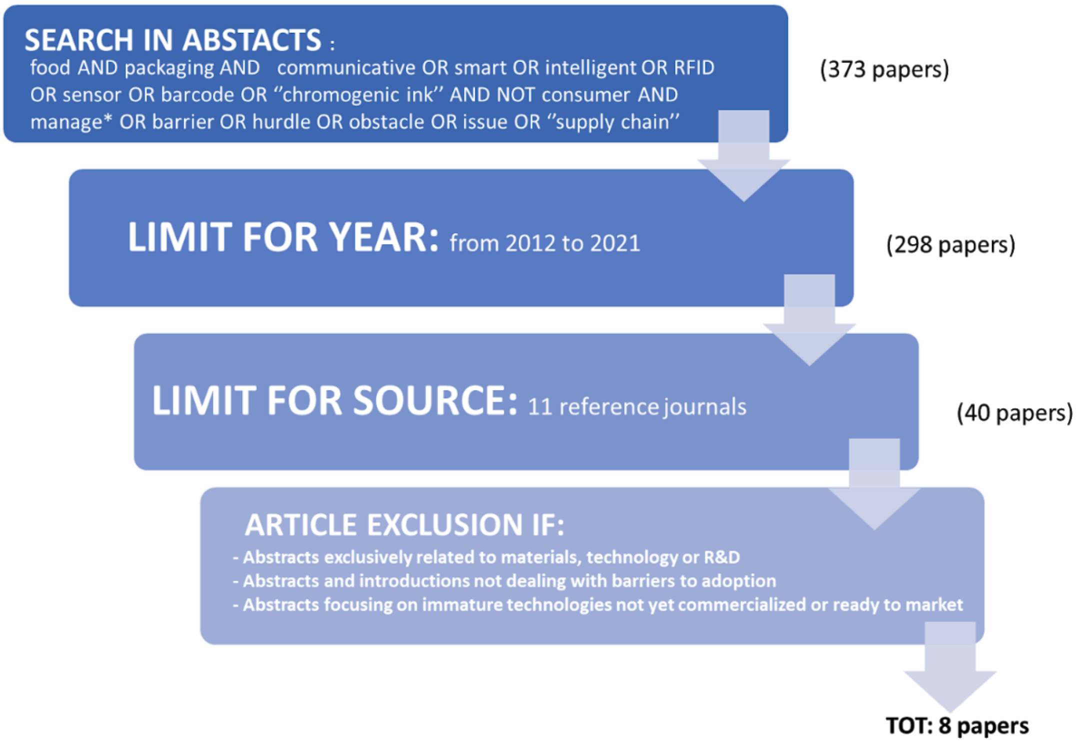

Figure 2.3: Methodology for barriers search in academic literature (Source: Author's elaboration)

The search of publications has been carried out in parallel to the analysis of grey literature on Google in order to have a broader range of analysis and to include also not academic sources that could include barriers to adoption of innovative and recent packaging technologies.

Specifically, e-magazines, blogs and specialized websites dealing with commercialized packaging technologies have been selected.

The snowball approach followed for the articles selection has been summarized in *figure 2.4*.

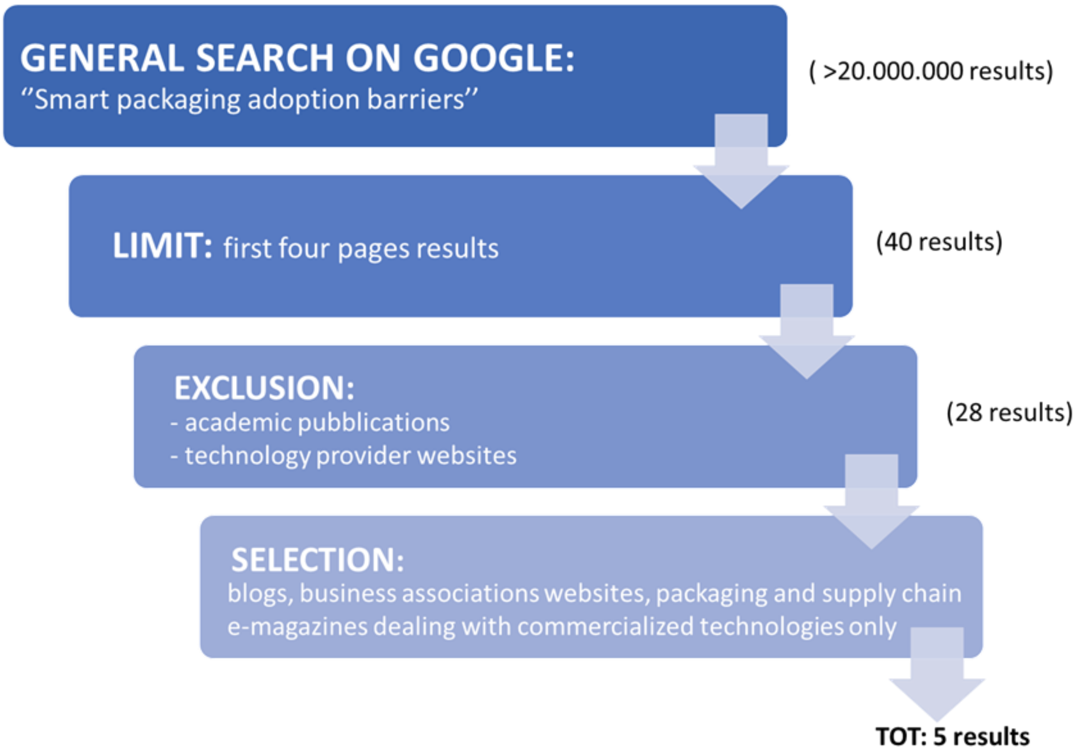

Figure 2.4: Methodology for barriers search on grey literature (Source: Aunthor's elaboration)

After the analysis of barriers to adoption, a step forward has been taken. The search has moved toward the drivers to overcome the barriers to adoption that emerged from the previous search. The same approach has been followed (see methodology in *figure 2.5*), but the extreme novelty of the them has preventing from having a wide range of articles to analyse. In fact only one article has been chosen following the selection criteria. The resulting article deals with generic drivers appliable to every sustainable innovation.

A deeper analysis of drivers for overcoming barriers to adoption has been conducted later through direct dialogue with stakeholders in the food supply chain who have adopted communicative packaging in the past.

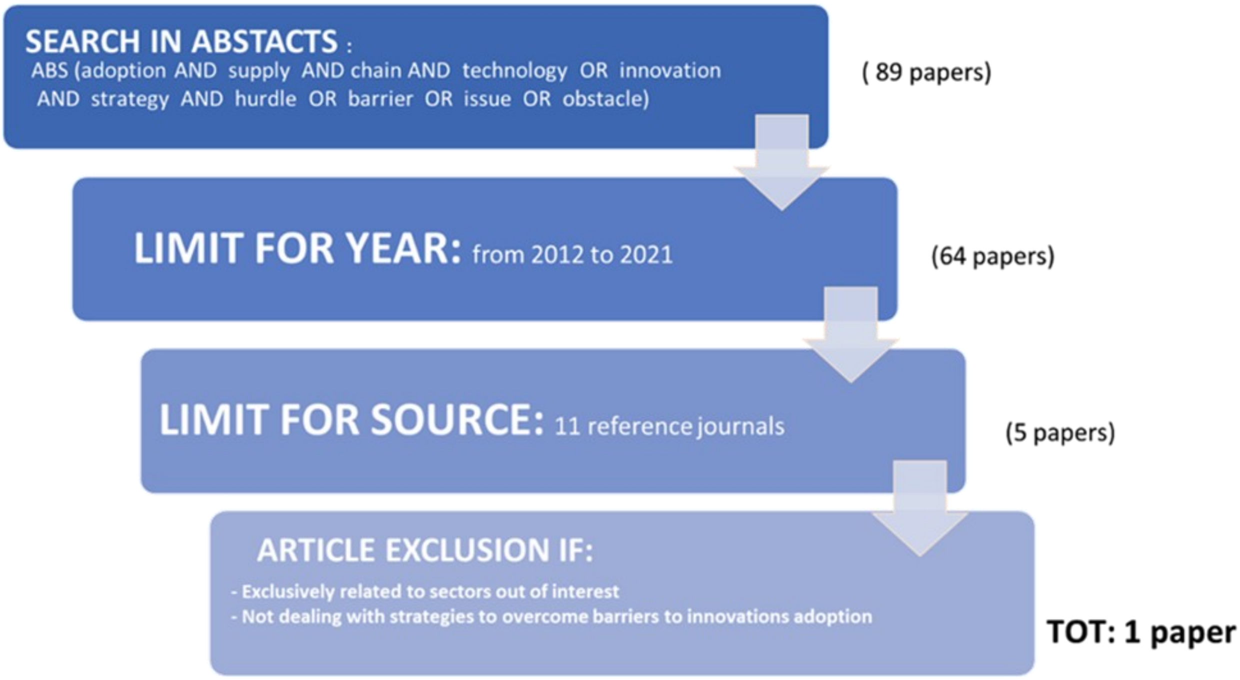

Figure 2.5: Methodology for drivers search in academic literature (Source: Author's elaboration)

From this literature review, some gaps have been identified (see chapter 3). Consequently, the Research of this thesis has been structured formulating two Research Questions (RQs):

- **RQ1:** Which are the barriers to adoption of communicative packaging technologies perceived by the actors of the supply chain?
- **RQ2:** Which are possible drivers to overcome barriers to adoption of communicative packaging technologies?

To answer RQ1 a taxonomy of barriers is proposed, classifying the barriers emerged in literature.
RQ 2 have been approached in the same way of RQ1 through a focused literature review, but a substantial gap emerged because of the extreme novelty of the topic. For this reason the drivers to overcome adoption barriers have been deeper discussed directly with the actors of supply chain during the interviews conducted by the Author.

2.2 Food packaging functions

Packaging has a key role to ensure the delivery of goods to the final consumer in the optimal conditions for the use (Lockhart, 1997). This definition focuses the attention on the importance that the packaging system assumes in the retail phase, so it is just described as a tool to distribute a quality food product to its buyer. But packaging has a big importance also at the producer level, being fundamental to guarantee safe distribution and storage in addition and to optimize logistics processes and costs while maximizing sales.

The packaging, as a whole system, could be composed by different material layers, called in the literature “levels” (Robertson, 2013):

- **Primary Packaging** consists in a layer in direct contact with the food product, which provides the first, and generally major, protective barrier. The material used for primary packaging are, for example, metal, carton, glass or plastic.

- **Secondary Packaging** is an additional layer that contains different food products already wrapped in their primary packaging; it is generally used at the retail level. Some examples of secondary packaging could be cases or boxes, or supplementary plastic films that help in multiple products handling (plastic wrap that contain 6 plastic beverage bottles).

- **Tertiary Packaging** is made up of more secondary packages, for example wrapped pallets. Tertiary packaging is fundamental for a well-organized handling process.

- **Quaternary Packaging** refers to metal containers up to 40m long that could hold different pallets used in transportation and distribution (in cargo ships, trains or camions). Some containers, generally for the transportation of chilled or fresh products, are integrated with special technologies to control temperature, humidity and gas atmosphere. As mentioned above, through the integration of packaging system the value of the product could increase.

Packaging is a socio-scientific discipline operating in society to ensure the delivery of goods to the ultimate consumer of those goods in the best condition intended for their use. (Lockhart, 1997). The primary function of packaging is obviously **containment** (Robertson, 2013); this means, when designing a new packaging, consider the potential leakage points of a pack, how and why failure could occur and ensure that the required performance characteristics are designed-in at the development stage, carefully specified on component and process. Food products have a long journey, from the initial manufacturer to the table of consumers.

For this reason, the second function that must be considered is **protection** (Robertson, 2013), that includes: prevent physical damage, contamination from microorganisms, pollution, protect against dehydration or dampness and protect the product’s nutritional and sensory characteristics. The protection function is achieved both through materials selection and design since packaging is shaped to contain a particular food so that the product is held securely and well protected from damage.

The third function regards **preservation** that means prevention or reduction of changes caused by biological and chemical hazards that would lead to product spoilage (Robertson, 2013). Signs of food spoilage may include appearance different from the food in its fresh form, change in color, in texture, unpleasant odor, or undesirable taste and the main causes for making food unsuitable for consumption are light, oxygen, heat, humidity, temperature or spoilage bacteria, that can all affect both safety and quality of perishable foods. When subject to these factors, food will gradually deteriorate and may cause food-borne infections (ingestion of microbes, followed by growth, tissue invasion, and/or release of toxins) and food-borne intoxications (ingestion of toxins in foods in which microbes have grown, e.g. staphylococcal food poisoning, botulism, *Clostridium perfringens* food poisoning, and *Bacillus cereus* food poisoning).

Another important function of packaging is providing **convenience** to customers (Robertson, 2013), in the sense that they expect from packaging an easy product access, for example an easy open, peeling features or boil-in bag and heat-in-tray food. Today this feature is becoming increasingly important in fact many materials have been chosen for ready-to-cook or ready-to-eat products that for example can be directly put into microwave ovens. In this sense a certain kind of packaging provides convenience because it fastens the process of cooking at home (De Nardo, 2019).

Another purpose of packaging, always related to final customer, is **communication**. Packaging is a real vehicle of information, which may concern different areas. The information that can be transported are many: from critical dates to nutritional values, from storage methods to information on the product's origin, but also information linked to the packaging itself, its composition and disposal methods.

Therefore, from this overview of the main functions of food packaging, it is clear that packaging not only offers commercial information about the product, but also a real convenience for the consumer.

In fact, on packaging there is a big variety of different communications, from nutritional indications to advice of use, even passing through recipes. In addition, packaging also provides regulatory compliance updates through trademarks. Thus, the main purpose of food packaging is, on the one hand, to obtain the maximum degree of protection for products in order to prevent them from being affected by risky alterations that may be harmful to human health and, on the other hand, to communicate additional product features to the final user. (De Nardo, 2019).

2.2.1 Communicative function of packaging

Given the enormous amount of information that can be conveyed through food packaging, the label that is placed on it plays a role of fundamental importance. That is the place in which can be found all the information not only regarding the food product contained and the materials used for packaging, but also information regarding the certification related to the product that can be showed through icons and symbols.

The European regulation EU 1169/2011 indicates the compulsory information that food packaging should include:

- name of food
- weight/volume
- list of ingredients and possible allergens
- quantity of ingredients for specific ingredients or categories (i.e. salt)
- the volume of alcohol, in form of percentage (if > 1,2%)
- the nutrition declaration, comprehensive of energy content
- the date of minimum durability or the BB date
- usage or storage conditions
- instructions in case of difficult usage
- the country or place of origin
- the name and address of manufacturer or distributor

In recent years the presence of QR codes simplified a lot the label design and enabled the communication of higher and higher amount of information just using a common smartphone to scan the printed code. Thanks to the development of IoT, QR code had permitted to save much space on packaging labels and redirect customers to an online page containing all this information. The types of information can cover a broad variety, starting from a deeper description of the product, till a description of the entire supply chain, highlighting good practices that enabled the achievement of certifications (e.g. FairTrade, UTZ, Rainforest Alliance Certified, etc.).

Besides the primary information such as ingredients and nutritional values and besides the additional information introduced thanks to the QR code technology, another important information that can be transmitted by packaging concerns the actual state of the food, beyond the fact that it is within the shelf life limits. This is made possible by modern smart label technologies, which will be discussed in detail in the next chapter under the umbrella of intelligent packaging. In short, smart labels are labels that change in appearance to let consumers know when food is no longer fit to eat. The label changes color for example when it detects that bacteria is starting to grow. The color changes occur in response to changing levels of oxygen and bacteria within the packaging. The smart labels solve a few problems with the current labelling system. First, the best before and use by dates are only given as guidance. They are not always accurate and, in some countries, dates are not even regulated. In many cases, the food is still safe to eat for long after the use-by date says the food has expired. This means that people are wasting food that is still edible. There are many benefits to using smart food labels that have both short-term and long-term positive implications. One of the main advantages is that using the labels will significantly reduce food waste, which is a global problem. People throw away billions of dollars of food every year that is perfectly good to eat.

Another of the main advantages is preventing illnesses that are caused by bacteria growing on food. This includes both E. coli and salmonella, both of which are potentially fatal forms of food poisoning. If people can clearly see that the food is no longer safe to eat, then they will not contract serious bacterial infections. Overall, smart food labels have great potential for the future. This technology is still in development and scientists are working on other uses for this labelling. One example is for packaging in the pharmaceutic and cosmetics industry. When an item of makeup is used several times and then stored away, bacteria can grow on the surface of the makeup, leading risks for skin or eyes infection.

2.2.2 Relevant information categories

After a description of the overall packaging functions and the focus on communication through packaging and labels, this section identifies the most relevant information categories conveyed by food packaging according to our Research Objectives. As said in the introduction, this Research deals with the main technologies of communicative packaging that can be adopted by different actors along the supply chain with the particular purpose of monitoring products to avoid the generation of surplus food and food waste along the supply chain until they reach the shelves in supermarkets. Thus, the information categories in line with these objectives has been selected.

As previously said, the communicative function of food packaging becomes fundamental not only as marketing tool, but also as it plays an important role in the effectiveness of consumers purchase and decision process. Moreover, the use of communicative packaging has a relevant impact not only on the demand side but even all along the supply chain, during retail and logistic operations. In this context the integration of information on secondary and tertiary levels of packaging became fundamental to guarantee process optimization.

This Research focuses on this last point and specific solutions of communicative packaging have been developed and described in the next section. The starting point of this Research was the result of a previous master thesis conducted by Facchini in 2020 dealing with communicative packaging solutions and sustainability issue.

In the above mentioned thesis a classification of the information categories, that the package system could convey, have been done, while, in the next paragraphs, only the ones relevant for the purpose of the study are described, specifically, dynamic information that enable to warn of possible problems, extend shelf life, increase safety and quality. In addition to them, a static information for SC management has turned to be “critical dates”.

According to Facchini’s re-elaboration of literature, communicated information can concern three different levels :

- the packaging system itself,
- the food product it contains
- information necessary for supply chain operations.(*figure 2.6*)

In some cases, the information is included in the packaging system a priori by the brand owner, in other cases it is the result of a dynamic control of the internal and external environment performed directly by the package system. As a result, the information conveyed could have a static or dynamic nature, depending if they evolve in time or not. Thus, the second parameter of categorization considered for classifying the information categories is the distinction between static and dynamic.

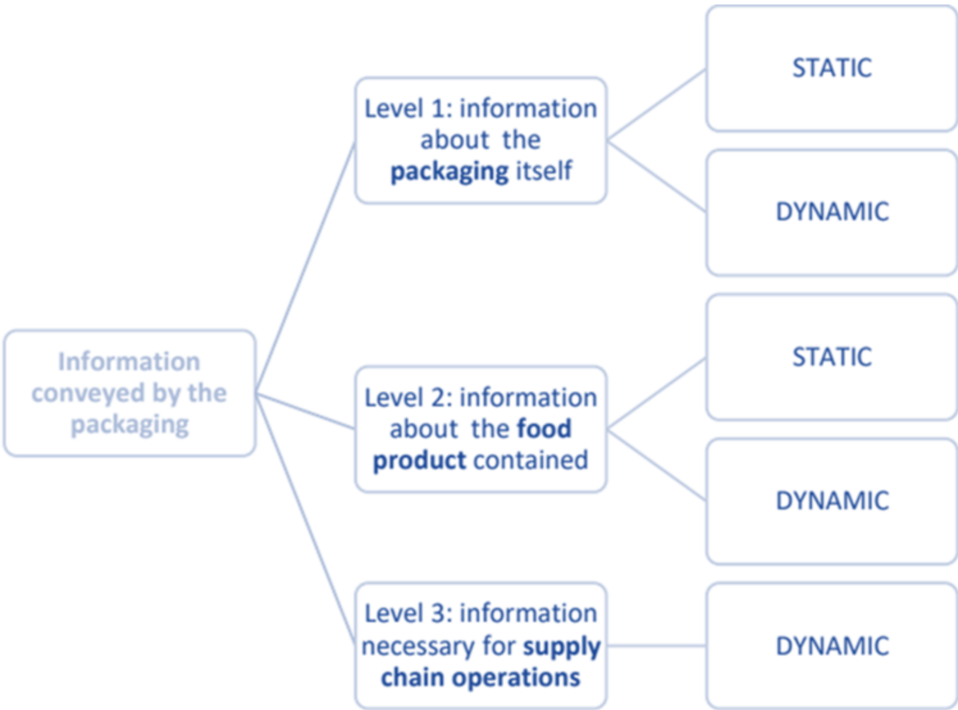

Figure 2.6: Levels of communication of the info that the packaging system could convey (Source: Facchini 2020)

After the description of the model used to classify all the different information a package can convey, only the relevant categories for this study have been kept. With respect to the aim of this work, the relevant categories are those able to communicate dynamic variation occurred inside the package, in order to advise supply chain actors if something strange happens and to take proper action to solve any issue in order to avoid unwanted surplus food and waste. At the same time the only one static information, relevant with a view to reducing waste, regards the critical dates. Knowing the expiry dates and monitoring in advance the approach of this date, would allow an optimization of warehouse management limiting as much as possible any risk of food waste.

At this point, starting from the framework elaborated by Facchini (*figure 1.2*) a list with only the selected dynamic and static information categories was done and a short description of each of them is provided below.

- *Material maintenance along the supply chain*
- *Interior conditions variation*
- *Nutritional content variation*
- *Organoleptic properties variation*
- *Instant status of the food*
- *Presence of toxic substances*
- *Food conservation along the supply chain*
- *Critical dates*

Material maintenance along the supply chain

This category corresponds to all the additional indication on how the packaging has been managed during operations (e.g. if it has been exposed to critical environmental conditions, such as inadequate temperature or prolonged light exposure). In this category are also classified all the information related to the correct handling of items along the supply chain in order to assure package conditions preservation (i.e. correct disposition on a truck during transportation). As a matter of fact, transportation, warehousing, distribution, and retail are sensitive steps of packed food value chain. Indeed, a continuous monitoring, and consequent communication, of the integrity of packaging layers becomes a useful way to guarantee service and product quality. A packaging is considered intact when its mechanical and structural properties do not change, and it is still able to guarantee food safety.

Interior conditions variation

This category regards the indications about variation of the package system's internal conditions, such as humidity, pH and oxygen, or other gasses concentration. The real time control of packaging status results extremely important to guarantee food quality and safety.

Nutritional content variation

For Nutritional content variation are intended the changes on the percentage of the different nutrients (e.g sugars, fats, salt, etc.). Due to natural processes, such as fermentation, leavening or ripening, nutritional values could change with respect to the indication inserted ex-ante, by the producer or brand owner, on the packaging system. A continuous control, possible thanks to the integration of innovative technologies, and a real time communication could have positive impacts on populations segments exposed to diet risks (i.e. people ill of diabetes, hypertension or cholesterol).

Organoleptic properties variation

Even though organoleptic properties are generally subjective, some characteristics could objectively alter during the product shelf life. Organoleptic properties variation includes a change of teste, smell, consistency and colour of the food product. The variation of organoleptic properties could be determined by some natural aging processes as maturation. A simple example is the taste, consistency and smell, of fruits. Consumers that love sour taste, tough consistency and fresh smell would wish to consume the fruit when it is unripe, rather if they prefer sugary taste, soft, and juicy, consistency and sweet smell, they would want ripe one.

Instant status of the food

This information enables to indicate if the product is still safe for users to consume. The variables that determine if the food is eatable are for example microbial proliferation, exposition above or below critical temperature, exposition to light sources or gas concentration. The presence of dynamic spoilage information is not function of the critical dates, reported on the package, and determined ex-ante through standards measures. Thus, it is a step forward compared with freshness control based only on best before date printed on packaging.

Presence of toxic substances

This information indicates whether the food product is contaminated with elements that could be dangerous for consumers' health. In general, such substances are linked to production practices, for example due to the use of pesticides, fertilizers, herbicide, antibiotics used during farming. Generally, the presence of dangerous substances is verified in controlled supply chains, for this reason a real time monitoring is useful for traceability and counterfeit assessment.

Food conservation along the supply chain

This information category is related to the historical management of food along the value chain, controlling temperature, water and light exposure. Static information is not enough to control supply chain actors' practices during warehousing, transport or distribution operations, but, thanks to the integration of dynamic monitoring, it is possible to obtain details about operation processes.

Critical dates

Information related to the critical dates are regulated by the norm EU 1169/2011 (EU Council, 2011). The date should be included following the scheme: day, month and year (depending on the type of product). It should be indicated with the formula "To consume before" for all fresh pre-packed foods as cheese, milk, fresh pasta, meat and seafood. In Italy, the date should be calculated in compliance with the standards set by the *Ministero delle politiche agricole, alimentari e forestali* and *Ministero della Salute*. The formula "To consume best before" indicates the date before which the product properties are maintained if correctly stored and it must be included for all long-lasting foods. For some products critical dates should not be included by norm, this rule applies for fresh fruit and vegetables (if not peeled, cut or transformed), salt, sugar in pounder, vinegar, wine, fresh bread and pastries, alcoholic beverages (with alcohol content>10%) and chewing-gums. The critical date should not be indicated even for fresh products distributed at the counter, but the conservation temperature must be included.

2.3 Packaging technologies enabling food waste reduction along the supply chain

The four technologies selected (chromogenic inks, barcodes, sensors and RFID) are also called in literature "intelligent packaging". Specifically, this is a subcategory of the so called "smart packaging", which comprehends both intelligent and active packaging. The ultimate purpose of applying smart packaging is to extend the shelf-life of the food product and keep its freshness for longer times, exchange important quality information with consumers, enhance product's safety, and improve traceability of the product while moving across the supply chain from farm to fork. In fact there are many possible waste generated at the different stages of the food supply chain.

For example in the final consumption step, the consumer's behaviour has a significant impact on food waste generation. Many people like to prepare oversized portions but finally waste the leftovers. However, few of them are aware of the negative impact of food waste on human health and environment. Moreover, contaminations and damages from inadequate safety controls, overstocking production, inappropriate labelling and product information missing are some of the most important causes of the food loss and waste along the other steps of the supply chain.

In this context, it must be noticed how technological innovations have a key role in order to solve this issues related to food waste. In fact, technological advances related to the safety issue of food is one of the top measures in preventing the loss and waste of foods (Chen et al., 2020). Some of these include technologies controlling temperature, novel packaging materials and designs, as well as smart monitoring systems.

In the last years smart packaging has become more and more popular thanks to its capability to help customers and businesses to make better decisions regarding food quality. Intelligent packaging is able to monitor the freshness and safety through the presence of external indicators, without acting on the food, while active packaging actively interacts through the material matrix to keep or improve quality of food (Beshai et al., 2020).

As far as intelligent packaging is concerned, it contains smart devices capable of tracing and monitoring the freshness of the product and it can also store and transfer these information to retailers and stakeholders to improve the technology. Intelligent packaging is described as the science and the technology that introduces the communication tools for a food packaging system to monitor changes in the internal and external environment of the system as well as the packaged food, in order to communicate the status of the system to the stakeholders of the supply chains including producer, retailers and consumers (Yam, 2012).

Thanks to its communication capability, intelligent packaging enhances food safety and helps to improve the final product quality by providing several information, and warning about potential problems occurred along the supply chain (Firouz et al.,2021).

Intelligent packaging can be classified into three main categories: sensors, indicators, and data carrier (Beshai et al., 2020).

Sensors are those able to directly sense if any physical or chemical damage occurred, while indicators are those who indicate through a visible modification if an unwanted variation occurred thanks the use of chromogenic inks).
The third class regards data carriers (i.e., RFID and barcodes) that are those able to communicate the gathered data through external readers in form of scanners. Each of them can be either placed inside or on the package to provide information about the package itself or the contained food matrix, or to monitor the environment surrounding the packages. Thus, this emerging technology, that acts as a barrier against environmental influences such as odours, dust, and micro-organisms, has a big potential to facilitate decision making regarding the storage and transportation of packaged food, leading to an optimized management of product flows along the supply chain.

In contrast, active packaging is defined as the system that incorporates active components such as scavenging or releasing substances in response to changes in package headspace to extend the shelf-life of the packaged food (Firouz et al., 2021). Active packaging can be further classified depending on the objects used inside the package into scavengers and releasers.

Scavenging objects concern the capture of excess moisture, odours, and gases such as moisture absorbers, oxygen scavengers, and odour absorbers. The releasing objects are usually emitters/generators that release substances such as antimicrobials agents, carbon dioxide emitters, and antioxidants (Firouz et al., 2021).

2.3.1 Technology overview

In this section the main technologies of communicative packaging emerged from a deep analysis of literature, are described. Specifically, the selected systems can be classified as follows:

- **chromogenic inks**
- **sensors**
- **barcodes**
- **RFID**

After a careful analysis or academic and grey literature, the most mature technology has turned to be the one related to indicators using chromogenic inks technology since it is one of the simplest to manage. These devices do not have a receptor or a transducer as in sensors, but they just rely on direct visible changes. This class of devices can be sub-divided into four main categories: time-temperature indicators (TTIs), gas indicators, humidity indicators and freshness indicators, that will be described in the following paragraph.

On the other hand, RFID and barcodes belong to the class of data carriers because they do not directly assess the quality of packaged food as indicators do, but they are integrated with sensors and indicators in the form of tags or labels that assess the quality of food and communicate data through external readers (Firouz et al., 2021).

In the end, there are many types of sensors that have the potential to be used in smart packaging. With respect to other intelligent systems, they have high sensitivity and accuracy and they are able to provide quantifiable measurement about certain parameters such as temperature, humidity and gas concentration inside the package. However, they are the most expensive devices right now, for this reason it is common belief that they will be the last to have a large market penetration (Beshai et al., 2020).

In this paragraph each kind of technology is deeper analysed and some commercial example found in literature or in specific websites are provided.

Chromogenic inks

Chromogenic inks are the general technology used in indicators, that can be characterized by different features with respect to the variable they measure. The working principles of chromogenic inks are the spread of a dye along a path or the change of colour due to chemical or biochemical reactions. In thermochromic inks for example this process is triggered by heat. These inks can reversibly undergo color change within a defined broad temperature range; they can lose their color and become colorless or change from one color to another (Kandirmaz et al., 2020). As previously said, these inks are used in indicators, that can be put on the primary package, but also on secondary or tertiary according to the need. The main types have been listed and described below:

1) **time-temperature indicators,**
2) **gas indicators,**
3) **humidity indicators,**
4) **freshness indicators.**

1) Time-Temperature indicators (TTIs)

This is a technology able to monitor the accumulative effect of temperature on food quality. Considering that the quality of food is severely dependent to its temperature history from production to consumption, temperature is a key factor in cold chain management systems. These indicators are attached on the surface of food packages and integrate the exposure of the packaged food to temperature by accumulating effects of such exposures along the entire cold chain. These indicators exploit different reactions between two or more materials (enzymatic, mechanical, chemical, etc.), and show the result through an irreversible discoloration of indicator.

This system has to be integrated in a user-friend tool (i.e. app/scanner system) to simultaneously deliver information about compensatory operations to temperature abuses (Beshai et al., 2020). These indicators can be classified into three main categories (*Table 2-1*) depending on the type of indication they provide (Behravesh et al., 2011). In fact they can indicate only if a certain temperature has been exceed, or they can indicate the temperature variation in a certain period of time, or in the whole period of storage.

Table 2.2: Types of time-temperature indicators (Source: Author's re-elaboration of the Research made by Beshai et al., 2020)

CRITICAL TEMPERATURE TTIs	They give limited information about the product and indicates only if a reference temperature was exceeded or not.
PARTIAL HISTORY TTIs	They provide accumulative temperature versus time changes with respect to a reference temperature.
FULL HISTORY TTIs	They provide all the temperature changes throughout the whole storage period.

Many TTIs were commercialized in these years and are widely used for monitoring perishable goods. An example is Fresh-Check®, produced by TEMPTIME Corporation (*figure 2.7*). This indicator is a full history type (see *table 2.1*) that is based on a solid-state polymerization reaction. The active centre polymer (diacetylene monomer put in the centre ring) changes the inner circle colour from red to black showing that package has been exposed to high temperatures over time, giving a visual indication regarding the quality of packaged food. The higher the temperature the package was exposed to, the faster the colour will change (Beshai et al., 2020). Thanks to the color change, just be reading the labels under the circle, it can be easily seen if the product needs to be used as soon as possible, if it is safe so that it can be used respecting the normal expiry date, or if can't be used due to a bad handling of the product in the distribution phase or due to other reasons that have led to the premature deterioration of product.

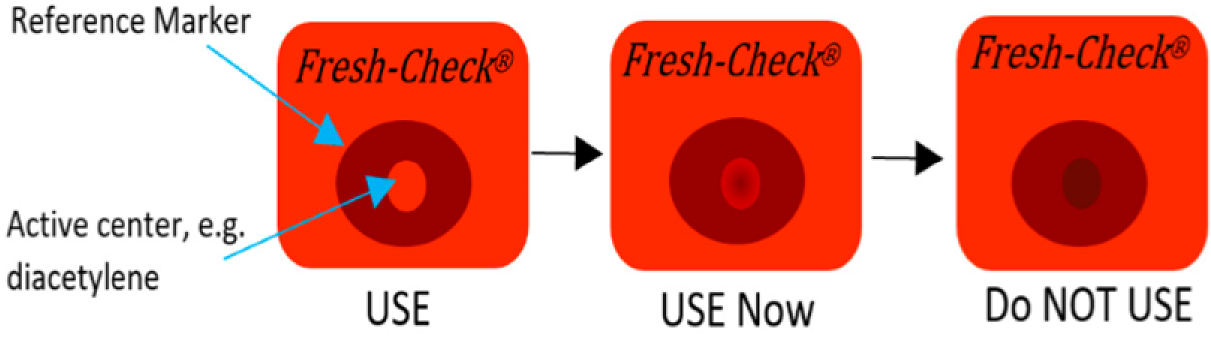

Figure 2.7:Commercial example of TTI (Source: Beshai et al., 2020)

Another commercial example was developed by Tempix (*figure 2.8*) and used in LIDL Finland in some of their fish packaging such as salmon. This type of indicator contains a liquid which is put just next to the barcode. Liquid reacts with temperature changes during transportation and storage phases and if temperature increases too high, liquid expands and covers a part of the barcode, Thus, the code cannot be read on the cashier, which prevents selling of possibly spoiled products (ActInPack, 2018). This is an example of mixed technology which comprehends barcodes coupled with chromogenic inks, different from the first case.

Temperature indicators based on chromogenic inks, in fact can be of different types. The first one presented in this sections consists in a simple circle containing a special ink, able to change its color and give information about the status of food. On the other hand, the second type proposed in this section regards a dynamic code, not in form of particular shape which changes color, but in form of a barcode which changes its bars. These are different ways to use chromogenic inks in temperature indicators in order to pursue the same objective, that is informing about unwanted changes in food products. Moreover these technologies can be used to do proper actions in the supermarkets because often, even if something wrong occurred, the product is still edible, as in the case in which the indication "USE Now" appears on the label (*figure 2.7*). Thanks to this dynamic information, these products can be sold with a lower price instead of thrown away, thus enabling a better management of shelves in supermarkets, decreasing the food waste in this phase of the supply chain.

Figure 2.8: Commercial example of TTI (Source: ActInPack 2018)

1) Gas indicators (GI)

This technology consists of an adhesive label placed on the package to show changes in the composition of the gas contained inside the package. Usually, this indicator shows the presence or the absence of gases such as CO_2, O_2 or C_2H_4 (De Jong et al., 2005). For example, when the percentage of CO_2 inside the headspace of the package increases, the colour of the films changes to give a visual index of the quality of the food matrix contained. The main advantage of this technology lies in its capability to accurately monitor quality changes of food which are not visible to the consumer, resulting in visible colour changes on the label.

A practical solution was developed by Ripesense company (Auckland, New Zealand) through a C_2H_4 gas indicator to recognize the degree of fruit ripeness (*figure 2.9*). This indicator is commercially available as a ripening sensor, therefore able to communicate if an organoleptic properties change occurred. The primary color of the indicator, also called ripening sensor label, is red, which indicates the premature state of the fruit. Gradually, the colour of the turns into orange and eventually turns to yellow which means that the fruit is fully ripped. This capability of monitoring the ripening status can be exploited in the distribution post-harvest chain. A colorimetric sensor can help to check the products and properly manage quality losses due to mechanical damages or unfavorable storage and handling conditions along the chain (Firouz et al., 2021).

Figure 2.9: Commercial example of gas indicator (Source: Firouz et al., 2021)

However, although the big potential of this technology, there is a lack of research on these indicators which very few scientific papers. Thus the technology is not mature enough and needs further development, especially regarding the materials, to provide the expected performance and to assure food quality and public health (Firouz et al., 2021).

2) Humidity indicators

This class of indicators is used to monitor the water content inside the package (Beshai et al., 2020). This is an important parameter to monitor, because it can led to undesired variation of organoleptic properties of food, and it can be necessary especially for high value products. These type of indicators can be commercialized in different forms. They can be printable label, films, or tablets that can be put inside the package to give information about the changes of humidity inside the headspace of packaged food.

For example, humidity cards that give visual colour indications of the relative humidity were developed by IMPAK (ActInPack, 2016) These cards are injected with a cobalt chloride solution that is able to change its color as the humidity increases. It can be easily seen through the color change that when it is brown they are dry, while, when the color goes to azure they are wet (*figure 2.10*).

Figure 2.10: Commercial example of humidity indicator (Source: ActInPak, 2016)

3) Freshness indicators

Freshness indicators are another class of indicators. They are able to detect the chemical changes or the microbial growth inside the packages based on reactions with the growth metabolites such as carbon dioxide, oxygen, ethanol, lactic acid, glucose, and the other volatile organic compounds (Beshai et al., 2020). In order to give the correct information, they require a direct contact of indicator with the food, for this reason all the materials used in this technology should comply with specific food regulations.

A commercial example of freshness indicators is Food FreshTM (*figure 2.11*). The indicator is made of polyethylene terephthalate (PET) that changes its color with time and enables the identification of the safe consumption period, easily readable thanks to the indication “just open”, “use soon” or “replace”. Typically, this type of product is used for food like meat and jars like mayonnaise (Beshai et al., 2020).

Figure 2.11: Commercial example of freshness indicator (Source: Beshai et al., 2020)

Sensors

This technology is considered as the most promising technology for the development and improvement of future intelligent packaging systems (Poyatos et al., 2018). The working principle is made of three steps: the first part senses the physical or the chemical properties and converts to an electric signal; then the signal amplifies, linearizes and scales, and, at the end, the final part can be in the form of an adapter, a simple mechanical connector, a wireless sensor and etc. (Korhonen & Ahola, 2018). The main difference between chemical sensors and biological sensors lies in the first part or in the identification layer. The sensing part in the chemical sensor consists of chemical components, while this part in the biosensor is composed of biological materials called bioreceptor such as antibodies, enzymes, deoxyribonucleic acid (DNA) or cells (Firouz et al., 2021). Biosensors detect, record, and convert biological responses into easily measured signals such as electrical or optical signals that can be easily analysed (Korhonen & Ahola, 2018). A sensor that measures a change in the environment should mediate a reversible reaction so that it can continuously monitor changes, especially when it is deployed at a remote location (Firouz e al., 2021).

Sensors are able to accurately measure the many factors, but their expensive manufacturing process would lead to decrease their competitiveness in the market that would not be viable, commercially. For this reason, due to the high prices, sensors are nowadays more used in labs of R&D, rather than on an industrial scale. (Banerjee et al., 2016).

A commercial example of oxygen sensor is O2xyDot (*figure 2.12*). This system is used to evaluate the presence of oxygen contained inside the packaging. The sensor is placed inside the package before

Figure 2.12: Commercial example of sensor (Source: ActInPak, 2018)

filling and sealing. When it is illuminated, a pigment absorbs light in the blue region to emit fluorescence in the red region of the visible spectrum. Oxygen inhibits this fluorescence. Therefore, from the duration of this fluorescence it is possible to determine the level of oxygen inside the packaging. (ActInPak, 2018).

In 2020 Innoscentia AB (Sweden) developed dynamic sensor labels (*figure 2.13*). Instead of static expiry date estimations on the packages, Innoscentia has developed materials that combine with the technology of flexible displays, enabling real-time quality monitoring of the food. In this way, thanks to the information which appears on the label it can be seen if the product needs to be consumed soon, if it is fresh or no more edible. And thanks to this dynamic labelling is possible to set also a dynamic price based on current status of food: going from higher prices for fresh food, to lower prices for less fresh food. As a result, thanks to this dynamic management of products and prices, this solution manages to reduce food waste significantly and detect spoiled food in time, even before the expiry date. In this way the highest level of product freshness through scalable IoT packaging solutions was achieved. This is a big step closer towards disrupting the current labelling system of food and helps creating a more sustainable food value chain in the future. (Aipia, 2020).

Figure 2.13: Commercial example of dynamic sensor label (Source:Aipia, 2018)

Barcodes

The barcoding technique was invented in the seventh decade of the last century to help the large retail and the grocery stores to manage their goods (Firouz et al., 2021). In compliance to European standards, all business must be able to identify origin and destination of any food product along production, processing and distribution phase of the supply chain (European Council, 2002). A solution to fulfil such requirements is the barcode, which can be printed directly on the packaging or on dedicated labels.

The barcode is placed on products in characters and numbers forms. The data stored in barcodes are read by an optical barcode scanner and then it is sent to a central system. Nowadays, the barcode technique is very common because it is very simple and it has very little cost (Firouz et al., 2021). Conventional barcodes (one-dimensional) are ordinarily created as wide or narrow black color vertical bars printed on white color background. The distance between those bars is also either wide or narrow. Barcodes are measured by recording the width of lines by mile. The blank distance to the right and the left of the barcode character, are also measured to ensure the authenticity of the barcode reading.

Barcodes are useful not only to encode lot number or article ID, but even to guarantee the product traceability and other additional details. The one-dimensional Universal Product Code (UPC) barcode is mostly used now. The location of every package along the supply chain as each one has a unique UPC (Beshai et al., 2020). Other widespread barcodes are the European article numbering (EAN), code 128, and code 39, which are very famous on all supermarket products.

The need to store more information on the barcode had led in recent years, to the emergence of a two-dimensional barcode format. Thanks to the introduction of Reduced Space Symbology (RSS), two-dimension barcodes were able to arrange spaces, dots and lines in an array or matrix, or Quick Response (QR codes) barcodes, that are able to store data in four different codes: numeric, alphanumeric, binary and kanji (Gahani et al., 2016). In this way the amount of information that can be stocked is much higher. Today, the format of QR code, Data Matrix and PDF 417 are the most utilized popular two-dimensional codes (Firouz et al., 2021). Some models of common barcodes are illustrated in *figure 2.14.*

Figure 2.14: Examples of most common barcodes. (Source:Firouz et al., 2021)

If we recall the theme of smart packaging, as a means to reduce food waste, it should be noticed that the common barcodes can be integrated with innovative technologies of chromogenic inks and sensors in order to become real "smart" codes. Becoming smart means, as mentioned before, being able to monitor the status of the food and communicate valuable information. Thanks to this communicative capability, therefore, scanning the code, or seeing its color change, it is possible to understand if an unwanted variation has occurred. They are real dynamic codes, i. e, they do not remain the same in time, but they communicate different information according to the conformation they assume in the course of time.

The working principle of this smart systems is erasing or modifying the barcode to make it unreadable and show contamination (Beshai et al., 2020). A real example is the “Food Sentinel System” (*figure 2.15*), a barcode capable of sensing the presence of pathogens and identifying whether a product is contaminated or not. This system uses labelled antibodies on the membrane of the barcode to identify specific antigens. When contamination is detected, the barcode will be unreadable because lines appear when antigens bind to the antibodies on the barcode or disappear due to their dissociation from the substrate in case of bacterial metabolite being present. (Beshai et al, 2020).

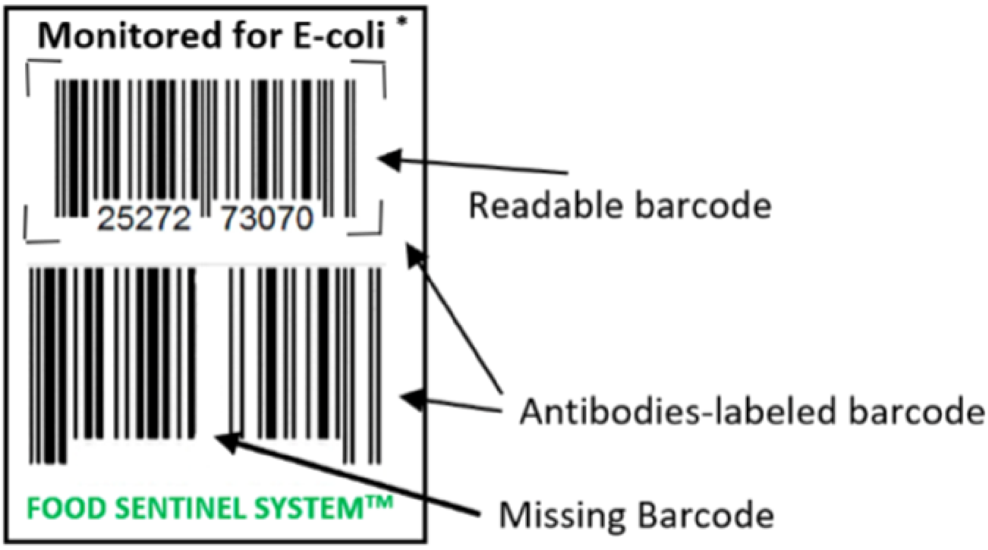

Figure 2.15: Commercial example of sensing barcode (Source:Beshaei et al., 2020)

A similar solution (*figure 2.16*) which changes the configuration of the barcode, in order to give a dynamic information regarding food, is based on pathogen detection. This technology of inks applied on barcodes is based on turning the membrane containing antibodies into red ink when a pathogen attaches to it. This makes the barcode unreadable by scanners showing that the food has been contaminated (Beshai et al., 2020).

Figure 2.16: Commercial example of barcode (Source: Beshai et al., 2020)

RFID

RFID (Radio frequency identification) technology presents an advanced data carrier system which has the capability of data storage up to 1 MB (Beshai et al, 2020). In comparison with barcodes, they are more expensive and need a more powerful electronic information network. RFIDs use electromagnetic field to monitor different measurements and can communicate the readings through a reader that emits radio frequency waves to capture the data stored on the chip with the use of antenna in the RFID. (Beshai et al, 2020).

The near field communication (NFC), chipped RFID, and chipless RFID are the three different types of Radio frequency identification systems that have been proposed to sense, obtain, and transmit the information of the atmosphere condition and identification of the package to a remote reader (Fathi et al.,2021).

NFC technology uses electromagnetic induction between two loops of antennas in both the tag and the reader and the data transmission happens based on inductive coupling between them. The technology is suitable for very short-range applications (1-2 cm) and guarantees very simple reader structure, which is available in recent mobile phones. RFID guarantees longer reading ranges and have the potential to adopt a very simple tag structure compared to NFC at the expense of complex reader structure (Fathi et al.,2021).

A typical RFID system is made up of three major components (*figure 2.17*):

- a tag containing identification and environmental information;
- a reader that generates a signal;
- a middle-ware which is an interface or software to transfer information from the reader to the computer and vice versa (Preradovic & Karmakar, 2010).

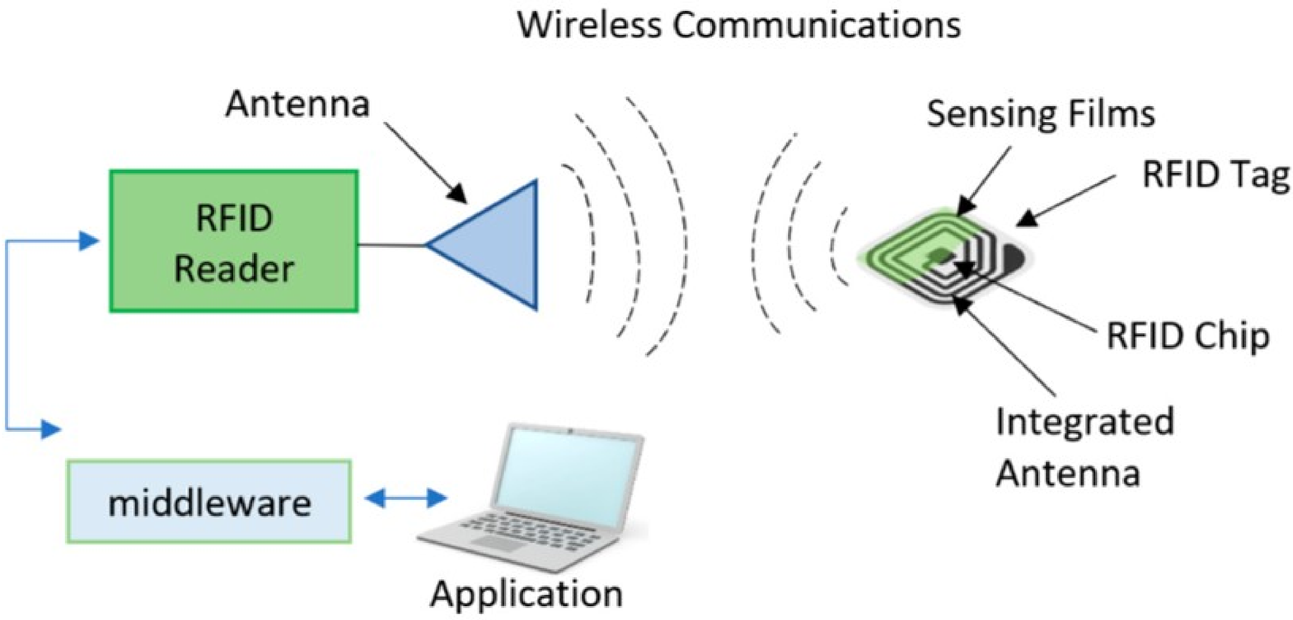

Figure 2.17: Working principle of RFID system (Source: Beshai et al., 2020)

RFID tags can be sub-classified into three main types (Bai et al., 2017):

1) **Passive tags** with no batteries on the chip. They are powered without a power source, but through the electromagnetic induction produced from placing the reader nearby. This type has a long shelf life, but a relatively short reading distance, in the range of few centimeters to 10 m (Firouz et al., 2021). These tags are cheaper (10 cents), smaller and have a much longer operational life than active ones.

2) **Semi passive tags** have a battery to power the chip, but the reader is essential to power broadcasting of the signal (Bai et al., 2021). This type is inactive most of the time, and it also has a long shelf life.

3) **Active tags** have onboard power supplies ,such as batteries, to power integrated circuit (IC) of sensors. The IC carries out all the communications between the tag and the reader. They have longer range of operation and higher operating frequency. The drawbacks of these tags are; high price of 20 $ to 100$, large size due to battery, and short life of the batteries (Firouz et al., 2021).

The presence of IC in all chip-based RFID tags guarantees high accuracy in reading process, but may increase the complexity and cost of the tag and makes it less robust and not easy to be integrated with package; on the other hand, in chipless RFID, the absence of IC suggests potentially lower costs, simple structure, longer storage life, robustness, and lower radiated power. However chipless RFID needs more research to solve many technical issues such as the reading accuracy, problems with interference, multiple parameter sensing and recyclability of materials, but it is expected to have a big growth in the next years thanks to its high potential in food industry. (Fathi et al., 2020)

In recent years, the spread of these tags as a part of smart packaging systems is increasing because they can store many data while simultaneously providing real-time monitoring for more than one type of information such as temperature, humidity and product information (Bai et al., 2017). In fact, some manufacturers in the packaging industry have integrated the RFID systems into the food box. *Mondi plus* is the name of an intelligent box containing the RFID tag on its surface that tracks the box throughout the production chain. The Intelligent Box enabled the full traceability of products throughout production and distribution, generating valuable real-time information on product availability and location. Mondi's RFID application process enabled 'out of sight' scanning, which means it is possible to scan an entire pallet as it passes a single point. The result is quicker receipting and distribution of goods, that were common bottle-neck processes within fast moving businesses. The company has developed an application process that automatically applied and verified RFID tags at high-speed so that the product is ready to use when received by the customer (Campelo, 2010).

Figure 2.18: Commercial example of RFID (Source: polibox.com)

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Another commercial solution in the Italian market is Smart Polibox Easy Plus (*figure 2.18*) It was created to intuitively simplify the traceability procedures of Polibox isothermal containers, certifying through "E-Signature" the operating processes normally used for the delivery of thermo perishable products. With this system it is possible to track: shipping, delivery and return. The device uses RFID technology, which as previously explained, is basically made of three elements: the tag, made of a chip and a small antenna that surrounds it, a second antenna that dialogues with the one of the tag by means of radio waves and a reader that on one side exchanges information, by means of the antenna, with the tag while on the other side addresses the computer system to which it is connected. The passive tag, often called smart tag, has as main component a small silicon chip surrounded by an antenna, normally made of copper, to which it is connected and from which it receives the energy needed to operate when it is hit by an electromagnetic field of the appropriate frequency. SmartPolibox® has obtained the SMART Label award in 2017, which is the recognition to innovation in the HO.RE.CA. sector, given to those products/services/projects that emerged for distinctive features in terms of functionality, technologies, environmental sustainability, ethics or social implications

2.4 Sustainability in food sector

Food is essential to life. It also forms an important part of our cultural identity and plays an important role in the economy. People are aware that the food they eat is an important factor affecting their health, but what is less well known is the impact producing and consuming food has on the world's resources. Alongside the cars we drive and the energy we use to heat our houses, the food we produce and consume has a significant impact on the environment through, for example, greenhouse gas emissions, the use of land and water resources, pollution, depletion of phosphorus, and the impact of chemical products such as herbicides and pesticides. A growing number of analyses questions the long-term sustainability of the current trends in the production and consumption of food. There are many different views related to what constitutes a 'sustainable' food system, and what falls within the scope of the term 'sustainability'. Strictly speaking, sustainability implies the use of resources at rates that do not exceed the capacity of the Earth to replace them. For food, a sustainable system might be seen as encompassing a range of issues such as security of the supply of food, health, safety, affordability, quality, a strong food industry in terms of jobs and growth and, at the same time, environmental sustainability, in terms of issues such as climate change, biodiversity, water and soil quality. (European Commission, 2016).

A very accurate quote says that *"The goal of sustainability is to meet the needs of the present generation without compromising the ability of future generations to meet their own needs"* (Brundtland Commission - World Commission on Environment and Development, 1987). Thus, another point that should be considered, talking about sustainability, is the social impact that an item, in general, could achieve. In 1994, John Elkington, the famed British management consultant and sustainability guru, coined the phrase "triple bottom line" (TBL) as his way of measuring performance in America. The idea was that a company can be managed in a way that not only makes money, but which also improves people and planet life (*figure 2.19*). According to TBL theory, to achieve sustainable development at the business level, companies should be working simultaneously on three bottom lines (Harvard Business Review, 2018):

1. **Profit:** traditional measure of corporate profit, thus the profit and loss (P&L) account;
2. **People**: measure of how socially responsible an organization has been throughout its history;
3. **Planet:** measure of how environmentally responsible a firm has been.

It is important to notice that Triple-bottom-line theory says that companies should focus as much attention on social and environmental issues as they do on financial issues.

Figure 2.19:Representation of the Triple Bottom Line Theory (Source: University of Wisconsin, Sustainable management)

After this simple explanation of TBL, it can be easily seen how wasted food is the antithesis of the triple bottom line: economically it is unsustainable due to financial losses associated with growing, transporting, processing and packaging food as well as lost revenues and sales associated with damage or overproduction.

Socially, wasted food represents a significant missed opportunity to distribute food equitably. (Tavill et al., 2020).

Lastly, the environmental impacts of wasted food are huge and include the land use, emission of pollutants into the soil and into the air and the emission of greenhouse gases (Garrone et. al., 2015). According to a study by FAO the impact of food waste on the environment is the third place after that generated by the industrial activities of the two largest nations (USA and China).

2.4.1 Surplus food along the supply chain

Food waste generation is a phenomenon that raises questions about the imbalances of consumption in the world and the social disparity between those who waste and those who have nothing to eat. Food poverty is a paradox today. A part of the population, even in the richest countries, is in a state of food insecurity. Although the availability of raw materials and food products would be sufficient to meet everyone's needs, but tons of food is wasted. tons of food are wasted. FAO estimated a world production of 3,9 billion tons of food in the world every day, and an amount of wasted food of 1,3 billion tons (*figure 2.20*), 4 times the amount of food needed to feed 795 million of undernourished people in the world (Garrone et al., 2015).

Figure 2.20: Comparison between food produced and wasted in the world (Source: Garrone et al., 2015)

The data concerning developed countries and those concerning developing countries are different. In fact, the percentages of food waste for medium and high income countries are higher in the last stages of the supply chain, especially in the consumption stage. The opposite happens in developing countries, in which food is mainly lost during the upstream levels of the supply chain, specifically during post-harvest and processing stages (FAO, 2011). The FAO indicates that 222 million tons of food are thrown away in industrialized countries, a figure equal to the food production of Sub-

Saharan Africa (approximately 230 million tons). On a European level, an average of 180 kg of food is wasted per capita per year; 42% of this waste occurs at a domestic level. The country with the highest per capita waste is Holland with its 579 kg per capita per year; the country that wastes the least is Greece (44 kg per capita per year) (FAO, 2019).

FAO considered as food losses or waste "the mass of food lost or wasted in the part of food chains leading to edible products going to human consumption" (FAO, 2011). But in order to better understand what is intended for surplus food and food waste, which are the subjects of this Thesis, the definitions are provided, referring to Garrone et al. 2015.

- **Surplus food**: percentage of food that for some reasons does not reach the final consumer for which it was produced in the first place. Therefore, it is an edible component that fails to cross the entire supply chain and that must be managed to find an alternative destination and prevent it from turning into waste.

- **Food waste**: surplus food becomes food waste when it is not used for its primary purpose, i.e., to feed people. When the surplus is directed towards an alternative channel, such as that of redistribution or donation to front-line charity organizations or food banks, but is still used for human consumption, it is not considered waste, because it satisfies the need for which it was produced. On the other hand, the product used for animal consumption, recycling, or energy recovery is considered food waste.

In terms of food groups, roots, tubers and oil-bearing crops report the highest level of loss, followed by fruits and vegetables. It is not surprising that fruits and vegetables incur high levels of loss given their highly perishable nature (FAO 2019).

In order to give a tangible idea of food losses along the supply chain, FAO has introduced the Food Loss Index, which highlights the losses from production stage until the moment the food arrives in the hands of retailers. Today this index indicates that all over the world 14% of the food produced is lost, in terms of economic value, from the moment it is harvested, to the moment it is distributed, excluding the retail and the consumption level (FAO, 2019).

As far as our nation is concerned, analysing food waste in the Italian food supply chain, every year 5.1 million tons of food are wasted, representing 15.4% of annual food consumption (made in shops or households) and 91.4% of surplus food. Food waste is generated in part (53%) by companies in the supply chain and in part by final consumers (47%). Focusing attention on the waste generated by companies alone and the contribution of the various stages, it can be seen that 65% of waste is generated in the primary sector, 3% in the processing stage, 25% in distribution stage and 7% in catering. (Garrone et. al, 2015). With reference to the Italian situation, the economic value of food wasted along the supply chain is obtained from food waste data and value density for the various stages of the supply chain. Overall, the annual value of food waste is around 12.6 billion euros. Comparing this value to the number of people residing in Italy, the value of food waste amounts to approximately 210 euros per person per year.

The direct causes and indirect drivers of food loss and waste are the results of how well the food system's elements (environment, people, inputs, processes, infrastructures, institutions, etc.) and activities relating to the food supply chain interact (FAO 2019). Examples of how food loss and waste may occur through a combination of direct causes and indirect drivers can be found across the various stages of the food supply chain (*figure 2.21*).

AGRICULTURAL PRODUCTION AND HARVEST, SLAUGHTER OR CATCH	STORAGE AND TRANSPORTATION	PROCESSING AND PACKAGING	WHOLESALE AND RETAIL	CONSUMPTION: HOUSEHOLDS AND FOOD SERVICES
INDIRECT DRIVERS (not exhaustive)				
Left in the field due to quality standards or sharp drop in prices	Lack of proper storage or transportation facilities (e.g. refrigerated trucks)	Inadequate processing capacity for seasonal production gluts	Variability of demand for perishable products	Multitude of date labels
DIRECT CAUSES (not exhaustive)				
Production and agronomic practices and choices (e.g. choice of crop varieties)	Poor management of temperature and humidity	Technical malfunctions (wrong size or damaged packaging)	Inappropriate product display and packaging	Confusion between expiration and preferred consumption date labels
Machine or labourer damage	Prolonged storage (e.g. due to lack of transportation)	Lack of proper process management	Removal of "imperfect"-looking foods	Poor storage or stock management in the home
Poor harvest scheduling	Logistical mismanagement (poor handling of delicate produce)	Excessive trimming to attain a certain aesthetic	Overstocking	Oversized portions

Figure 2.21: Potential direct causes and indirect drivers of food loss and waste (Source: FAO 2019)

After this explanation of food waste generation along the supply chain, we must ask ourselves how can be possible to avoid it. A useful instrument to reduce surplus food and food waste generation in the different phases of the supply chain is represented by packaging. In fact packaging is a communication vehicle that delivers storage, preparation, usage and, in some cases, disposal information. For this reason, new technologies for packaging may be able to help identify loss of freshness along the supply chain and avoid premature disposal and subsequent food wastes along the supply chain (see *section 2.4.2*). This is a solution to eliminate the possible causes of food waste. Therefore, through the correct use of packaging, it is possible to control the state of the food and make sure that it does not undergo any change that would compromise the sale, generating waste. However, in case the variation has already occurred, it is necessary to find ways to reuse this food and not make it a waste.

Depending on the way the surplus food is managed, and it is possible to consider different perspectives. (Garrone et al. 2015)

- **Social perspective**: surplus food becomes food waste when it is not used for its primary purpose, which is to feed people. When the surplus is directed towards an alternative channel, such as that of redistribution or donation to charity organizations or food banks, but is still used for human consumption, it is not considered waste because it satisfies the need for which it was produced. On the other hand, it is considered waste the portion of food that is still edible but is not recovered for human consumption;

- **Zootechnical perspective**: when surplus food, as alternative destination, is used to feed animals directly or to make animal feed through processing industry, does not fall within the definition of food waste;

- **Environmental perspective**: this last perspective considers as food waste the portion of food that is not recovered in any way, (for human consumption, for animal feed, to obtain energy or other materials). When surplus food is landfilled or incinerated, it is considered waste.

As a result, for the best management of food waste, was established in Europe the so called "*Food Waste Hierarchy*" (*figure 2.19*) The "waste hierarchy" ranks waste management options according to what is best for the environment. It gives top priority to preventing waste in the first place. When waste is created, it gives priority to preparing it for re-use, then recycling, then recovery, and last of all disposal e.g. landfill (Defra, 2011).

The principles behind the waste hierarchy were introduced into European policy as early as the 1970s, with the 1975 Directive on Waste (European Parliament Council, 1975) and the EU's Second Environment Action Program in 1977 (European Commission, 1977). The waste hierarchy was then clearly defined in European legislation in the Community Strategy for Waste Management in 1989 (European Parliament Council, 1989). Since then, the waste hierarchy has been adopted worldwide as the principal waste management framework The Food Waste Hierarchy prioritizes actions organizations can take to prevent and divert wasted food. Each tier of the Food Waste Hierarchy focuses on different management strategies for wasted food. The top levels of the hierarchy are the best ways to prevent and divert wasted food because they create the most benefits for the environment, society and the economy.

According to the social perspective, the surplus food must be redistributed or reused in secondary markets, always to satisfy the primary objective for which it was produced in the first place: the human consumption. When redistribution and reuse of surplus are no longer possible for reasons related to food safety, the surplus becomes waste, according to the social perspective. This waste can be managed in different ways: firstly, it can be redirected to reuse for animal consumption, thus avoiding "zoological waste", linked to the second perspective (zoological perspective). If this first option is not feasible, recycling can be used for the production of fertilizers and finally, energy recovery. When none of the previous destinations is chosen for waste management, the waste is disposed in landfills or incinerated, and therefore becomes waste also from an environmental point of view, in accordance with the third and last perspective (environmental perspective).

In summary, surplus food management concerns everything that falls within the redistribution through non-standard sales channels, such as donations to food banks or other non-profit organizations. On the other hand, food waste management involves any strategy that does not foresee human consumption as its final destination (Garrone et al., 2015),

The *Food Sustainability Observatory of Politecnico di Milano*, in the last years, deeply analysed the Food Waste Hierarchy (*figure 2.22*) providing an accurate image of where and why food wastes and losses occur, finding concrete application in the valorisation of surplus food and in the elimination of waste along the entire value chain. Based on the evidence gathered from the analysis of business cases and experimental research projects, the Food Sustainability Observatory highlighted the actions of prevention, redistribution and reuse of surplus for human consumption, placed in the highest levels of the hierarchy, leveraging on technological innovations that increase efficiency. Thus, supply chain collaborations represent an enabling factor to ensure scalability. Moving progressively towards the lowest levels of the hierarchy, the valorisation of surplus food for animal consumption, for the production of other products and for energy recovery, passes through process innovations, which combine new technologies and collaborations with companies and players of other sectors and supply chains, able to integrate the necessary skills and specific technological and market know-how.

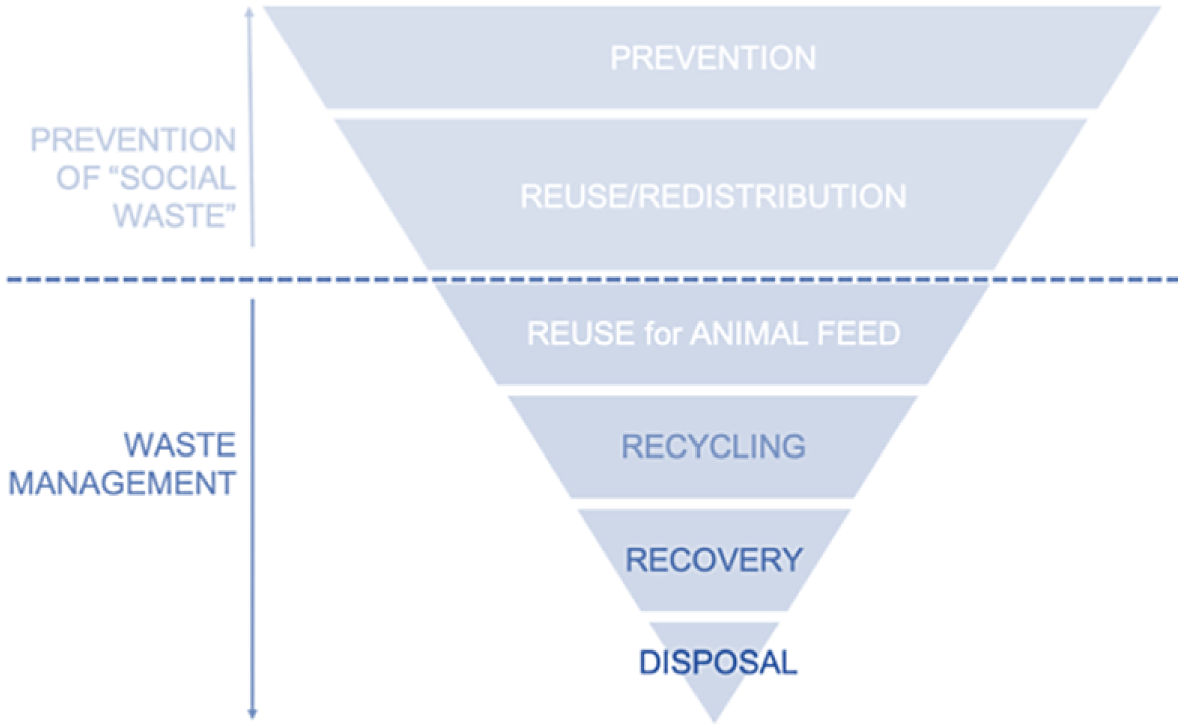

Figure 2.22: Food Waste Hierarchy (Source: re-elaboration by Food Sustainability Observatory)

Businesses in the food sector are gradually working to meet this challenge, putting into practice the various options for the prevention and management of food surpluses outlined by the Food Waste Hierarchy and adopting an increasingly supply chain approach. In summary, the Food Sustainability Observatory noted the existence of two different strategic approaches to the application of the circular economy paradigm for the reduction of food waste, which are complementary to each other. Firstly they explored the food circularity at the system level i.e. looking at the supply chain as a system based on partnership between companies. Secondly, they explored the food circularity at a company level, which means from the point of view of the single company which has a specific role in the supply chain i.e. harvesting, manufacturer, logistic operator and retailer. Principal aspects are summarized in the table below (*table 2.2*) and then described in detail step by step.

Table 2.3:Two approaches to the application of circular economy paradigm. (Source: Author's elaboration of Osservatorio Food Sustainability Report"La filiera agroalimentare si muove e cambia pelle: circolarità, prossimità e packaging degli alimenti, 2019).

FOOD CIRCULARITY: SYSTEM - PERSPECTIVE	Each level of the FWH offers numerous possible solutions to implement, requiring collaborative supply chain efforts and a systems approach to expand their number and scalability. This is pursued especially thanks to the innovations developed by young companies or startups and thanks to the exploitation of partnership opportunities between companies in the supply chain, companies in other sectors and non-profit organizations, capable of bringing new knowledge and resources for the recovery of surplus food.
FOOD CIRCULARITY: AT A COMPANY LEVEL	The individual agri-food enterprise strives to activate all possible options of the FWH, giving priority to the first levels of the hierarchy (i.e. prevention, reuse and redistribution of surplus for human consumption), and then moving progressively towards the lower levels, maximizing the economic, social and environmental value generated by the FWH. In this case, the company adopts an "internal" circular approach, which passes through the maximization of the usage of the productive resources employed and the optimization of business processes.

Food circularity: system perspective

Adopting a system perspective, for each level of FWH various alternative solutions are emerging thanks to the spread of technological innovations and the opportunities generated by new forms of collaboration between companies of different sizes, non-profit organizations, and actors from other sectors. Prevention is made possible by new technologies: information systems, data analysis, biochemical solutions and control of critical parameters for the preservation of products.

Analysing the main solutions adopted by companies to prevent the generation of food waste, the fundamental role of technology as an enabling factor emerges. In fact, these solutions are mainly oriented towards extending the shelf life of products and to act on the causes of the generation of surplus. The latter objective is pursued mainly through the monitoring and/or better forecasting of demand to avoid overproduction and the resolution of management problems.

1) Prevention of surplus food

At the level of prevention, there are numerous applications of information systems and data analytics, i.e., data collection systems capable of forecasting agricultural production, monitoring storage conditions and select products to improve the quality of supply. Most of these solutions are adopted in the upstream stages of the supply chain, primarily in agricultural production in all its phases: harvesting, selection and storage, packaging, and shipping.

On the other hand, Artificial Intelligence systems are used to make purchasing plans for large-scale retailers, predicting distribution, forecasting the demand of individual stores thanks to probabilistic methods, historical series, weather forecasts, analysis of competitors and the impact of holidays.

Optimizing the match between supply and demand directly impacts the prevention of surplus generation and can also be achieved through cultivation monitoring systems. The goal is to enable producers to take corrective action by increasing productivity and crop quality and reducing waste in the field. These sensing systems in fact, inserted at different depths in the soil, can collect information about its composition, absorption capacity, moisture levels, and then analyse them in order to understand the health status of plants and their rate of productivity and growth.

The information systems of data collection and data analysis are also effectively applied in the transport phase of fresh and perishable foods such as fruit and vegetables. Monitoring the transport conditions and giving visibility along the supply chain allow to take actions in real time ensuring an optimal product quality at destination. Other recent technologies used along the supply chain to monitor food status and reduce food waste are: sorting technologies, additional chemical substances and controlled atmosphere.

At the manufacturing stage, experimentation with chemicals for use at the product and packaging level is observed in the marketplace. These substances can be agropharmaceuticals and biosolutions that protect plants against external adversities and avoid the production of non-edible crops, or even intelligent fertilizers capable of releasing nutrients in a gradual manner.

Preventing the generation of surplus food is also made possible by the establishment of partnerships and collaboration along the supply chain. In some cases, these are horizontal collaborations, with the purpose of sharing know-how for the development of a new technology or to integrate processes for the adoption of new information systems. On the other hand, vertical collaborations along the supply chain are also favoured by the adoption of prevention technologies such as those of forecasting and sorting. In fact, to be able to use production forecasting systems, the firm must share a range of information with the technology provider, from those of manufacturers to those of its customers. In order to take full advantage of the benefits brought by these information and process systems, the actors in the supply chain are therefore led to adopt transparency and information sharing.

2) Transformation and re-distribution of surplus food

At the level of surplus management, technological innovations make it possible to give value back to products, transforming them and re-directing them to new markets or allowing their redistribution for social purposes. So basically, at the management level, process technology is used by processors to recover value from surplus food by creating new market opportunities. Processes already consolidated are for example the transformation of agricultural products, unsold due to aesthetic defects, over-ripening, packaging and labeling errors or other damage, into finished products characterized by a longer shelf life (e.g. production of juices from fruit).

Another area of surplus management is the sharing of products and their donation to non-profit organizations. In these cases, it is the collaboration between different players in the supply chain that allows the recovery and use of products that would otherwise be thrown away. It is facilitated by digital platforms that put donors and beneficiaries in direct contact. For example, thanks to the development of a smartphone app able to connect the user with the food vendor, it is possible for supermarkets, restaurants and catering services present in this digital platform, to offer at lower prices what is left at the end of the day. Thanks to a signal to users through the mobile app, costumers can come to pick up directly in the supermarket or restaurant. Thanks to this kind of apps and web interfaces work is underway on improving the system, because the management of redistribution networks through cloud platforms means that the system is scalable nationally and internationally,

Another model that is spreading to increase the effectiveness of food surplus redistribution is the creation of local networks based on territorial hubs that act as collection, storage and redistribution centers. These networks see the involvement of non-profits companies and institutions that play different roles in the definition of the model and its operational management. There are projects that use different channels to collect surplus food from supermarkets, markets, small businesses, allowing redistribution to local communities through direct collection or thanks to the intermediation of a Food Bank. A practical example of local network leveraging on a hub managed by a Food Bank is the one included in the project "*Smart City and Food Sharing*", activated in January 2019 in Milan. The project had the objective of proposing an innovative model of recovery and redistribution of surplus food suitable for the urban area, extensible and replicable, based on fast circuits of collection and redistribution of surplus edible food products. The project is still ongoing and it consists in the withdrawal of unsold fresh and dry products from participating supermarkets and their storage in a hub, the creation of a balanced mix of food and the distribution to local non-profit organizations.

3) From Animal Feeding to Energy Recovery

Moving down the levels of FWH, from the recovery of surpluses for animal feed production, to recycling for fertilizers production and to energy recovery, technological innovations and collaborations with companies open up alternative ways to recover the value of waste. Advanced technologies can automatically sort food waste from processing plants and recover its value by transforming it into food products for animal feed. In this way, production companies can recover value from the sale of waste (at prices that vary depending on the type and quality of the waste) and animal feed producers have access to quality raw material in large volumes.

Alternatively, innovative technological solutions also allow to recycle non-edible waste for the production of alternative products (e.g. food packaging from food waste) or to recover them in other sectors, such as energy or construction are becoming more widespread. However, the technological solutions available on the market for the transformation (of food waste into other products or energy) are still immature.

Food circularity: company level

Going from a system perspective to the vision of the single enterprise, the actors of the agri-food chain are moving in the direction of optimizing processes internally and introducing new solutions to implement different practices to reduce food waste. The reasons are many, such as the need to adapt to regulations, reduce costs associated with the waste of resources and waste disposal, business opportunities and strategic positioning in the market, strengthen brand image and reputation, social responsibility, etc.

It emerges that, in line with the FWH model, at a company level, rules are being adopted to define priorities for intervention, which regard in particular prevention and redistribution of food to people in need. This is followed by actions related to recycling and to feed and fertilizer production, and finally energy recovery, with disposal as the last option. There are several levers that companies can adopt, also exploring innovative technological solutions that differ according to the position along the supply chain .

1) Harvesting

In the agricultural enterprises, prevention involves the improvement of cultivation techniques and production planning through the renewal of the fields and the analysis of production and sales data, made even more efficient and effective by new digital technologies, which integrate external information (e.g. weather conditions) and directly collected from the field (e.g. data on the state and quality of the crop). In addition, advanced sorting and sizing technologies are also employed, allowing to expand the possible uses of a product based on its internal and external characteristics. The objective is that a product always finds its destination of use, maximizing the economic value generated, avoiding any loss or waste for the company, taking advantage of a variety of distribution channels and putting into practice the different management options suggested by FWH.

Depending on the market demand, each product can have different possible uses, including:

- traditional sale to distribution chains that require certain market standard characteristics;
- sale at a reduced price to distribution chains that require less stringent characteristics (e.g. size and colour)

- direct sales to consumers through company-owned stores or intermediaries (e.g. through purchasing communities of local producers and fair trade purchasing groups);
- sale of the product to processing companies for the production of jams, juices and other products with a longer shelf life;
- donation for social purposes through collaboration with Third Sector organizations.

If none of the above options are feasible, the channel of sale to processors for the production of feed (where possible) or other products (e.g. distillates) is opened. Finally, as the last options, the surplus is used for energy recovery, for example through biodigesters, or for composting production.

2) Manufacturers

For processing companies, the transition to an internal circular approach focuses on the valorization of the different types of surplus generated (finished products, but also production waste and semi-finished products), rationalizing production processes and taking action on the causes of the generation of surplus.

For prevention purposes, manufacturers are exploring new packaging solutions and preservation technologies that can extend the shelf life of products. In addition, they are optimizing internal production processes through increasing plant automation and process mechanization to reduce processing errors and minimize waste.

At the management level, in addition to the donation of surplus finished products through agreements with the Third Sector, processors are activating mechanisms for the recovery of edible waste generated along the production lines for human consumption, acting on the single phases of the process, raising the awareness of the personnel involved and collaborating directly with non-profit organizations. Also in this case, where recovery for human consumption is not possible, the processing company activates the option of selling the waste to feed producers or to companies involved in energy recovery.

3) Logistic Operators and Retailers

Retailers are responding to the challenge of circularity by expanding the range of options for preventing and managing surplus in the warehouse and at the point of sale, combining innovative technological solutions and new supply chain collaborations, in order to pursue objectives of of maximizing economic value and corporate social responsibility.

At a level of prevention, retailers reduce the various forms of surplus in the phases of purchase, transport and sale of products by optimizing demand forecasting systems and stock management in the warehouse, through new data analytics systems, coordination mechanisms with suppliers and constantly monitoring perishable products in the warehouse.

In addition to constant monitoring of stock and unsold items, a policy of price reductions (discounts and promotions) is usually adopted on products near expiry. Ad-hoc exhibitors are set up for discounted products and mobile apps developed by startups, which signal offers in real time, are becoming more and more widespread and they are able to attract price-sensitive consumers to the store. An alternative or consequent option to selling at a discounted price is the donation to non-profit organizations. Retail chains are working to optimize and computerize the donation process also through the use of digital apps, capable of tracking the flow of donated products and facilitating administrative tasks.

In addition, bulk products or residues from the processing of fresh products that are still edible are reprocessed into other products with a longer shelf life and sold in store (fruit salad, breadcrumbs, cooked meat, etc.), while those that cannot be valued for human consumption are sold to the processing industry for animal consumption (e.g., bones) or energy production (e.g. recovery of waste oil).

In conclusion, the Observatory analysis confirmed the great attention paid to the theme of prevention and management of surplus food and food waste, with a wealth of specific innovative solutions and collaborations between the parties. New packaging technologies are increasingly playing the role of an enabling factor, whose effectiveness must be carefully evaluate taking into account all the variables of the context.

2.4.2 The role of food packaging for surplus food prevention and management

Food packaging has a key role for reducing surplus food and waste because, as mentioned many times, not only it has a protection function, necessary to maintain the correct storage conditions and guarantee the correct product shelf life, but also it can be seen as a vehicle of information. The information communicated through packaging are many and regards a lot of aspects. For example package can display critical dates enabling the correct handling and managing of product flows, but it can convey also dynamic information regarding the package itself or the food contained, that are fundamental in order to monitor food, assure correct storage and handling, identify causes of problems for food safety and take proper actions. All these packaging features are necessary to monitor product flows along the supply chain, thus prevent or manage surplus food.

Considering the 17 SDGs (*figure 1.1*), packaging can be an enabling factor to pursue the objective 12 "Responsible production and consumption", more specifically target 12.3. (*figure 2-14*). Pursuing the SDGs requires a holistic approach and looking at the three aspects (society, economy, and

Figure 2.23: Target 12.3 of SDG 12 (Source: fao.org)

environment) together. The goals to be pursued are the reduction and optimization of single-use packaging, the enhancement of reusable packaging and the revision of eco-sustainable design criteria (Food Sustainability Observatory, 2021). In order to understand the potential of food packaging for the reduction of food waste, the Observatory has studied the main areas involved with the aim of defining guidelines for the reduction of food waste and offering an integrated design tool for the design of food packaging functional to the reduction of waste. These areas are: packaging design, logistics and technology. They are explained in detail below one by one.

Packaging Design

The first declination, packaging design, answers the question "How does the design of the attributes of food packaging affect the reduction of food waste?". In fact the technical, ergonomic, informative attributes of the food packaging lead the consumer to follow sustainable behaviours or not with respect to food waste. Specifically, packaging design has to deal with:

- **Technical attributes**: material performance, mechanical and physical-chemical protection, mass and volume, shape and type
- **Ergonomic attributes**: ease to open and handle, ease to portion, ease to clean, resealability
- **Informative attributes**: critical dates, sustainability information, quality information etc.

Logistics

The second declination, logistics, answers the question "How the design of packaging related to the logistic phases can avoid/reduce food waste and loss?". Packaging used in logistic phase (secondary or tertiary packaging) must have:

- **Technical characteristics:** enabling protection, stability, efficiency in handling and stackability; ease of aeration
- **Relationship characteristics:** enabling interaction and collaboration between actors in the supply chain (e.g. standardization, processes efficiency, inverse logistics)
- **Informative characteristics:** enabling information sharing (e.g. identification, traceability, monitoring)

Technology

The third declination, technology, answers to the question “How integrated packaging technologies packaging can avoid food waste?”, that is is precisely the focus of this thesis. There are two types of technologies enabling food waste reduction: “quiet” and “talking technologies.

- “**Quiet” technologies**: include technological innovations that act directly on the packaging or on the food it contains without involving communication with the stakeholders of the supply chain (e.g. active packaging such as absorbers, emitters)
- “**Talking” technologies:** refer to technological innovations that create a direct connection between the packaging and the consumer or the SC actor, operation on communication side (e.g. intelligent materials, indicators, external devices).

2.4.3 Sustainable food packaging: the framework developed by the Food Sustainability Observatory

As explained in section 2.2, food packaging has not only the protective function, but it should also integrate environmental friendly practices and encourage social development. Therefore, the Food Sustainability Observatory of Politecnico di Milano in the past years developed a framework to define when a packaging solution could be considered sustainable (Food Sustainability Observatory, 2019). Specifically, the framework aims to characterize the positive impacts of innovative solutions introduced in the food packaging industry.

Figure 2.24: Three pillars of the framework. (Source: Food Sustainability Observatory, 2019)

The framework (*figure 2.25*) presents the issue of sustainability with respect to three Declinations (*figure 2.24*): Food Safety, Environmental Conservation and Social Value. The Declinations are translated into Objectives, each of them representing the fulfilment of the positive impacts related to the correspondent Declination. Each Objective depends on choices and behaviours of different sides of the value chain, from suppliers to final users. In the framework, the supply corresponds to all the actors responsible for the product or packaging transformation, transportation, retail and disposal. While the demand corresponds to the users or the stakeholders, not directly involved in economic transactions but who are affected by the packaging solution. In this optic, Food Sustainability Observatory states that "*a packaging solution is defined sustainable according to one or more Declinations, when it presents characteristics that enable the packaging to pursue one or more Sustainability Objectives related to those specific Declinations*" (Food Sustainability Observatory, 2019).

Environmental Conservation

The first declination is "Environmental Conservation", divided in six objectives respectively supply side and demand side. With "Resource Efficiency" they refer to the optimization of production processes and transportation thanks to the optimization of the packaging shape in terms of mass and volumes and thanks to the use of renewable or recycled materials. Whereas with "Recyclability of resources" they refer to the possibility to re-use the same package or the possibility to recycle parts of if after the disposal. The voice "Behaviour of SC actors" regards the information sharing between SC actors to coordinate and achieve the correct handling of products along the journey. "Responsible behaviour in packaging end-of-life management" comprehends the ease with which products are redirected into specific chains and the ease with which the product can be broken down to be properly recycled. "Responsible behaviour in purchasing" regards the final user and its ability to buy consciously a certain product, thanks to labels that facilitate the comprehension of necessary information and thanks to the proper design that enhance product visibility. In the end "Responsible behaviour on food conservation at home" implies the presence of labels with information regarding the correct storage conditions.

Food Safety

The second declination is "Food Safety", further divided into two objectives: "Safe packaging supply" and "Safe behaviour on food". Specifically, the former is pursued when manufacturing processes, production and assembly, meets the safety standards, when food contamination is prevented and when, thanks to specific materials, bacterial growth is limited or monitored. The latter Objective is achieved through the presence on labels of clear guidelines that enable the correct management of the product during the entire period of conservation and consumption.

Social Value

The last declination is "Social Value" and contains three objectives. "Extended access to food" can be achieved for example thanks to easily readable labels or shapes and dimensions that facilitate the opening/closing of a package, because in this way they give access to food also to those people who are deprived of it because of geographic, cultural or income issues. "Augmented income and work empowerment" can be achieved through production processes that create source of revenue for unfortunate people, such as Fairtrade certificate. Then there is the objective "increase health", reached if labels contain information related to healthy lifestyle in order to reduce social costs related to bad diet.

In conclusion, this framework is very useful in the evaluation of a packaging system, and in our specific case, in the evaluation of a communicative packaging system, in order to understand in what dimension this can be considered sustainable. From the environmental point of view it can be considered sustainable if it is able to minimize the environmental impact of the use of resources and to limit the waste of food contained in the package; from the food safety point of view, if it is able to preserve and improve the hygienic-sanitary safety of the food contained in it and finally, from the social point of view, if it allows to promote the inclusion of fragile stakeholders in the access to food and economic resources and health.

DECLINATIONS	OBJECTIVES	LEVERAGES	
Environmental Conservation	Resources efficiency	• Materials from renewable or recycled resources • Mass/Volume optimization • Energy for production and transportation • Rationalization of the packaging system design	SUPPLY
	Recyclability of resources	• Reusability and Recyclability of materials • Energy for recycling • Re-usability of packaging for the same function	
	Responsible behaviour on food surplus of supply chain actors	• Product status information and reporting function • Easy handling in the supply chain	
	Responsible behaviour on food surplus in purchasing	• Information on packaging' s and food product' s environmental impacts • Product recognition • Perceived fruition of the product and its size	DEMAND
	Responsible behaviour on food surplus in conservation	• Information for conservation guidelines • Mechanical resistance in use contexts • Easy handling at home	
	Responsible behaviour in packaging end-of-life management	• Information for the correct placement to the recycling chain • Easy to prepare for recycling • Size and recognizability of materials	
Food Safety	Safe packaging supply	• Clean packaging manufacturing and wrapping process • Physical packaging properties • Materials that reduce bacterial proliferation	SUPPLY
	Safe behaviour on food	• Clean labels for conservation guidelines • Clean labels for critical dates • Labels for product quality • Clean label for real time information	DEMAND
Social Value	Extended access to food	• Labels that increase readability and interpretation • Packaging shapes that increase food fruition and conservation	SUPPLY
	, Augmented income and work empowerment	• Manufacturing and disposal processes as material feedstock diversification to enable communities' integration • Transparent Labels of the product origin • Labels to identify social inclusion • Recycled materials retrieved by disadvantaged communities	
	Increase health	• Labels that help the compression of energy intake, nutritional values and food composition • Labels that promote healthy lifestyle and sport	DEMAND

Figure 2.25: Food packaging sustainability framework. (Source: Food Sustainability Observatory, 2019)

2.5 Barriers to adoption

After the deep description of the functions of packaging, of the latest technological innovations in communicative packaging sector, and their great potential as a means of reducing surplus and waste along the supply chain, it is relevant to understand why they are not yet widely used in agri-food industry. As mentioned many times, communicative packaging solutions have multiple advantages. They are able to control the conditions of food inside the package, detect in advance spoilage reactions occurrence and communicate with actors of supply chain anything related to the quality of food and its history along the chain. But why are they not so widespread in industry yet? Through the analysis of academic and grey literature regarding smart packaging technologies, several barriers to adoption emerged.

When it comes to adopting innovative technology systems, there are several hurdles that must be overcome. Indeed, these technologies are expensive and often require substantial plant changes. It is necessary to be prepared to take risks, since these are young technologies with little market. They imply many advantages, but also many unexplored dangers due to the youth of these technologies and to the lack of experience with innovations. Especially chromogenic inks and sensors are very young technologies. They have a great potential but need to solve several problems, in terms of accuracy and precision (Mohammadian & Mahmood 2020).

To maximize smart-packaging efficiency in association with food waste decrease, these technologies should have a slight false positive as possible. For this purpose, more and vast validation studies should be accompanied by larger sample sizes and test as much as possible. Advanced guidelines, protocols, and standard testing assays would support in the development of smart systems indicators and their future transfer into industrial scale (Aliakbarian, 2019).

On the other hand, RFID and barcodes are certainly the most widely used in industry, and also the least expensive among the technologies of communicative packaging selected in this Thesis.

The price is one of the main factors to consider when adopting a new technology, because, as every innovation, requires a certain amount of money to invest. An amount of money that is not always justified by an economic return, but rather in most cases it is an economic return not perceived at the beginning, but only after a certain period of time. Smart packaging solutions are not cheap, especially compared to more traditional packaging solutions such as corrugated boxes, stretch wrap, and pallets. One reason for this extra cost is that smart packaging is not yet in the mass manufacturing stage, which would reduce its costs (Aliakbarian, 2019)

It must be considered that not all communicative packaging systems have the same costs: barcodes, QR codes or even passive RFIDs are inexpensive technologies, while more intelligent solutions that use active RFID or technologies that track temperature and shock, require sensors that are too expensive to use, making certain smart applications cost-prohibitive (Deloitte Insights, 2018). However, it must be noticed that it is not only a matter of costs related to the purchase of these innovative technologies, but it is also a matter of costs related to adapting or changing current production processes after introducing these systems. In fact, there can be the need for new manufacturing techniques. Before smart packaging can be applied to a variety of products, manufacturers will need to develop techniques for fabricating for example sensors and indicators that are compatible with current packaging standards (Aliakbarian, 2019). In some cases they need to integrate new technologies into existing line, thus it must be considered time and money needed to change existing production processes. For example, adopting new systems of RFID or barcodes is not immediate, but requires some time and money to integrate systems in the existing lines (Arvanitoyannis & Stratakos 2012).

A careful cost-benefit analysis is necessary in order to understand the real advantages that a company can gain from it and, if the cost-benefit ratio is not satisfactory, it will be difficult to obtain an adequate diffusion focusing only on technological innovation. An investment done only to follow technological innovation, does not make sense if there is not an economic return after some time. (Poyatos et al., 2018).

The relative youth of smart technology makes it difficult to make definitive statements on profitability and cost efficiency, because the technology hasn’t been around long enough to produce meaningful long-term data (Agility-Logistic insights, 2020). This lack of long-term data inhibits companies and prevents them from broadening their horizons and make investments based on meaningful past data (Aliakbarian, 2019).

Moreover, there is not yet any sense of the total cost of ownership for smart packaging, nor a comprehensive estimate about the costs that the technology could remove from the supply chain or the value it could provide (Aliakbarian, 2019). Industry needs a comprehensive end-to-end value chain study that includes: the final cost of the packaging solutions, where these solutions can be deployed, who are the key customers most willing to adopt new packaging solutions, and where the technology has the maximum potential to provide a significant impact. (Aliakbarian, 2019). All these issues slow the diffusion of these technological innovations on a large scale.

If on the one hand these technologies need a big investment by food companies, on the other hand they can bring many benefits to the company. More companies would embrace intelligent packaging if they were convinced that it could be used to encourage engagement that could build ongoing relationships between consumers and brands (Packaging news, 2019). Therefore, there is the strong need to educate stakeholders on the extra benefits arising from intelligent systems. This can be achieved using clear information about the device, e.g., what purpose it serves, how it works, and how to use it (Ghaani et al., 2016). For example, as largely discussed before, the use of these packaging technologies can lead to a positive contribution to waste reduction efforts.

If supply chain visibility and transparency is ensured, this means that brands can check at any time where and in which conditions their products are. This would help them to optimise distribution to reduce inventory shrinkage and waste (Packaging news, 2019). Once understood the potential of these technologies, companies should design a profit model that gives them a share of the new value created through the adoption of smart packaging (Deloitte insights, 2018).

Another factor to consider is the legislative and regulatory aspect. Like everything else, communicative packaging must be subjected to a series of guidelines and regulations to ensure its safety, even more so when it comes in contact with food. From a legislative point of view, the lack of an adequate regulatory framework in the EU for intelligent packaging systems until 2004 hindered the diffusion of new packaging solutions into the market, in contrast to the United States, Australia, and especially Japan, where intelligent packaging systems are widespread (Ghaani et al., 2016). The lack of a clear regulatory framework for many years led to reluctance by food packaging manufacturers to take on new concepts that are not fully covered by the legislation on food contact materials (Ghaani et al., 2016). This slowed a lot the adoption of innovative technologies of intelligent packaging. It must be said that smart packaging's complex composition creates legal complexity. This happens because this type of packaging is made up of a large number of different components, thus, it is subject to more regulations than traditional packaging (Aliakbarian, 2019).

Another critical point is the interaction of active and intelligent packaging with the food and the environment. Current regulation limits a lot the number of substances that can be used in smart packaging applications and this issue offers a serious barrier regarding the development of new technologies, because the authorization of a new substance for food contact is a long, complex and expensive procedure (Poyatos et al., 2018).

Thus, tracking and complying with these regulations will require significant time and resources (Mohammadian & Mahmood, 2020). Moreover, as innovative solutions are developing fast and manufacturers and customers want to incorporate these new technologies into their packaging, legislation frameworks need to be flexible and easily updated to support and keep up with this highly innovative and fast-moving sector (Aliakbarian, 2019).

Since smart packaging technologies are made of different materials, there it is necessary to also consider their disposal and recycling. Considering that communicative packaging technologies are a necessary tool for reducing surplus food and waste and pursuing sustainability goals, it is inevitable that the materials from which it is made must also be in line with these sustainability principles. It would be a paradox to create non-recyclable waste from the use of packaging, which would have the purpose of limiting waste. The extensive use of many different materials inevitably results in complex and expensive recycle processes and reduced performance (Vanderrost et al., 2014). In the specific case of RFID technology for example there is the need for a specific recycling programs for the RFID sensor tags separating all the different parts of which it is made (Poyatos et al., 2018). In addition, when tags are attached to products and improperly removed, the impact on the recycling processes could be huge. Materials such as adhesives, chips, pieces of metal from the antenna and conductive inks can affect the recycling process of paper, plastic and metal (Bibi et al., 2017).
Moreover, many of the smart packaging components, for example, batteries, sensors, displays, and circuits are not completely sustainable. Sensors and circuits, for instance, are challenging to recycle (Aliakbarian, 2019). However, although this problem, these technologies can help reduce the million tons of food waste produced annually, so the recycling challenges of smart packaging can be offset by its ability to keep food fresh and moving down the supply chain (Agility-Logistic insights, 2020).

Since these technologies need to be integrated along the supply chain and used by the various actors, a great deal of collaborative effort is required from all stakeholders and there are many organizational issues to consider. First of all, smart packaging relies on the creation and effective maintenance of an ecosystem of partners (Deloitte insights, 2018). The challenge is the complexity of securing and managing network of capabilities distributed along the supply chain. To be able to excel in smart packaging, companies have to invest in their partnering capabilities, learning how to form various types of alliances to quickly add and drop critical assets and capabilities (Deloitte insights, 2018). This is not an easy task, especially because smart packaging products are still in the early stage of development and there are no long-term proven successes (Agility-Logistic insights, 2020). This lack of data makes it difficult not only to develop a solid and robust commercial business model for the product (Aliakbarian, 2019) but also to follow Best Practices already present in the market. This means that there are no proven best methods for production, i.e., there are no repeatable procedures that have proven to be better over time in terms of both efficiency (less effort) and effectiveness (better results), ensuring that objectives are achieved with maximum economy and quality.

Achieving the same sustainability goals requires the coordination of all the supply chain actors and the share of a large amount of sensitive information and data. For this reason, the issue of trust between partners is of paramount importance and, if not properly considered, can become a real barrier to the adoption of smart packaging along the supply chain (Food Navigator, 2020). Then, all these data must be secured, in order to protect by any unauthorized access. Smart packaging technologies are capable of collecting a large amount of data about different steps in the food supply chain, and, as in any context where third-party information is collected, smart packaging need to respect privacy laws. In particular, solution providers should be able to manage privacy issues with their customers through contractual agreements with their B2B partners (Deloitte insights, 2018). Among the principal solutions to address these types of issues related to security and privacy are cryptographic and blockchain systems. (Food Navigator, 2020)

After considering the importance of trust in sharing sensitive information and talking about the need to secure access to data, consider how best to manage it in order to derive value from it. Since smart packaging is able to provide a large amount of data related to the food contained or the environment in which it is placed, it is necessary to understand how to handle and manage this information properly. At the level of the entire supply chain, mathematical models are needed to process signals deriving from smart packaging, analyse data obtained, make predictions for the future and estimations based on historical and present data ,e.g., shelf life predictions, food loss estimations (Vanderrost et al., 2014). All these actions are necessary to support producers, distributors and decision makers in taking appropriate and effective actions and understanding their implications. Moreover, these systems are able to detect external or internal conditions variation during the entire product journey, but identifying the failing step (and thus the responsibility for that abuse) in the supply chain might be difficult (Aliakbarian, 2019). For example, some devices, like time-temperature indicators, might display temperature abuses that occurred before the food reached the retailers' shelves, but it is not always clear who is the "guilty" along the supply chain. For this reason, responsibility identification is a critical topic that must to be properly considered when a company adopt smart packaging systems along the supply chain.

In conclusion, even if smart packaging is an innovation with countless benefits, it can be said that there is no real competitive market for these products as they are still relatively young and have a long way ahead to spread in the mass market (Deloitte insights, 2018). Companies should be bolder and more creative, think outside the box and seize the opportunities that the external environment offers: bold actions and new business models have a key role in the data-enabled world of smart packaging.

2.6 Drivers to overcome adoption barriers

After analysing the findings of the literature regarding barriers to the adoption of communicative packaging, the Research continued by looking for possible drivers to overcome these barriers. As already said in section 2.1, a substantial gap emerged because of the extreme novelty of the topic and only one scientific paper, deriving from search for drivers (see *figure 2.5*), has been analysed.
The article deals with supply chain sustainable innovation and describes the drivers to overcome barriers to the adoption of these innovation. The discussion can be extended to communicative packaging, as a sustainable innovation to be adopted along the supply chain, but it will be deepened later through case studies and dialogue with companies. Given the lack of academic articles on the topic of drivers, it was preferred to keep the drivers on sustainable innovation only as a starting point, but RQ2 was answered later through the experiences of the actors directly involved.

The drivers referred to SC sustainable innovations have been adapted to the case of communicative packaging and have been summarized in a table. (*Table 2.4*)

Table 2.4: Drivers to overcome barriers to adoption (Source: Author's elaboration of the study made by Gupta et al., 2020)

DRIVERS	DESCRIPTION
REGULATORY SUPPORT	Formulation of various policies by policy-makers to promote sustainability practices within companies (in the form of tax relief, access to the latest green and sustainable technologies, infrastructure support, waste management and recycling policies, support for the development of intellectual property related to innovative products and processes)
INTERNAL DEVELOPMENT	Internal promotion of technological skills that can help in sustainable development and aims at promoting the allocation of separate funds for sustainability innovation initiatives (e.g. acquisition of the latest technologies, development of recycling and reuse facilities within the organization).
R&D ACTIVITIES	Development of research facilities within the organization for developing and improving products and processes innovation. This includes setting up research labs for material reduction, energy management etc.
COLLABORATION AND NETWORKING	Building collaborative capabilities and competencies within the organization and between external organizations and institutions. Collaboration can be in terms of technology exchange, training of employees, and joint development of new sustainable technology along with some R&D labs or institutions.
MARKETING AND PROMOTION	Promotion of the benefits of sustainable products to the customers so that the demand of the products increases.

3. Research gaps and RQs formulation

The analysis of the literature has allowed to have a very wide, but at the same time precise picture of what are the characteristics of food packaging. It allowed to have a clear picture of all the sustainability issues related to packaging, how it is essential not only to protect the food, but also to convey valuable information and reduce food surplus along the supply chain. It was possible to deepen the theme of communicative packaging and its "smart" functions that allow to collect data related to food throughout the supply chain, communicate with different actors in order to optimize the management of product flows and minimize waste. It was also possible to identify the difficulties that these technologies bring with them, both economically and environmentally, but also from an organizational point of view, as their implementation requires the collaboration and coordination of all actors involved.

A first substantial gap, however, has emerged with respect to this point. In the literature, in fact, most of the discarded articles concerned the barriers perceived by the final customer rather than by the supply chain actor, and the number of publications that looked at the topic of smart packaging adoption by supply chain actors point of view was very limited.

In addition, it was difficult to find articles regarding the barriers and difficulties associated with adopting communicative packaging. There is a lack of a clear picture in the literature showing all the barriers that need to be overcome to achieve the diffusion of these technologies. In the academic articles, but also in the inspected grey literature, there is a tendency to describe the benefits that can be obtained through the adoption of these technologies, but little study has been done regarding all the problems that need to be faced and in what way, through what drivers, it is possible to overcome them. For this reason, once understood the great potential of communicative packaging, thanks to its ability to convey important information and minimize surplus food generation, this Research aimed at understanding the reasons that slow down the spread of these technologies, the barriers that are perceived by the actors of supply chain., in order to have a clear picture that summarizes these practical issues related to the adoption of these technologies.

These issues led to the formulation of the first Research Question (see RQ1 in *figure3.1*), which had the objective to bring a clear classification of the barriers to the adoption perceived by the actors of the supply chain.

In the last part of literature review, another substantial gap emerged regarding the possible drivers to follow along the supply chain in order to overcome the barriers to adoption which were found in literature. The extreme novelty of topic of communicative packaging prevented from having much information regarding possible drivers to solve issues, because the technology is still immature. Therefore, many barriers emerged from literature are still too strong to enable the formulation of proper drivers to facilitate the adoption of these kind of technologies.

This lack of information regarding drivers led to the formulation of the second Research Question, which had the objective to propose a number of drivers to overcome barriers to adoption of communicative packaging technology along the supply chain.

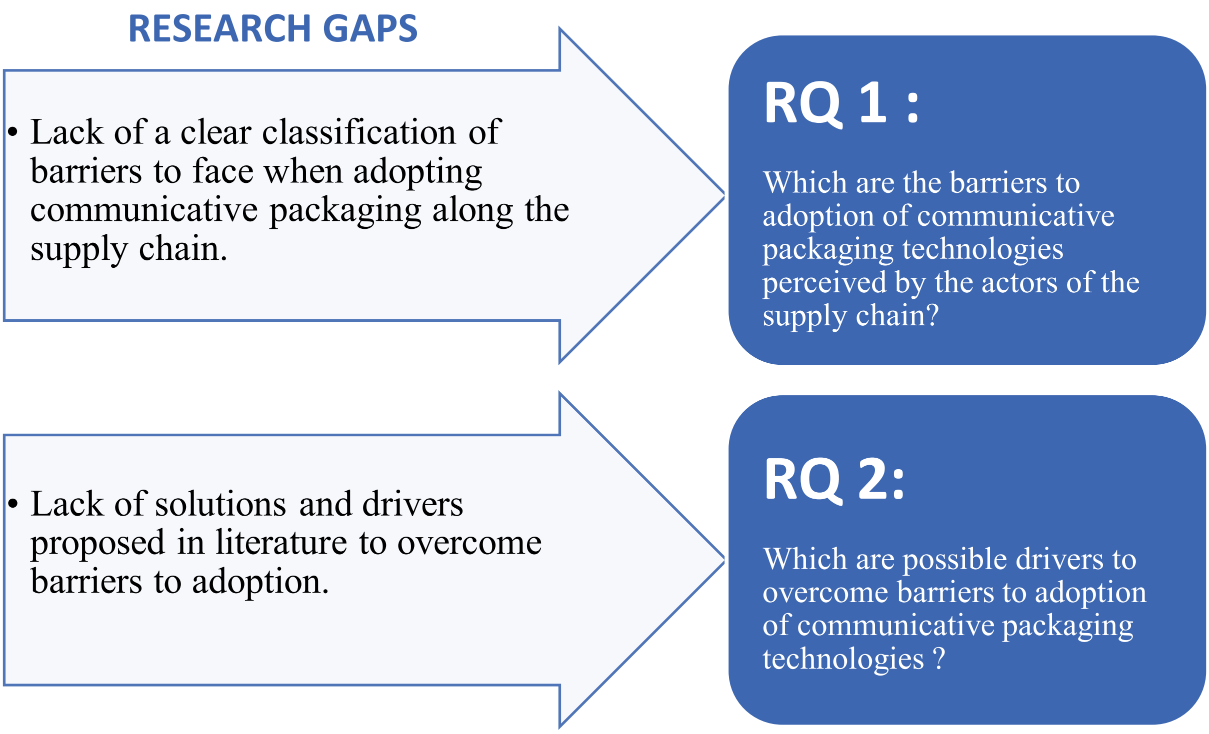

Figure 3.1: Research Questions formulation (Source; Author's elaboration)

To further explore the first Research Question, it was appropriate to look at the barrier issue not only from the single actor point of view, but from a technology perspective as well.

To answer RQ 1, firstly, a taxonomy of barriers has been elaborated, classifying the barriers emerged and the specific actor of the supply chain who perceive them. The taxonomy is an output of a literature systematization. The final output has been elaborated with the support of a table on Microsoft Excel in which the different barriers reported in academic literature have been listed and each of them have been associated with the actor who may face them along the supply chain. To make the table visually clear, barriers have been labelled with standard periphrasis. The taxonomy serves to create a conceptual model in the form of a matrix in which the barriers are disposed in the vertical axis, while the actors are in the horizontal one (*figure 5.3*). The result is a reference barrier-actor framework that allows understanding which barriers a specific actor have to overcome to adopt communicative packaging technologies within the supply chain.

After that, it has been possible to go into more details about the single technology, in order to understand which barriers is perceived with respect to the technology to be adopted. The same taxonomy of barriers has been enlarged to the technology point of view and the result is a reference barrier-technology framework (*figure 5.4*) in which the barriers are disposed in the vertical axis, as in the first framework, while the technologies are in the horizontal one.

RQ 2 have been approached in the same way of RQ 1 through a focused literature review, but a substantial gap emerged because of the extreme novelty of the topic. For this reason, the drivers to overcome adoption barriers have been deeper discussed directly with the actors of supply chain in the phase of Case Study.

4. Methodology

This chapter provides the description of the Research methodology applied in order to address the Research Questions. In Section 4.1 the first part of the Research methodology is explained, that is the re-elaboration of academic and grey literature results, which allowed to classify barriers to adoption dividing them into six macro-categories and to produce two conceptual frameworks (*figure 5.3* and *figure 5.4*) analysing the barriers emerged from the actors point of view and from the single technology point of view. These frameworks are shown and described in Chapter 5.

Section 4.2 describes instead the methodology adopted in the second phase of the Research, to consolidate the theoretical frameworks obtained through the analysis of real case study. This second phase was conducted through interviews with selected companies, with the objective to corroborate and expand the results obtained from the literature review and elaboration of conceptual frameworks. The information gathered by literature analysis has been triangulated with the ones obtained from dedicated interviews. The structured decision-making process that led to the choice of the case study is illustrated in section 4.2, with also all the steps of the case study design, including the identification of the unit of analysis, the selection of the case, the data collection, the data analysis, and the final results interpretation.

4.1 Conceptual frameworks

A detailed analysis of the literature on the topic of communicative packaging related to reducing the generation of surplus food and waste along the supply chain has led to a large amount of disconnected information. Although young, the topic is gaining popularity. In fact, especially in recent years, literary articles related to smart packaging technologies are becoming more widespread. The youth of these technologies, however, does not allow to have a complete picture not only of its advantages, but also of all the obstacles that must be overcome to adopt these systems. In fact, as explained in Chapter 3, a large gap emerged regarding the sphere of barriers to adoption by different actors in the supply chain. There is no clear classification of barriers in the literature, but the topic is treated in a general way and there is no real focus on the difficulties involved.

Therefore, once the main barriers to adoption were identified from the literature analysis, it was appropriate to re-elaborate them in a schematic way, in order to identify those related to the single actors in the supply chain, rather than to the end customer, and to provide a clear mirror of barriers to be resolved when discussing the adoption of communicative packaging along the supply chain.

The articles selection criteria explained in *section 2.1* have led to the selection of a total of 14 articles: 9 from academic literature (search for barriers and drivers) and 5 from grey literature. An Excel sheet was necessary to schematize the barriers emerged, group them according to similarities and keep track of source of origin.

A summary of the process followed to obtain the final conceptual frameworks is proposed in *figure 4.1*.

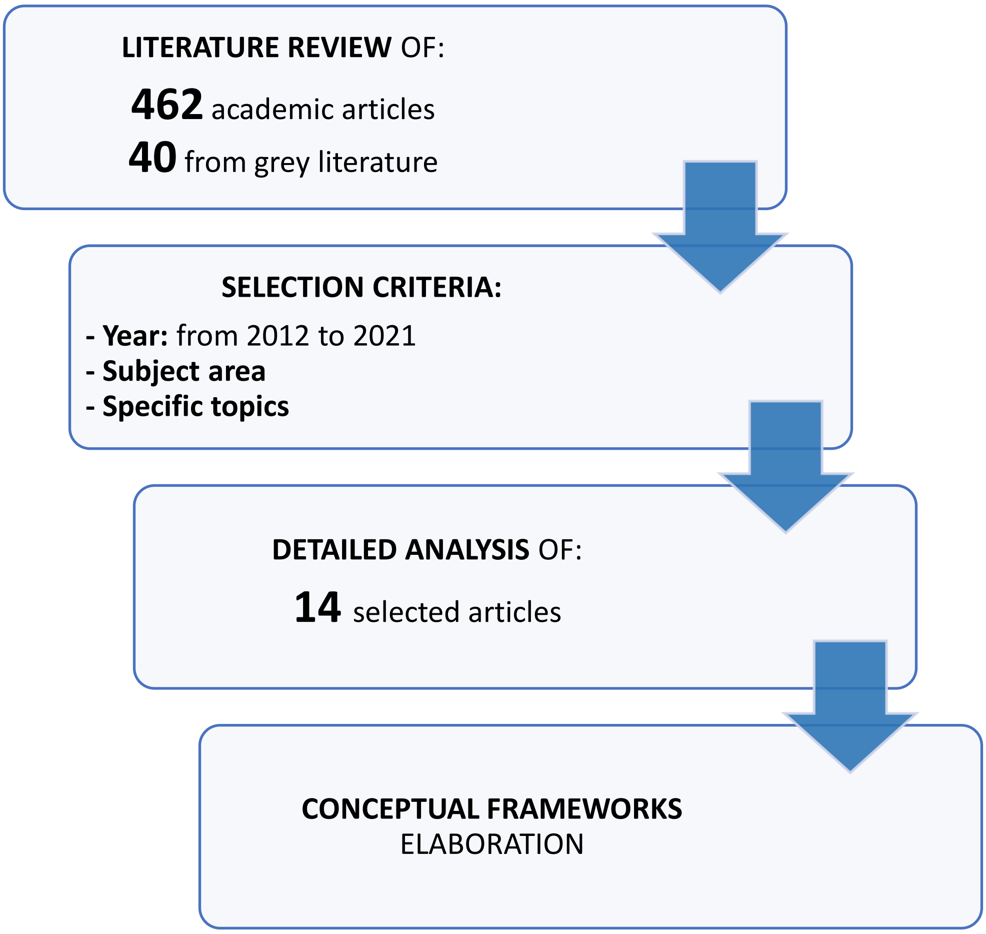

Figure 4.1: Methodology for conceptual framework elaboration (Source: Author's elaboration)

All the barriers emerged in literature have been grouped and divided in six macro-categories following the subdivision done by Gupta (2020). This paper has been taken as a model because it led to a clear classification of barriers, obtained through the analysis of academic articles and through the testimony of experts in different sectors, among which the food one. This research identified a list of barriers that hinders adoption, implementation and upscaling of sustainable supply chain innovation in the manufacturing industry. The division taken as a model for this Thesis regards six macro-categories of barriers:

- **technological and environmental barriers,**
- **economic and financial barriers,**
- **regulatory barriers,**
- **cultural barriers,**
- **organizational barriers,**
- **market barriers.**

These six macro-categories were only the starting point that enabled to have a broader view of all the spheres touched by the barriers. The use of this categorization have been confirmed by the fact that communicative packaging fall under the umbrella of supply chain sustainable innovations. In fact, *"Sustainable innovation may be defined as modified product or production process changes that seek to minimize socio-environmental impact while increasing the triple-bottom-line." (*Gupta et al., 2020). Therefore, they can benefit organizations in many ways including improving social image and profit, and reducing operational cost (Gupta et al., 2020). These objectives are the same of our previous discussion and reflect the purpose of smart packaging, in fact, communicative packaging can lead to many benefits regarding optimization of supply chain management and minimization of surplus food, leading to a positive impact on society, environment, but also on economy.
Thus, this initial classification have been selected as a starting point for a classification of barries and then it has been enlarged to our research objectives, creating for each macro-category some sub-categories specifically related to communicative packaging subject.

After a careful analysis of the selected papers, it has been possible to schematize the results through an Excel table reporting citations and main concepts of each article. The common aspects have been grouped in the same sub-category in order not to have repetitions, but to have a complete picture of the main barriers which have been identified from literature.

To have a punctual picture of which actor in the supply chain perceives the barriers, literature findings have been schematized in a proper way: each barrier emerged has been referred to the actor who has to face it along the supply chain. Specifically, the problem has been studied from the offer side, in the shoes of technology providers, and from the demand side, in the shoes of the other supply chain actors i.e., post harvest, manufacturers, logistic operators and retailers.

Secondly, to have a punctual picture of barriers perceived with respect to the single technology adoption, barriers have been referred to the specific technology i.e., barcodes, RFID, chromogenic inks and sensors.

This re-elaboration has led to the development of two conceptual frameworks that allow a clear visualization of the results. The first elaborated framework is denominated for simplicity "framework barrier- actor SC"(*figure 5.3*) and the second one "framework barrier-technology " (*figure 5.4*). They are explained in detail in *section 5.2*.

After this literature analysis, the study continued by analysing the degree of relevance of the single barrier at a global level, i.e. considering the number of times they were mentioned in the selected articles, without distinguishing between supply chain stages nor between single technologies. The result was a prioritisation of barriers dividing them into high, medium or low relevance barriers. The final classification can be seen in *section 5.3*.

4.2 Case Study

A case study is defined as "*an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident*" (Yin, 2003). This highlights the purpose of the case study, which is to investigate a complex phenomenon within its context, since contextual conditions also play an important role in the study (Ghezzi, 2019). The investigation is developed on multiple sources of evidence. This shows the need for data triangulation and implies that the researchers must use both primary and secondary information to ensure that the data converge and are aligned (Ghezzi, 2019).

Theoretical propositions, previously developed on the basis of information found in literature about the phenomenon under analysis, can bring benefits and guide the data collection and subsequent analysis in the appropriate direction. In fact, the starting point of this Research was the analysis of the existing literature, from which a theoretical framework has been derived with regard to barriers to adoption of communicative packaging along the supply chain. This served as a guide for the second phase of the Research, which was the collection of data for the case study to corroborate results deriving from literature analysis.

Three different macro types of case study can be found: descriptive, explanatory, and exploratory. The descriptive case study has the objective of accurately describe something, which may be a person, a situation, or a process. In this case, previous theories already present in the literature, are fundamental in order to define the variables and events to be further investigated through the case study (Ghezzi, 2019).
The explanatory case study adds a contribution to the theory, exploring in the case the hypotheses generated on the basis of the theory and trying "to explain the presumed causal links in real-life interventions" (Yin, 2003).
Finally, the exploratory case study is applied when most of the variables are uncertain and it is not possible to develop hypotheses a priori, when a given phenomenon is new and still unexplored (Ghezzi, 2019).

The type of case studies in this thesis is explanatory, that means study the reflection of hypothesis in real cases and make a contribution to theory. The purpose of interviews is to corroborate literature results in order to add value to the theoretical framework elaborated. Specifically, the purpose is to see if companies are in line or not with barriers emerged from the analysis and understand which can be possible drivers to overcome barriers to adoption, from the point of view of the supply chain actors directly involved in communicative packaging adoption.

For the selection of case studies the structured methodology explained by Yin (2003) has been used and it is described step by step in this paragraph (*figure 4.2*).

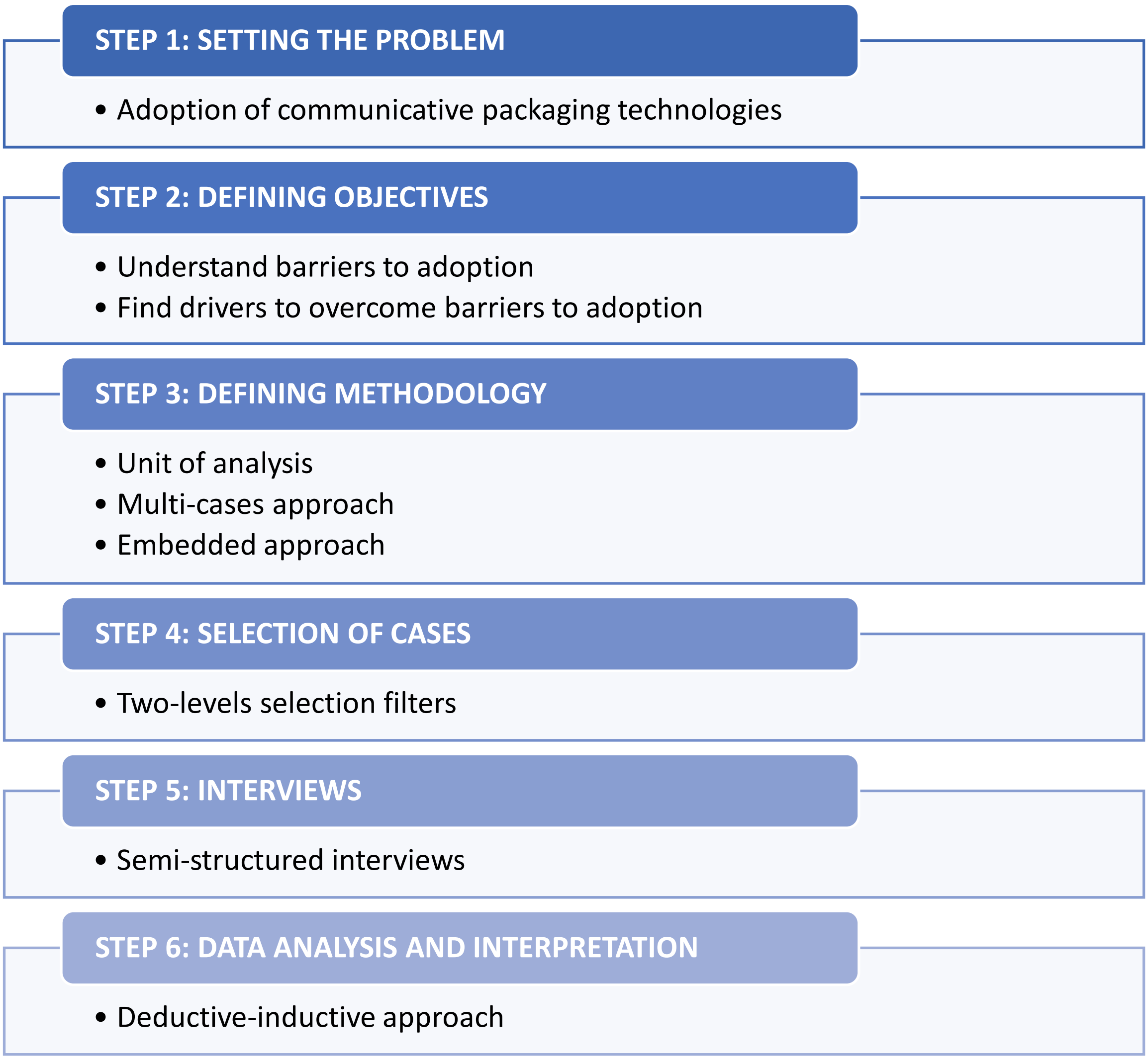

Figure 4.2: Methodology for case study selection (Source: Author's elaboration of methodology described by Yin, 2003)

STEP 1: Setting the problem

The investigated problem regarded the adoption of communicative packaging technologies along the supply chain in the Italian context, which have the potential to reduce the generation of surplus food and waste.

STEP 2: Defining objectives

The first objective was understanding the barriers to the adoption of these technologies perceived by the different actors of the supply chain, from the offer side (i.e. technology providers), to the demand side (i.e. post harvest, manufacturers, logistic operators and retailers). In addition, the second objective was understanding the possible drivers to overcome these adoption barriers from the point of view of actors directly involved.

STEP 3: Defining methodology

3.1 Units of analysis

When defining the methodology, it is necessary identify the unit of analysis of the case study, which outlines the boundaries of the case. Identifying where the phenomenon is located and which is the main object under analysis help to understand what information should be included in the investigation and which neglected. The unit of analysis can be different based on the type of study. It can be represented by individuals, single decisions, organizations, or processes, etc. The formulation of the Research Questions generally allows to identify a certain unit of analysis, which is the most appropriate research object (Yin, 2003). In this case the units of analysis are the actors of the food supply chain (with the exclusion of final customer). The single company in the different phases of the chain has been analysed to answer our Research Questions understanding the different points of view of the actors involved and the differences between the adoption of the different technologies.

3.2 Multi-cases approach

After identified the unit of analysis, the second step of the case study design is the selection of the cases. Yin (2003) outlines two different types of case studies approaches: single-case and multiple-cases. A single-case study is an ideal approach if the case has specific characteristics (i.e. pilot cases, longitudinal cases, revelatory cases, representative cases, etc.). Multiple-cases, however, provide more relevant results with respect to single-cases and allow the analysis of a wider number of results that entail a richer range of considerations. For these reasons, in this thesis, a multi-cases approach has been adopted.

3.3 Embedded approach

When selecting the cases studies, it is necessary to distinguish embedded and holistic case studies (Yin, 2003). Respectively, an embedded case study involves more than one specific unit of analysis, while a holistic case study examines the global nature of a phenomenon. The embedded approach is only suggested if it actually adds value to the study, because considering different units of analysis significantly augments complexity (Ghezzi, 2019).For our specific purpose, an embedded case study has been preferred, because it induces to a very high level of attention to the original Research Questions.

STEP 4: Selection of the cases

Two-levels selection filter

To choose the actors to be interviewed the first filter used had the objective to give a full coverage of the entire food supply chain.

The first filter regards the supply chain phases. Actors of every stage of the SC - technology providers, post-harvest, manufacturers, retailers and logistic operators - have been selected. Specifically, both actors who developed new technologies and actors who adopted them in their company have been interviewed. In this way it has been possible to analyse either the point of view of the technology providers from the offer side, and the point of view of the other supply chain actors from the demand side.

The second filter regards the technology subject of analysis- RFID, barcodes, chromogenic inks and sensors- used or developed by the target actor, in order to have a tangible impact on food waste reduction along the food supply chain. This two filters used are schematized in *figure 4.3*.

The two-levels selection filters enabled to have a broad range of analysis considering the heterogeneity of actors interviewed and enabled to widely extend the discussion of barriers and drivers from the literature point of view to real cases.

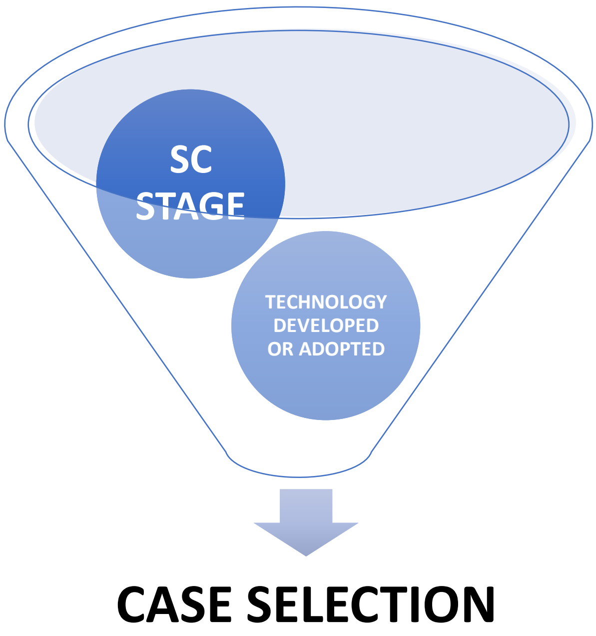

Figure 4.3: Two- levels filter used for case study selection (Source: Author's elaboration)

Thanks to the information found in specialized websites and to the collaboration of Food Sustainability Observatory, it has been possible to find nine companies to interview, which were in line with our above mentioned filters. Some of them were part of the Food Sustainability Observatory Community, others have been contacted through the net. Managers and technology specialists have been contacted through LinkedIn and e-mails and interviews took place on Microsoft Teams.

STEP 5: Interviews

The type of interview chosen for this thesis is semi-structured. This means starting from a certain number of predetermined questions, then arguing and asking further questions that emerged. The line followed in the interviews were focused on four points:

1) ***Which technology did you implement ?***

   This question allowed to frame the companies with a specific technology that has been adopted or with which they had some experience, i.e, if in the past they considered adopting it or if they used it in a past project, even if currently no longer in use.

2) ***Which barriers to adoption did you perceived ?***

   This question, after an introduction in which we reported the literature findings and described the barriers that emerged from the literature review, let the companies tell us about their experience trying to understand if they agreed with the barriers proposed or, if they did not agree, what other barriers they have perceived.

3) ***Which obstacles did you manage to overcome and how (strategies adopted and possible drivers)?***

   This question aimed to understand which barriers are no longer perceived by the actors because they been overcome; further it aimed to understand how they have managed to do so and to identify possible strategies already adopted or drivers perceived.

4) ***Which barriers are still so strong to prevent the adoption of this technology ?*** This last question aimed to understand which barriers are still too difficult to overcome and why, trying to understand what could be possible drivers to overcome these difficulties in the future.

Before the day of the interview, the selected actors received a document to introduce the objectives of this research. The document contained a section explaining the purpose of the work, a section summarising the methodology used for the literature research and a section reporting the results from the literature and thus the two conceptual frameworks developed. It also anticipated the questions that would be asked of companies to guide the conversation about the barriers to adopting communicative packaging and the drivers to overcome them.

The four questions mentioned above have been only the starting point of the discussion, and the resulting information have been triangulated with data coming from the previous literature analysis.

STEP 6: Data analysis and interpretation

In order not to allow personal considerations to take over in the analysis and selection of the collected data, interviews have been recorded and transcribed. After transcription of all the interviews, the text has been deeply analysed. It consisted in the analysis of the contents with the purpose to identify significant events, patterns, relations, etc., which can be referred to as concepts. This process is called "coding". A code is defined as a label, a concept, a word that signifies what is going on in this piece of data (Ghezzi, 2019). Giving labels to the information found is like reducing data into specific categories. This is a very important practice, because it allows to focus the analysis on the concepts that are truly relevant for the purpose of the Research, without going outside the scope of the Research Questions.

The **coding process** for the interview analysis can be approached in two ways: following an inductive approach or a deductive approach. Inductive research involves the search for pattern from observation and the development of theories through series of hypotheses. (Bernard, 2011).

Labels are not predetermined on the basis of theoretical concepts but are defined starting from the text of the interviews. It is an "open coding", which is used especially when the phenomenon under analysis is mostly unknown. This means that the final generalisation is achieved through inductive reasoning. On the other hand, following the deductive approach, the definition of codes is made starting from the existing theory. In this way, the theoretical elements deriving from the study of the literature are selected deductively within the text of the interviews, aligning the interpretation of data (Ghezzi, 2019).

For the interviews analysis a **mixed approach has been followed**. Firstly, a **deductive approach** was useful to identify codes, used to extract the primary information from the transcribed text of the interviews. Therefore, the labels for barriers to adoption were defined based on the literature and following the classification of barriers explained in Chapter 5. However, considering the nature of the semi-structured interviews and the fact that new themes could emerge during dialogues, new elements could be included within the coding. Therefore, the coding process started from a deductive approach and continued following an **inductive approach** to have a broad view of the phenomenon and a deep analysis of the real context, starting from the literature one.

The codes extracted from the analysis of the interviews were reported in tables by dividing the actors according to the stage of the supply chain to which their company belongs and considering their degree of experience with the individual technology under exam.

In order to make a detailed analysis of how barriers are perceived by the supply chain actors, the coding process was repeated individually for each stage of the supply chain: technology provider, manufacturer and retailer. For each stage, the experiences of the different companies belonging to that stage of the SC were aggregated into a single sample and reported in a single overall table. It was therefore possible to collect information from:

- a sample of 4 companies for the technology provider stage,
- a sample of 3 companies for the manufacturer stage,
- a sample of 1 company for the retailer stage

Moreover, in the specific case of RQ1, it was possible to make an analysis of the data by considering either the stages of the supply chain and the technologies. For each interview, the questions concerned both their direct experience with the adoption of a specific technologies and also their knowledge of other technologies, even if not used by their company. In this way, it has been possible to extend the discussion to all communicative packaging technologies existing on the market, whether they are more or less widespread. Interviewing actors in the supply chain who have had direct experience with the implementation of these systems has been very important in order to understand what barriers have been faced during the adoption. Moreover, since the focus of this Thesis is understanding the barriers to overcome, discussing with experts the reasons why they have not used other technologies is of equal importance, because it leads to understand what hurdles are still so difficult to overcome in order to have a large-scale diffusion of communicative packaging technologies.

In the case of RQ2, on the other hand, it was possible to structure the analysis in a more general way, distinguishing between the stages of the supply chain but without going into the details of the individual technology.

As far as barriers are concerned, it is possible to see all the tables used for coding interpretation in *Chapter 6*, specifically in *section 6.3*.

Now a table is reported as an example. The coding process (deductive approach) comprehends:

- **Company name**: each company interviewed was associated with a letter from A to I to maintain anonymity;

- **Technology:** the technology being discussed, whether the company has had direct experience or not. A distinction between application or only knowledge of technology has been done through the asterisks: two asterisks if the company adopted or developed the specific technology, one asterisk if it did not;

- **Macro-category barriers**: the six macro-categories from the literature were used as codes to understand at an overall level what the most critical issues were;

- **Sub-category barriers**: sub-categories from the literature were used as codes to go into more detail and this column also lists new barriers mentioned in the interviews, which were not identified in the literature (identified with the symbol “#”in this column);

- **Quote:** here are reported some meaningful extracts from the interviews..

Table 4.1:Example of coding process for barriers (deductive approach) (Source:Author's elaboration)

COMPANY	TECHNOLOGY	MACRO-CATEGORY BARRIERS	SUB-CATEGORY BARRIERS	QUOTES
Name	• Barcodes • RFID • Chromogenic inks • Sensors	• Technological/ environmental barriers • Economic/ financial barriers • Regulatory barrier • Cultural barrier • Organizational barriers • Market barriers	• Lack of proper R&D activities, protocols and standard tests • Lack of recyclability for some smart packaging components • Lack of mass market and affordable prices • Lack of long-term profitability perspective • Lack of adequate regulation • Inertia toward new technology adoption • Lack of collaborative processes along the SC • Lack of Best Practices in the market to follow • Lack of solutions for security, privacy, and data ownership issues • Lack of a data management system for decision-making/ difficulty in identifying responsibility along the SC • Lack of trust in sharing information with other actors along the SC • Lack of smart technology market-competitiveness • Difficulty in interpreting information conveyed by technology#	*Quote from interview*

After the first coding process for analysis of barriers, the transcribed texts have been re-analysed to find possible drivers to overcome these barriers. This step was more complex since there are not existing solutions already in place, but experts talked about market trends and ideas shared in this sector to solve the issues related to smart packaging adoption on a large scale.
It has not been possible to find a strategy for each barrier deployed, due to the youth of technologies, neither it has been possible to find a strategy specific to each technology since the difficulties are the same for all of them.

However, many common points emerged from the discussion with companies in different stages of the supply chain. The codes used in this phase relate to drivers derived from literature. The coding process is shown in *chapter 6*.

Now an example is reported in *Table 4.2* and include starting from left: the company name, the barrier under analysis, the driver to overcome it and a quote from the experts' speeches.

Also in this case to make a detailed analysis of how barriers can be overcome by the supply chain actors, the coding process was repeated individually for each stage of the supply chain: technology provider, manufacturer and retailer.
For each stage, the experiences of the different companies belonging to that stage of the SC were aggregated into a single sample and reported in a single overall table. It was therefore possible to collect information from:

- a sample of 4 companies for the technology provider stage,
- a sample of 3 companies for the manufacturer stage,
- a sample of 1 company for the retailer stage

Table 4.2: Example of coding process for drivers (inductive approach) (Source: Author's elaboration)

COMPANY	MACRO-CATEGORY BARRIERS	DRIVERS	QUOTES
Name	• Technological/ environmental barriers • Economic/ financial barriers • Regulatory barrier • Cultural barrier • Organizational barriers • Market barriers	• Regulatory support • Internal development: • R&D activities: • Collaboration and networking: • Marketing and promotion	*Quote from interview*

Once a clear outline of the data emerging from the case study was obtained through the coding process, the analysis continued with the **interpretation of the results**. It was possible to identify the barrier experienced by each respondent and to assess the degree of relevance of the single barrier both from the point of view of the literature and from the point of view of the case study.

This step of interpreting the results is of great importance. By analysing the results of the case study it was possible to confirm some barriers that had previously emerged, to understand if they were exhaustive, if there were some not reported in the literature or if there were some not perceived.
In this way it has been possible confirm the barriers, understand if they are exhaustive, if some are not perceived, if there are others.

Tables have been used in the interpretation of the codes for each specific SC stage. In this way it was possible to compare the literature and case studies in detail for each stage and distinguishing between the individual technology.

5. Conceptual frameworks

After the analysis of academic and grey literature regarding smart packaging technologies, several barriers to adoption emerged. In the literature review chapter, in section 2.5, are extensively described the main obstacles that emerged. A systematization of the findings led to a classification of barriers. A more punctual description of each barrier is proposed in this chapter. The methodology followed for the literature systematization and the final elaboration of conceptual frameworks is explained in chapter 4.

The two summary frameworks (*figure 5.3* and *figure 5.4*) have been elaborated to comprehensively present all the barriers to adoption that emerged from the articles in academic and grey literature, first with a focus on the actors who face them and then with a focus on the technologies to which those barriers relate. Through the reading of these frameworks, it is possible to have a visually clear image of barriers to adoption, answering to RQ1. Each barrier included in the classification is described in detail in section 5.2.

5.1 Classification of barriers based on academic and grey literature findings

This section will describe the barriers that emerged from the review of the selected articles (see *figure 2.3* and *figure 2.4* for the selection methodology).

Because the literature has led to a not deep understanding of the barriers to adoption of communicative packaging, this Research aims to clearly outline them through the use of a classification. The first step in the review of the academic and grey literature was to identify the macro-categories of barriers, i.e. technological/environmental, economic, organizational, cultural and market barriers, thanks to research on supply chain innovations by Gupta (2020). From here it has been possible to summarize the results of the literature detailing these six macro areas. Sub-categories barriers have been labelled for each macro-category by the Author of this Thesis, to accurately describe all the barriers that relate to each specific area.

A summary of the barriers is provided in the *table 5.1*. Through the table, it is possible to read all of the subcategories linked to the six main areas, allowing for a clear view of any critical issues identified through the analysis of the academic and grey articles.

It has been possible firstly to identify all the single sub-categories through an accurate analysis of the articles found, and then to group the common points of the different articles through Excel tables containing keywords and citations. From these common points the Author identified sub-category barriers in order to comprehensively present the theme of barriers to adoption of communicative packaging along the food supply chain.

A detailed description of the sub-categories of barriers, with the literature references that allowed for the creation of this taxonomy of barriers is provided in this section.

Table 5.1: Summary of barriers to adoption (Source: Author's elaboration)

	SUB-CATEGORY BARRIERS
TECHNOLOGICAL AND ENVIRONMENTAL BARRIERS	Lack of proper R&D activities, protocols and standard tests
	Lack of recyclability for some smart packaging components
ECONOMIC AND FINANCIAL BARRIERS	Lack of mass market and affordable prices
	Lack of long-term profitability perspective
REGULATORY BARRIER	Lack of adequate regulation
CULTURAL BARRIER	Inertia toward new technology adoption
ORGANIZATIONAL BARRIERS	Lack of collaborative processes along the SC
	Lack of Best Practices in the market to follow
	Lack of solutions for security, privacy, and data ownership issues
	Lack of a data management system for decision-making and difficulty in identifying responsibility along the SC
	Lack of trust in sharing information with other actors along the SC
MARKET BARRIERS	Lack of smart technology market-competitiveness

5.1.1 Technological and Environmental Barriers

Starting from the analysis by Gupta (2020) of barriers to supply chain sustainable innovations, the first aspect to consider has been technological and environmental. These barriers relate to the technological development of the technologies under consideration, their degree of maturity, and anything that can be improved from a technological standpoint to increase their performance, minimize errors, and thus succeed in reaching a mass market with lower prices.

Alongside this point of view is the environmental one. In fact, since these technologies have an important role in terms of sustainability, as they are valid solutions for reducing food waste, they must be sustainable from every point of view, not only social and economic, but also environmental. The environmental barrier is therefore related to the need to make all the components of sustainable innovations compatible with the environment, i.e. recyclable or reusable, in order not to create further waste through the arrangement of these system.

This macro-category barrier, enlarged to our specific case of communicative packaging, thanks to the literature review has been more detailed and has been divided into two sub-categories described below: *"lack of proper R&D activities, protocols and standard tests"* and *"lack of recyclability for some smart packaging components"*.

Lack of proper R&D activities, protocols and standard tests

The smart packaging technologies selected for our study, i.e., chromogenic inks, RFID, sensors, and barcodes, are not all at the same level of maturity. For example, RFID and barcodes are certainly the most widely used in industry, as well as the least expensive, while, due to some limitations such as accuracy and quality indication by visible color changes, the commercialization of sensors and indicators (based on chromogenic inks) is still at the beginning stages and they need more R&D activities to solve several issues (Mohammadian & Mahmood, 2020).

At the industrial level, more research is needed to scale-up for example the production of freshness indicators based on chromogenic inks and to develop technically and economically feasible methods to include them in the common packaging used in food. (Becerril et al., 2021). Apply natural colorants may not be stable enough, whereas chemical ones may lead to safety concerns. Therefore, stability and safety of colors is required to be further studied and considered (Mohammadian & Mahmood , 2020). To maximize smart-packaging efficiency in association with food waste decrease, these technologies should have a slight false positive as possible. A packaged food thrown away because smart packaging signals an anomaly by mistake, while it is still edible, would led to further food waste. And this kind of error is absolutely not acceptable with respect to the objective of minimize food waste thanks to these technological solutions. Another common error regards shade of color that sometimes confuses and does not give clear and unambiguous information about the product contained. For example if the indication of color from edible to non-edible is from white to red, when the indicator will show a color similar to pink it is not clear if the food is still good or must be thrown away. It could be thrown away because the indicator is not perfectly white, although the food contained is still good to eat. This, like the previous example would lead to further food waste and go against the sustainability principles that smart packaging pursues. For this purpose, more and vast validation studies should be accompanied by larger sample sizes and test as much as possible. Advanced guidelines, protocols, and standard testing assays would support in the development of smart systems indicators and their future transfer into industrial scale (Aliakbarian, 2019)

As far as sensors are concerned, they are still considered as useful research tools rather than necessity which can improve food safety and quality and attract new customers because they show very low profit margins in the food industry due to the very high cost (Banerjee et al., 2016). The diversity of packaged products is another issue because, for many of them, packaging materials and sensor materials should be individually tailored, and proper R&D activities need to be performed. (Banerjee et al., 2016). In conclusion, even if these technologies show a huge potential in the food sector, more R&D is fundamental to improve the performance, lower the prices and facilitate the adoption.

Lack of recyclability for some smart packaging components

Considering that communicative packaging technologies are a necessary tool for reducing food waste and pursuing sustainability goals, it is inevitable that the materials from which it is made must also be in line with these sustainability principles. It would be a paradox to create non-recyclable waste from the use of packaging, which would have the purpose of limiting waste. For this reason, it is necessary that these technologies respect the environment and do not produce further waste. Packaging materials (e.g., inks) and intelligent devices (e.g. sensors, RFID tags) are not designed or selected with closed-loop recyclability in mind. The lack of foresight in the design of packaging and the extensive use of many different materials inevitably results in complex and expensive recycle processes and reduced performance (Vanderrost et al., 2014). In the specific case of RFID technology for example there is the need for a specific recycling program for the RFID sensor tags separating all the different parts of which it is made (Poyatos et al., 2018). In addition, when tags are attached to products and improperly removed, the impact on the recycling processes could be substantial. Materials such as adhesives, chips, pieces of metal from the antenna and conductive inks can affect the recycling process of paper, plastic and metal (Bibi et al., 2017). Furthermore, intelligent devices are often conceived as disposable single-use devices, ignoring concepts such as reusability and/or reversibility. (Vanderrost et al., 2014) Thus, a first challenge could be to think of reusable, reversible, and long-lasting devices instead of the current single-use, irreversible, and disposable items (Ghaani et al., 2016). Unluckily, many of the smart packaging components, for example, batteries, sensors, displays, and circuits are not completely sustainable and simply do not fit into the environmentally friendly, green world that customers expect. Sensors and circuits, for instance, are challenging to recycle (Aliakbarian, 2019). However, although this problem, these technologies can help reduce the million tons of food waste produced annually, so the recycling challenges of smart packaging can be offset by its ability to keep food fresh and moving down the supply chain (Agility-Logistic insights, 2020).

5.1.2 Economic and Financial Barriers

The second macro category of barriers relates to the economic and financial sphere. In fact, like any technological innovation, the adoption of new communicative packaging technologies requires a certain amount of financial availability on the part of companies to invest in new projects, not only to purchase new technologies, but also to modify existing production lines. Costs don't necessarily relate only to the purchase of new technology. In fact, it is often necessary for these emerging technologies to be compatible with the information systems and production lines already in place in the company, so that it does not take too much time and money to adopt them along the chain. Otherwise, you need to consider the implementation time and costs associated with change along the process. Cost is therefore a very delicate issue and, given the extreme novelty of these technologies, one of the main barriers to adoption along the supply chain. Also, in this case this sphere has been further detailed through the literature review of academic papers and grey literature and has led to the subdivision into two sub-categories, namely *"lack of investments, unaffordable prices and lack of mass market",* and *"lack of long-term profitability perspective"*.

Lack of investments, unaffordable prices and lack of mass market

Smart packaging solutions are not cheap, especially compared to more traditional packaging solutions such as corrugated boxes, stretch wrap, and pallets. One reason for this extra cost is that smart packaging is not yet in the mass manufacturing stage, which would reduce its costs (Aliakbarian, 2019). Another reason is that the field has only recently started to develop and only when companies will adopt smart technology en masse, costs will fall (Agility-Logistic insights, 2020). It must be said that not all communicative packaging systems have the same costs: barcodes, QR codes or even passive RFIDs are inexpensive technologies, while more intelligent solutions that use active RFID or technologies that track temperature and shock, require sensors that are too expensive to use, making certain smart applications cost-prohibitive. (Deloitte Insights, 2018). As far as RFID is concerned, its cost should be kept as low as possible so has not to impact the final cost of food products. The cost of tags below an order of 1 million is of $0.3 each (Bibi et al., 2017), unfortunately more expensive than barcodes. This limits their usage as some companies found that moving to RFID technology is unaffordable (Bibi et al., 2017). While RFID has more advantages than barcodes, it comes at a high cost currently for many businesses. (Arvanitoyannis & Stratakos, 2012)

On the other hand, the technology of sensors shows the highest costs and, its relative complexity, the general lack of flexibility and integration options make most of them unsuitable and unaffordable for large scale use in the food industry. (Banerjee et al., 2016)

However, brands, retailers and packagers are using lower-cost smart technologies on primary package and they are experimenting with more powerful sensors on secondary/ tertiary pallet-level packaging, or on the primary packaging of high value goods such as liquors. (Deloitte Insights, 2018). Moreover, it must be noticed that it is not only a matter of costs related to the purchase of these innovative technologies, but it is also a matter of costs related to adapting or changing current production processes after introducing these systems. In fact, there can be the need for new manufacturing techniques. Before smart packaging can be applied to a variety of products, manufacturers will need to develop techniques for fabricating for example sensors and indicators that are compatible with current packaging standards (Aliakbarian, 2019). Printing is one manufacturing technique that has received significant attention from the research and manufacturing community. Researchers have found printing methods to be revolutionary approaches for fabricating smart packaging due to their ability to directly deposit electronics (for example sensors, batteries, RFID tags, and displays) on flexible substrates in an efficient, scalable, and cost-effective manner (Aliakbarian 2019). Moreover, adopting new systems of RFID or barcodes is not immediate, but require some time and money to integrate systems in the existing lines (Arvanitoyannis & Stratakos, 2012). In conclusion, investments must be done in order to implement these technologies and adapt production processes to them. Obviously, a careful cost-benefit analysis is necessary in order to understand the real advantages that a company can gain from it and, if the cost-benefit ratio is not satisfactory, it will be difficult to obtain an adequate diffusion focusing only on technological innovation (Poyatos et al., 2018).

Lack of long-term profitability perspective

As widely discussed before, communicative packaging is a technological innovation that has been evolving rapidly in recent years. The interest of companies in these intelligent systems is growing, as is also growing the attention of both companies and end consumers to sustainability and environment. But, if on the one hand this technological trend seems to be growing steadily, on the other hand there is something holding it back and not allowing it to show its full potential. In fact, the relative youth of smart technology makes it difficult to make definitive statements on profitability and cost efficiency, because the technology hasn't been around long enough to produce meaningful long-term data (Agility-Logistic insights, 2020). This lack of long-term data inhibits companies and prevents them from broadening their horizons and make investments based on meaningful past data (Aliakbarian, 2019). This insecurity is a major barrier that slows the diffusion of these technological innovations on a large scale.

5.1.3 Regulatory Barriers

The third macro category of barriers concerns the legislative and regulatory aspect, which should not be underestimated when talking about packaging that must be placed in contact with food. It is therefore necessary to comply with a large number of regulations attesting food safety and experimenting with new materials takes a long time before new substances are accepted and regulated. Moreover, the bureaucratic process is very complex and slow, so it is considered a real barrier to the adoption of new technologies as they may take too long to be accepted and regulated. This macro-category barrier is described in detail through the sub-category *"lack of adequate regulation"* which, as anticipated, includes all the different legislative aspects.

Lack of adequate regulation

From a legislative point of view, the lack of an adequate regulatory framework in the EU for intelligent packaging systems until 2004 hindered the placement of new packaging solutions into the market, in contrast to the United States, Australia, and especially Japan, where intelligent packaging systems are widespread (Ghaani et al., 2016). The lack of a clear regulatory framework for many years led to reluctance by food packaging manufacturers to take on new concepts that are not fully covered by the legislation on food contact materials (Ghaani et al., 2016).

It must be said that smart packaging's complex composition creates legal complexity. This happens because smart packaging is made up of a large number of different components, thus, it is subject to more regulations and legislation than traditional packaging (Aliakbarian, 2019). Another critical point is the interaction of active/intelligent packaging with the food and/or their surrounding environment. For this reason, these packaging creates new challenges to the assessment of their safety with respect to the traditional packaging (Mohammadian & Mahmood, 2020). There is no special directive or regulation for the active/intelligent packaging at this moment and they have to comply with the Framework Regulation 1935/2004/EC and 450/2009/EC authorized by EFSA (Food Navigator, 2020). The general principles applicable to food contact materials are set out in Regulation (EC) No 1935/2004 stating that materials and articles in contact with food shall only be authorised if it is demonstrated that they do not present risks to human health (Article 8), and more than that, shall not transfer constituents to food which bring about an unacceptable change in the composition and bring about deterioration in organoleptic characteristics thereof (Article 3). Therefore, this regulation establishes that active and intelligent materials and articles are included in its field of application and sets out general rules applicable only to active and intelligent materials. Regulation (EC) No 450/2009 is a specific measure that lays down specific rules for active and intelligent materials and articles to be applied in addition to the general requirements established in Regulation (EC) No 1935/2004 for their safe use (Enescu et al., 2019).

Current regulation limits seriously the number of substances that can be used in smart packaging applications and this issue offers a serious barrier regarding the development of new technologies, because the authorization of a new substance for food contact is a long, complex and expensive procedure (Poyatos et al., 2018). Thus, tracking and complying with these regulations will require significant time and resources. Moreover, as innovative solutions are developing fast and manufacturers and customers want to incorporate these new technologies into their packaging, legislation frameworks need to be flexible and easily updated to support and keep up with this highly innovative and fast-moving sector (Aliakbarian, 2019).

5.1.4 Cultural Barrier

This macro-category concerns a sphere that is not so much technical as "psychological". This barrier has been translated into "*inertia towards new technologies*" in the sense that often a company is used to traditional technologies, and is not able to follow an innovative drive to adopt new technology that would give countless advantages. This cultural barrier does not allow the diffusion of innovations on a large scale and it would be necessary to increase awareness on sustainable issue and convince stakeholders to innovate more. This barrier, like the previous ones, has been explored extensively through literary analysis and is described in detail below.

Inertia towards new technologies

More companies would embrace intelligent packaging if they were convinced that it could be used to encourage engagement that could build ongoing relationships between consumers and brands (Packaging news, 2019). There is the strong need to educate stakeholders on the extra benefits arising from intelligent systems. This can be achieved using clear information about the device, e.g., what purpose it serves, how it works, and how to use it (Ghaani et al., 2016). For example, the use of these packaging technologies can lead to a positive contribution to waste reduction efforts. Ensuring supply chain visibility means that brands can check at any time where and in which conditions their products are, helping them to optimise distribution to reduce inventory shrinkage and waste. Therefore, the increased sustainability and transparency can go a long way towards establishing trust in brands (Packaging news, 2019).

To be able to capture value and leverage the enormous potential of smart packaging, companies must be able to identify their unique and differentiated contribution to the smart packaging solution. This contribution gives them a seat at the "value-added table" and a stronger claim to gain access to the data generated by the smart solution (Deloitte insights, 2018). Data is key to new revenue streams and often to premium pricing. Once understood the potential of these technologies, companies should design a profit model that gives them a share of the new value created through the adoption of smart packaging. It is important to leave behind the traditional way of doing things and experiment with new pricing approaches (Deloitte insights, 2018).

5.1.5 Organizational Barriers

The fifth macro-category barrier concerns the organizational sphere. Involving so many players, the adoption of sustainable innovation, and specifically communicative packaging technologies, requires a great deal of collaborative effort and coordination among partners along the supply chain. Therefore, there are several aspects that need to be carefully considered and evaluated. For this reason, each aspect that emerged from the literature review regarding organizational problems was explored in detail and several labels for sub-category barriers have been created:

- *"lack of collaborative processes along the SC";*
- *"lack of Best Practices in the market to follow";*
- *"lack of solutions for security, privacy, and data ownership issues"*;
- "*lack of a data management system for decision-making and difficulty in identifying responsibility along the SC";*
- *"lack of trust in sharing information.*

Lack of collaborative processes along the SC

Smart packaging is a solution that requires collaboration among a number of organizations: consumer and industrial product manufacturers, material substrate providers, packagers, retailers, transporters. Very few players have all the necessary components in house. Therefore, smart packaging relies on the creation and effective maintenance of an ecosystem of partners (Deloitte insights, 2018). The challenge is the complexity of securing and managing a web of capabilities you don't own. To be able to excel in smart packaging, companies will have to disproportionately invest in their partnering capabilities, learning how to form various types of alliances to quickly add and drop critical assets and capabilities (Deloitte insights, 2018).

Lack of Best Practices in the market to follow

As previously said, since smart packaging products are still in the early stage of development, there are no long-term proven successes (Agility-Logistic insights, 2020). This lack of data makes it difficult not only to develop a solid and robust commercial business model for the product (Aliakbarian 2019) but also to follow best practices already present in the market. This means that there are no proven best methods for production, i.e., there are no repeatable procedures that have proven to be better over time in terms of both efficiency (less effort) and effectiveness (better results), ensuring that objectives are achieved with maximum economy and quality.

Lack of solutions for security, privacy, and data ownership issues

Smart packaging technologies are capable of collecting a large amount of data about different steps in the food supply chain, and, as in any context where third-party information is collected, smart packaging is likely to run afoul of privacy laws. In particular, solution providers should be able to manage privacy issues with their customers through contractual agreements with their B2B partners (Deloitte insights, 2018). Among the principal solutions to address these types of issues related to security and privacy are cryptographic and blockchain systems. (Food Navigator, 2020)

Then, another critical point regards the data ownership. The question of who owns the data that the packaging generates need to be addressed. For example, a large packaging company let the retailer "own" the data generated by smart cardboard displays in the store, and could use that data for marketing purpose to prove the value of smart displays. (Aliakbarian, 2019). Thus, the different players must not be interested in owning the data exclusively, but rather must claim their rights to capture the value that comes from the appropriate use of the data, whether it is to improve a production process, monitor the distribution phases or advertise its products (in the case of the technology provider) etc.

Lack of a data management system for decision-making and difficulty in identifying responsibility along the SC

Since smart packaging is able to provide a large amount of data related to the food contained or the environment in which it is placed, it is necessary to understand how to handle and manage this information properly. At the level of the entire supply chain, mathematical models are needed to process signals deriving from smart packaging, analyse data obtained, make predictions for the future and estimations based on historical and present data (e.g., shelf life predictions, food loss estimations). All these actions are necessary to support producers, distributors and decision makers in taking appropriate and effective actions and understanding their implications (Vanderrost et al., 2014). Moreover, these systems are able to detect external or internal conditions variation during the entire product journey, but identifying the failing step (and thus the responsibility for that abuse) in the supply chain might be difficult (Aliakbarian, 2019). For example, some devices, like time-temperature indicators, might display temperature abuses that occurred before the food reached the retailers' shelves, but it is not always clear who is the "guilty" along the supply chain. The matter of responsibility is a critical topic that must to be properly considered when a company adopt smart packaging systems along the supply chain.

Lack of trust in sharing information

As repeated several times above, the adoption of smart packaging technologies requires a collaborative effort from many supply chain actors, from the farmers to the producers and from the retailers to the distributors and logistic operators. Achieving the same sustainability goals requires the coordination of all these players and the share of a large amount of sensitive information and data. For this reason, the issue of trust between partners is of paramount importance and, if not properly considered, can become a real barrier to the adoption of smart packaging along the supply chain. For this reason, cryptography systems could be a good solution to protect sensitive data and allay any fear (Food Navigator, 2020) because they make them " blurred " so that they cannot be read by non-authorized, thus guaranteeing, in a modern way, the requirement of confidentiality or privacy typical of IT security.

5.1.6 Market Barrier

The last macro-category barrier concerns the market. Particularly because, as mentioned several times, these technologies are extremely young, there is not yet a mass market, nor a competitive market. Therefore a lack of competitive drive is seen as a barrier to adoption of sustainable innovations and more specifically also for communicative packaging. This macro-category barrier has been translated in our specific case of communicative packaging as "*lack of smart technology market-competitiveness*" and it is further detailed below.

Lack of smart technology market-competitiveness

As mentioned many times, smart packaging is a very innovative emerging technology that has not yet had a chance to fully develop and reach a large industrial scale. Although it is an innovation with countless benefits, it can be said that there is no real competitive market for these products as they are still relatively young and have a long way ahead to spread in the mass market. Players in the traditional packaging arena ignore smart packaging at their peril, as underestimating the potential of this technology could lead to the disruption of their existing business model by making their traditional packaging business irrelevant (Deloitte insights, 2018). To capture the rewards and avoid irrelevance, participants should be bolder and more creative, think outside the box and seize the opportunities that the external environment offers: bold actions and new business models have a key role in the data-enabled world of smart packaging.

5.2 Elaboration of frameworks

After identifying the barriers to the adoption of communicative packaging technologies from a general point of view, a more specific analysis was made. The classification made for barriers to adoption was further detailed to answer the first Research Question. As explained in chapter 3, RQ 1.1 aims to specify which barrier is perceived by which actor in the supply chain, while RQ 1.2 aims to understand which barriers is perceived with respect to the technology to be adopted.

The first analysis was performed to identify the specific actor in the supply chain that perceives the single barrier during the adoption of these technologies. The second analysis, on the other hand, was done to identify the perceived barriers during the adoption of the single technology.

The in-depth reading of the articles aimed at identifying the barriers following these two points of view and led to the elaboration of two conceptual frameworks that allow a clear visualization of the results. Through the first elaborated framework, denominated for simplicity "framework barrier- actor SC" (*figure 5.3*) it is possible to visualize clearly which barriers are perceived from which actor of the supply chain, i.e. technology provider, post-harvest, manufacturer, logistic operator and retailer. The second framework, called for simplicity "framework barrier-technology " (*figure 5.4*), allows to visually identify which barrier is perceived according to which technology they want to adopt, i.e. RFID, barcodes, chromogenic inks or sensors.

Starting reading the single barrier reported in the left column, it is possible to identify through the "X" the actor in the supply chain who perceives it when adopting these technologies. Similarly, in the second framework, starting from the single barrier reported on the left, it is possible to see through the "X" which technology it refers to, i.e. if it is a difficulty related to the implementation of barcode, RFID, chromogenic inks or sensors along the food supply chain

5.2.1 Framework barrier - actor

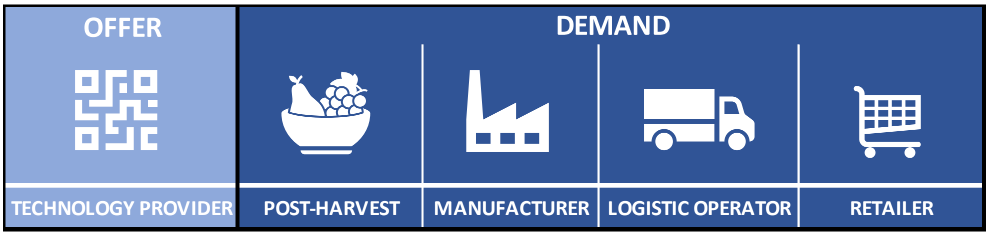

Figure 5.1: Supply chain actors involved in the analysis (Source: Author's elaboration)

The analysis of selected articles from highly specialized journals has identified barriers to the adoption of technological solutions by all the supply chain (see actors in *figure 5.1*), both on the offer side (technology provider) and on the demand side (supply chain actors: post-harvest, manufacturers, logistic operators and retailers).
Although the literature research has been conducted to identify the barriers for the five different stages of SC, in the conceptual framework developed it has been preferred to distinguish only in two cases, namely offer side and demand side, since the barriers perceived by the four stages of the supply chain related to post harvest, manufacturer, retailer and logistic operator were found to be the same. The framework barrier-actor (*figure 5.3*) has been elaborated to clearly identify the barriers perceived by the single actor of the supply chain distinguishing between offer and demand side.

In particular, from the reading of the framework, it emerges that the technological barriers are the ones perceived only by the technology providers since they need to do more R&D to refine materials, improve performance and lower the price. In addition, they are the most sensitive to the regulatory barrier because they have to comply with strict rules concerning the use of particular substances that can be put in contact with the food matrix. In addition, the authorization of a new substance is a long, complex and expensive procedure that slows down the diffusion of these technologies on a large scale.

On the other hand, other barriers perceived only by the demand side are:

- Lack of long-term profitability,
- Inertia toward new technologies adoption,
- Lack of Best Practices,
- Lack of data management system,
- Lack of trust,
- Lack of competitiveness

This is because the supply chain actors have to deal with all the obstacles concerning the purchase of technologies, from the economic point of view, to the organizational one. They perceive the barrier of unaffordable prices because of the youth of communicative packaging technologies, as they perceive the barrier of lack of long-term profitability perspective.
Thus, initially they are not sure of the investment needed to adopt these innovations and need to be convinced of the benefits arising from communicative packaging adoption. This reflects on the cultural barrier: the lack of interest and knowledge of the huge potential of these technologies prevent from the diffusion on large scale.

In addition, once convinced to adopt new technologies, they have to face all the organizational barriers: from the lack of trust in sharing information to the lack of Best Practice already used in the market that could speed up the adoption of technologies. In an optic of shared information, from the demand side, there is still the need to implement proper data management systems and to deal with the identification of responsibility along the SC if a problem occurs. Finally, the lack of competition is another barrier because there is not yet a mass market for these technologies, meaning that few stakeholders have adopted them along the supply chain. What is missing, therefore, is a competitive push that would lead more actors to adopt these systems throughout the supply chain.

In conclusion, always from the literature point of view, some barriers are equally perceived by all the actors of the supply chain, from the offer side, to the demand side. These are barriers that concern the lack of collaboration practices between all stakeholders in the supply chain, including technology providers, but also the barrier that concerns privacy, security and data ownership, issues that must be considered both by those who provide the technology and by those who adopt it. The lack of a mass market is perceived by everyone, as well as the technological barrier related to the recyclability of materials. This is a problem that must be taken into account by both those who sell and produce the technology and those who buy it, who must consider proper recycling programs after the adoption of these systems along the supply chain.

5.2.2 Framework barrier-technology

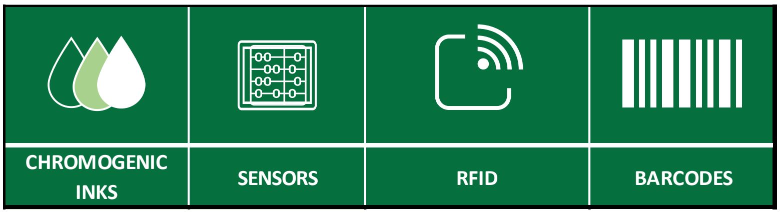

Figure 5.2: Technologies involved in the analysis (Source: Author's elaboration)

The framework barrier-technology (*figure 5.4*) allowed to schematize the barriers perceived by the actors of the supply chain referring to the single technology they adopted (*figure 5.2):* chromogenic inks, sensors, RFID and barcodes.

What emerged from the reading of the framework is that barcode is the most mature and cheap technology. Its adoption does not encounter technological barrier, neither the "lack of affordable price". This is because it is the oldest technology among the four selected ones. It exists and has been widely used in food companies for several decades so it has been perfected over the years and is not affected by the technological barrier as it is already effective and efficient as it is. It could be affected by technological barrier if we consider barcodes integrated with chromogenic inks. They are innovative dynamic barcodes that are being developed only in recent years and are affected by the barriers related to chromogenic inks, as they are codes printed with inks of this type.

At the same way the barrier of "lack of recyclability" is not perceived by common barcodes and chromogenic inks because codes are usually directly printed on packaging materials and don't include particular components requiring ad hoc recycling measures.

However, the other barriers, organizational, cultural etc. are still reported in literature.

As far as RFID is concerned, they are more expansive than barcode since their working principle is more complex than common barcodes. In addition, it is an expensive solution because, if the company does not yet use this type of technology, it is necessary to make substantial investments to align the warehouses and implement this technology from the beginning, and also the time to renew the process is long and can represent a barrier to adoption. Thus, the adoption of RFID technology meets the economic barrier and, since devices are made by several components, the environmental barrier of recyclability is still perceived in literature.

If on the one hand barcodes and RFID are the most mature technologies, on the other hand, chromogenic inks and sensors are the youngest ones. At the same time they have also the biggest potential in terms of food waste reduction, but they need more R&D to refine materials in accordance to current regulations, improve technology performance to decrease false positive and reach affordable prices to be adopted by mass market.

The remaining barriers perceived by the actors, from the literature point of view, regard equally the adoption of all these technologies. All the four technologies address the organizational barriers because, whether the technology is cheaper or more expensive, a great deal of collaborative effort is required from all actors involved in order to achieve common goals along the supply chain. The cultural barrier also concerns all these technologies because they are innovative technologies, even though they may be more or less young in the market. This means that they are not diffused yet and the culture of innovation must be spread among people to convince companies to implement these emerging technologies.

Therefore, since they are all innovations, they also suffer from the market barrier, i.e. the lack of competitiveness in the smart packaging sector. Finally, the legislative and regulatory issue concerns all technologies in the same way, as they must comply with stringent and constantly changing regulations.

		OFFER	DEMAND
	SUB-CATEGORY BARRIERS	TECHNOLOGY PROVIDER	SUPPLY CHAN
TECHNOLOGICAL AND ENVIRONMENTAL BARRIERS	Lack of proper R&D activities, protocols and standard tests	X	
	Lack of recyclability for some smart packaging components	X	X
ECONOMIC AND FINANCIAL BARRIERS	Lack of mass market and affordable prices	X	X
	Lack of long-term profitability perspective		X
REGULATORY BARRIER	Lack of adequate regulation	X	
CULTURAL BARRIER	Inertia toward new technology adoption		X
ORGANIZATIONAL BARRIERS	Lack of collaborative processes along the SC	X	X
	Lack of Best Practices in the market to follow		X
	Lack of solutions for security, privacy, and data ownership issues	X	X
	Lack of a data management system for decision-making/ difficulty in identifying responsibility along the SC		X
	Lack of trust in sharing information with other actors along the SC		X
MARKET BARRIERS	Lack of smart technology market-competitiveness		X

LEGEND	
X	barrier perceived by the corresponding SC actor

Figure 5.3: Adoption barriers faced by each SC actor (Source: Author's elaboration of literature results)

	SUB-CATEGORY BARRIERS	CHROMOGENIC INKS	SENSORS	RFID	BARCODES
TECHNOLOGICAL AND ENVIRONMENTAL BARRIERS	Lack of proper R&D activities, protocols and standard tests	X	X		
	Lack of recyclability for some smart packaging components		X	X	
ECONOMIC AND FINANCIAL BARRIERS	Lack of mass market and affordable prices	X	X	X	X
	Lack of long-term profitability perspective	X	X	X	X
REGULATORY BARRIER	Lack of adequate regulation	X	X	X	X
CULTURAL BARRIER	Inertia toward new technology adoption	X	X	X	X
ORGANIZATIONAL BARRIERS	Lack of collaborative processes along the SC	X	X	X	X
	Lack of Best Practices in the market to follow	X	X	X	X
	Lack of solutions for security, privacy, and data ownership issues	X	X	X	X
	Lack of a data management system for decision-making/ difficulty in identifying responsibility along the SC	X	X	X	X
	Lack of trust in sharing information with other actors along the SC	X	X	X	X
MARKET BARRIERS	Lack of smart technology market-competitiveness	X	X	X	X

LEGEND	
X	barrier referred to the corresponding technology

Figure 5.4:Barriers perceived to the adoption of the single technology (Source: Author's elaboration of literature results)

5.3 Prioritization of barriers

After analysing the papers in depth to find out which actor perceives which barrier and with respect to which technology, a new analysis was made to summarise which barriers were the most relevant globally. Articles from grey and academic literature have been analysed in order to make a relevance list of the barriers. Specifically, the list of barriers developed in the elaboration of conceptual framework has been updated taking into account the degree of relevance of the individual barrier.

Table 5.2 shows the results of the prioritisation of the barriers based on literature findings. Colours give immediate visual information on the degree of relevance: in particular the barriers in red are those that were found to have the most impact as they were mentioned in 6 or more articles out of a total of 14. Then there are the barriers corresponding to the orange colour which indicated a medium relevance as they were mentioned in at least 3 up to 5 articles. In yellow are the least relevant barriers, i.e. mentioned in only 1 or 2 articles.

It can therefore be stated that the most impactful barriers, according to the literature, are:

- Lack of recyclability for some smart packaging components,
- Lack of mass market and affordable prices,
- Lack of adequate regulation.

This means that 6 or more articles out of a total of 14 mentioned this barrier as relevant, agreeing that they are the main barriers to overcome when it comes to the adoption of communicative packaging.

After them, the barriers that were found to be of medium importance are the ones coloured in orange:

- Lack of proper R&D activities, protocols and standard tests,
- Inertia toward new technology adoption.

In the end, the ones considered of lower importance are the once that were mentioned only in one or two articles, meaning that they are not shared as much as the others do. They are reported in the table below with the yellow colour and they are:

- Lack of long-term profitability perspective,
- Lack of collaborative processes along the SC,
- Lack of Best Practices in the market to follow,
- Lack of solutions for security, privacy, and data ownership issues,

- Lack of a data management system for decision-making/ difficulty in identifying responsibility along the SC,
- Lack of trust in sharing information with other actors along the SC,
- Lack of smart technology market-competitiveness.

Table 5.2: Prioritization of barriers based on literature findings (Source: Author's elaboration)

	SUB-CATEGORY BARRIERS	RELEVANCE
TECHNOLOGICAL AND ENVIRONMENTAL BARRIERS	Lack of proper R&D activities, protocols and standard tests	[orange]
	Lack of recyclability for some smart packaging components	[red]
ECONOMIC AND FINANCIAL BARRIERS	Lack of mass market and affordable prices	[red]
	Lack of long-term profitability perspective	[yellow]
REGULATORY BARRIER	Lack of adequate regulation	[red]
CULTURAL BARRIER	Inertia toward new technology adoption	[orange]
ORGANIZATIONAL BARRIERS	Lack of collaborative processes along the SC	[yellow]
	Lack of Best Practices in the market to follow	[yellow]
	Lack of solutions for security, privacy, and data ownership issues	[yellow]
	Lack of a data management system for decision-making/ difficulty in identifying responsibility along the SC	[yellow]
	Lack of trust in sharing information with other actors along the SC	[yellow]
MARKET BARRIERS	Lack of smart technology market-competitiveness	[yellow]

	LEGEND
[yellow]	LOW RELEVANCE: mentioned by 1-2 articles
[orange]	MEDIUM RELEVANCE: mentioned by 3-5 articles
[red]	HIGH RELEVANCE: mentioned by 6-8 articles

6. Empirical refinements: case study

The present Chapter presents the empirical refinements obtained through the case study.
The elaborated frameworks were the starting point of the discussion with the supply chain actors and enabled to give a clear image of the current state of the art regarding barriers to adoption. The interviews with companies permitted to corroborate literature results with real industrial world of agri-food sector. For this reasons companies to interview have been carefully selected, as explained in *section 4.2* of methodology, in order to comprehend both the different roles identified along the food supply chain and the four technologies under analysis, i.e. chromogenic inks, RFID, barcodes and sensors. The different stages of the supply chain analysed through the case study are: technology provider, manufacturer and retailer. Post-harvest and logistic operator stages have been excluded.

Interviews, conducted between July and October 2021, involved various professional figures within the selected companies. The companies themselves identified the proper professional figure within their reality, considering the competences and experiences in food packaging innovative technology. The discussion was not only based on their direct experience with the four technologies, but, thanks to their competence in the sector, it was also possible to analyse the technologies that they have not adopted, but whose characteristics they know. In fact, even if sometimes the discussion focused on technologies that the company does not use, the dialogue with the experts was very valuable in understanding the reasons why they are not used, i.e. the barriers that still need to be overcome in order for these technological solutions to develop and diffuse in industrial world.

The interviews enabled to validate frameworks regarding barriers to adoption and drivers thanks to the dialogue with experts in the smart packaging sector. In this way it has been possible to verify which barriers and drivers were the most perceived according to the different stage of the supply chain.

To have an idea of companies interviewed a summary table is provided. *Table 6.1* comprehends:

- **Company name:** code names from A to I for maintaining anonymity;
- **SC stage:** technology providers, manufacturers or retailers;
- **Technology**: there are two asterisks in case the interviewee has had direct experience with a specific one; in case the respondent has a certain degree of knowledge but not a direct

experience with the specific technology, just one asterisk is signed in the proper column. For both, whether used or not, it was possible to understand through dialogue with experts what are the barriers to adoption for the individual supply chain actor, and possible drivers to overcome them;

- **Company dimension:** information on turnover and number of employees;
- **Location:** company headquarters;
- **Job title:** role of the respondent.

In *section 6.1.*, the context of each company interviewed has been described, introducing firstly the history of the company and its business unit, secondly its degree of experience with the communicative packaging technologies. In that paragraph are presented some projects launched by companies in the past, other still ongoing are presented in this part.

In *section 6.2.* the coding process and its interpretation is described. This part consists in the explanation of how interviews have been analysed in order to extract real data, based on scientific evidence and not personal interpretation. The starting point of the coding process, as explained in case study methodology (see *section 4.2*), was the classification of barriers based on literature review. Information derived from literature are called secondary information, and constitutes a source of evidence, needed to triangulate the data deriving from the primary information (extracted from interviews). Sub-category barriers have been used as codes, and, after the transcription of interviews, it has been possible to identify barriers in line with literature findings and also other possible barriers not deriving from literature, but coming from direct experience of supply chain actors.

The analysis for drivers has been quite similar. The five drivers emerged from literature (see *section 2.6*) have been used as codes to extract and analyse primary information from interviews.

In the end, *section 6.3* contains a discussion on common points and differences of case study with the conceptual frameworks previously proposed.

Table 6.1: Details of the companies interviewed in the Case Study part (Source: Author's elaboration)

COMPANY	SC STAGE	TECHNOLOGY	COMPANY DIMENSION	LOCATION	JOB TITLE
Company A	Technology provider	- QR codes** - RFID* - sensors* - chromogenic inks*	375mln, more than 1800 employees (2021)	Daverio (VA)	Digital printing business development manager
Company B	Technology provider	- chromogenic inks** - sensors** - RFID*	23mln, more than 50 employees (2020)	Rivoli (TO)	Global Sales Director
Company C	Technology provider	- QR codes**	579mln (2020)	Lomazzo (CO)	Project manager
Company D	Technology provider	- chromogenic inks**	12,35mln (2019)	Milano (MI)	Commercial director
Company E	Manufacturer	- barcodes** - RFID* - chromogenic inks*	841mln (2020), 1300 fixed employees and 1400 seasonal employees (2017)	San Lazzaro di Savena (BO)	-Information system director - R&D director
Company F	Manufacturer	- QR codes**	23,7 mln, 49 employees (2019)	Castel Volturno (CE)	Marketing manager
Company G	Manufacturer	- chromogenic inks**	485mln, more than 1600 employees (2020)	Castel D'Azzano (VE)	Logistic manager
Company H	Retailer	- QR codes** - chromogenic inks**	17,7 billion (2019), more than 53.000 employees (2016)	Casalecchio di Reno (BO)	R&D coordinator
Company I	Technology provider	- QR codes**	16mln, less than 50 employees (2020)	Carmignano di Brenta (PD)	- Quality manager - Marketing manager

**: direct experience (technology adopted or developed by the actor)

*: knowledge (technology not adopted or developed by the actor)

6.1 Context of companies interviewed

As already explained, the objective of the Case Study is to understand the points of view of all the actors involved along the supply chain regarding the barriers to adoption of communicative packaging technologies and possible drivers to overcome them. Moreover, to have a full picture of communicative packaging technologies adoption, the second objective was to consider all the four technologies selected for each stage of the supply chain.

The companies contacted were more than twenty, but the final sample consists of nine companies touching all the four technologies and almost all stages of the supply chain. In this section the different business contexts of the companies interviewed have been described.

6.1.1 Company A

Company A is a packaging company born 170 years ago. The Group now has over 1,800 employees and a turnover of about 375 million euros (2021). It offers packaging solutions in a variety of industries, but it is recognized as a real point of reference in many sectors: coffee (51,3%), food packaged in aseptic (19,3%), industrial products (11,4%), food (9%) and others (2020). Since 1850 the Company A has been designing, developing and manufacturing complete packaging systems. The offer includes flexible packaging, rigid plastic accessories and machines for any packaging need. It is a world leader in flexible packaging systems for retail, food service and industry. The company is a partner of the most important industrial realities in the World and it is highly appreciated for innovation, service and quality of its products.

Among their packaging offerings, the aseptic system solution is particularly relevant to this Thesis. It consists in a Progressive QR Code (*figure 6.1*), which is a special unique digitally printed code put on Company A aseptic bags. Thanks to the introduction of the progressive QR Code packaging can be considered unique and unambiguous, as all traceability data can be associated to it, guaranteeing product tracking. Control and localization are therefore extremely simplified, while metadata associated to each selling unit can be processed in real time. (Company A website, 2021) The recorded data are unique, certain, brief and can trace back with precision to the main phases of production, processing and distribution while at the same time assuring authenticity.

Figure 6.1: QR code printed on Company A bags (Source: company A website)

From the interview emerged that these QR codes are applied on aseptic bags from 5 to 1500 kg, used for unfinished goods, not yet intended for sale. These codes enable to know everything happened along the supply chain: each code owns its unique number, in form of QR code, which includes all the information regarding the internal process that the product has undergone. In addition, the customer (B2B), has the possibility to add in the same database all the information considered necessary. In the opinion of the interviewed, this technology could have a great value also in the distribution stage. As an example, a food product which could exploit the QR code technology is fresh salads, because it would allow to know in real time which goods are near to expiry, to do promotional actions and manage inventories organically.

6.1.2 Company B

Company B is a company specialized in the design, production and distribution of products and systems for packaging and wrapping, present on the market for over fifty years. Established in the distribution of traditional packaging products, company B has continuously evolved and, taking advantage of the experience gained in this field, has specialized in the area of packaging, suitable to protect any type of product in the most severe conditions of transport and storage. The company presents a wide range of products for humidity and temperature control during transport and storage, applicable in the food sector. In fact, the company commercializes humidity and temperature indicators to protect materials from humidity and thus preserve product quality over time. company B was born, grows and develops just to prevent and avoid quality damages, providing the necessary and always up-to-date instruments to keep under control the possible harmful agents. Their devices are based on chromogenic ink technologies and also on sensors. These are real time and temperature indicators, capable of monitoring the product along its entire distribution line.

Thanks to the dialogue with the packaging expert of the company it has been possible to deepen some technologies sold by company B applicable to the agri-food sector.

Emerson Loggers are electronical devices (*figure 6.2*) used in the cold chains. They are able not only to detect if the cold chain has been broken, but when and where. They record any exceeding critical

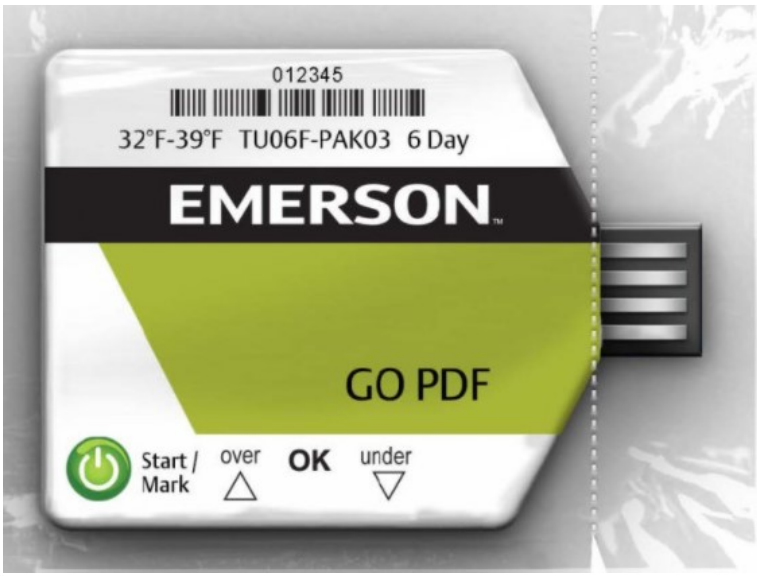

Figure 6.2: Emerson Logger indicator (Source: company B website)

threshold every 4, 8 or 12 minutes. If a problem occurs a red light appears on the device and, at the end of the distribution phase, you put the USB in your PC and a pdf with all data regarding temperatures along the way. More precise and reliable devices are *Go Real Time*: they are black boxes which are able to detect temperature, humidity, light and geolocalization in order to easily identify the responsible of possible damages along the distribution channel.

Other temperature indicators simple, economic and easy to use are *Coldmark* and *Warmark.* They are able to record the exceeding of the minimum or maximum temperature limits previously chosen, informing promptly upon arrival of the goods of any malfunction of the cooling systems or insulation in the package. They are ideal for controlling products that undergo changes in their properties when subjected to certain temperatures, therefore not only in the food industry, but also in the pharmaceutical one. This device therefore is not able to give very precise information, as in the previous case, on the time and place where the temperature variation took place, but only communicates a change through the red color (*figure 6.3*), which can be brief, moderate or prolonged.

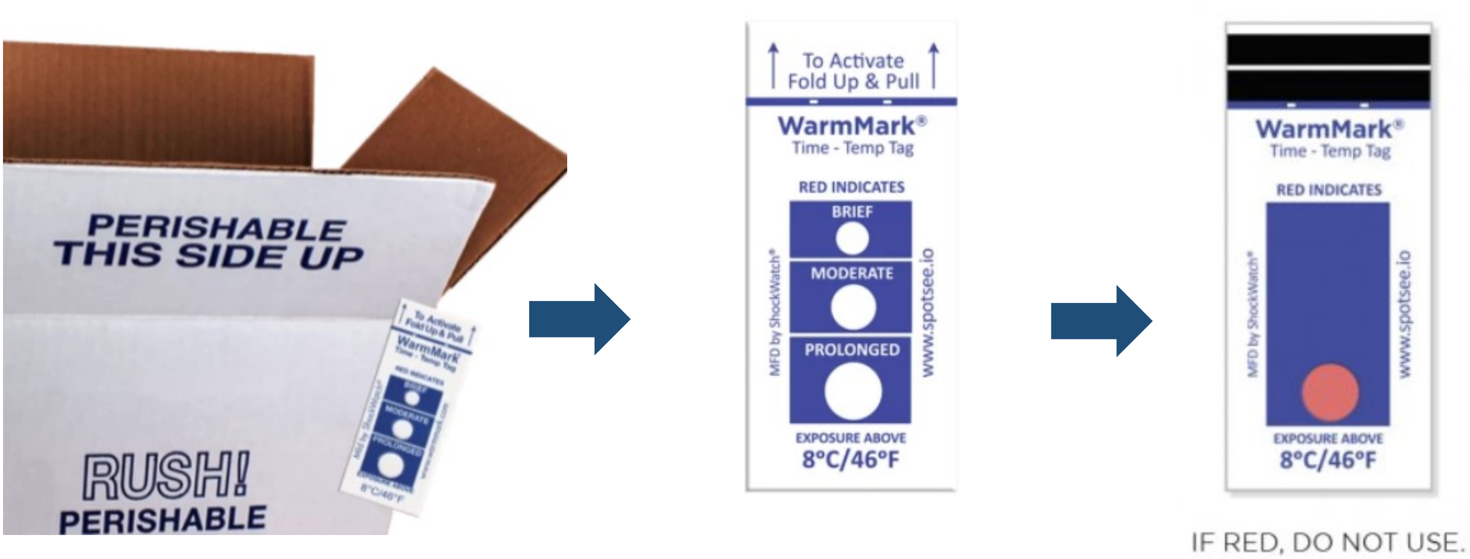

Figure 6.3: Functioning of WarmMark time-temperature indicators (Source: company B website)

A similar temperature indicator, but which adds to this information a more precise information regarding the time of exposure is *TimeStrip* (*figure 6.4*). The information related to time refers to the period in which the product was subjected to temperatures out of the pre-established range, that can be in the range of ½, 2, 4 or 8 hours, or other time range according to the model of indicator. As shown in *figure 6.3* the indicator has to be activate pressing on the button on the left, and looking in the window on the right it is possible to check if the temperature exceeded.

Figure 6.4: Functioning of the Timestrip time-temperature indicator (Source: Company B website)

6.1.3 Company C

Company C is a young company born by a start-up, which tracks food products from origin to end consumer using blockchain technology. The blockchain is a public, distributed, decentralized ledger in which encrypted information is securely stored. The data once entered into the system and validated, is unalterable. Thanks to IoT (Internet of Things) devices, it is possible to implement a traceability that covers every stage of the supply chain from production to logistics and distribution. Company C allows food companies to improve internal resource efficiency and reduce waste by storing and integrating information through a combination of blockchain technology and IoT devices that can provide real-time data on the development of each process. This enables to lower costs derived from quality management and from logistical inefficiencies and at the same time minimize the reaction time to solve problems related to possible food hazards. The company can choose what information to share and with whom, through a system of customized privacy levels. In fact, within the blockchain, different types of data (text, images, video...) can be inserted and associated with a unique code. Through the web platform and mobile app, the company can decide whether the information entered remains private, and therefore inaccessible to third parties, or if they can be shared with certain actors in the supply chain, or completely public. The final result is a QR code applied to product packaging that transforms normal labels into "smart labels", increasing consumer confidence in the company because they can check all the information about the product.

In the interview with the project manager of company C we talked about their solution which followed the way of a bag of coffee of the Slow Food Presidium of Sao Tomé, an isle in central Africa. The traceability started from the farmer and went up to the coffee shop. All coffee packages have a QR Code (*figure 6.5*) and by scanning it with a smartphone, the entire history of the product could be checked, from harvesting to the shelf, including certificates of origin, customs documents, delivery notes and transport stages.

Every transaction that takes place along the supply chain is in fact reported in the blockchain that acts as a validator and generates a unique code enclosed in a printable QR code. The possibility to see all the data entered in the upstream supply chain is very much appreciated by the customer because the code eliminates the possibility of fake data, giving information symbol of high quality, control along the supply chain and valorisation of the product. A careful control of the supply chain and its production steps leads to an optimized management of the finished product and minimization of any kind of waste.

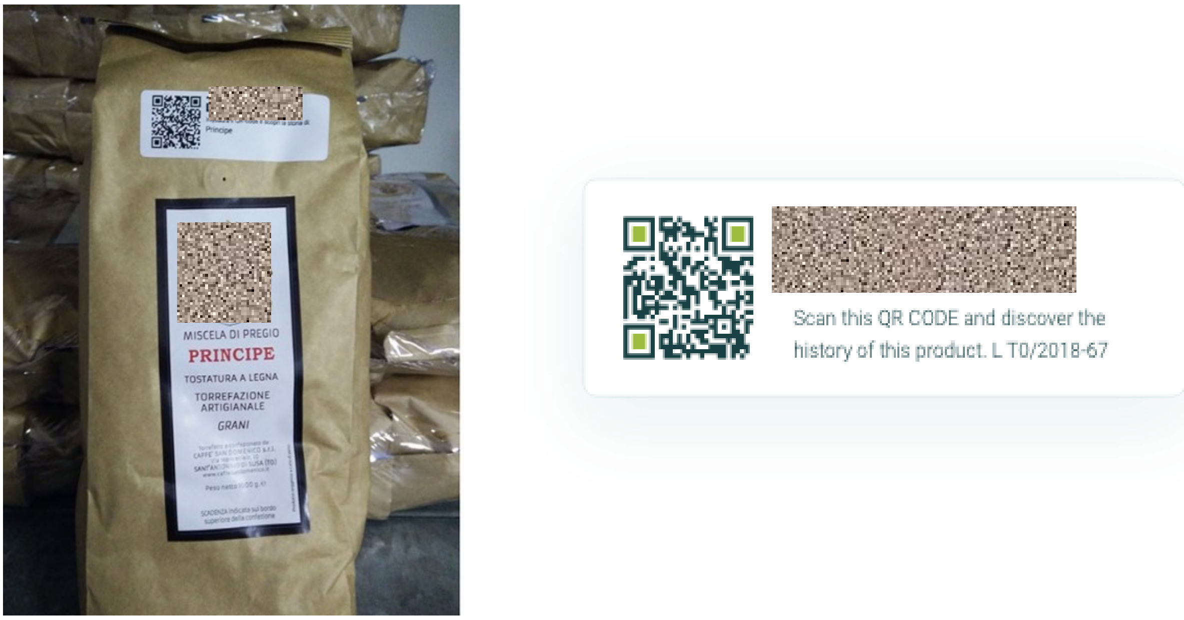

Figure 6.5: QR code powered by Company C applied on coffee bags (Source: company C website)

Another similar solution was applied on a company that produces large volumes. The solution sold by company C in this case was more focused on the benefits of operability, minimizing downtime related to a product flow management based on old and ineffective systems, which did not allow a good management of products with excessive food waste. With the blockchain technology provided by company C, the management of logistics flows is facilitated, allowing the customer company to serve its customers with quality, efficiency and speed.

6.1.4 Company D

Company D was founded in 2001 and immediately demonstrated high competence in the sector. It has been able to respond to the needs of important brands, growing the company's credibility and establishing important business partnerships with leaders in the IT sector. The Company D team performs an active and constant search for information, tools and insights, to test and acquire the most innovative technological solutions, becoming for the customer a real engine of business development.

The innovative technology offered by company D is a smart label as a data collection tool which provides information on temperature, product position and e exposure time of products above or below fixed threshold values. The solution takes advantage of barcode technology that can be scanned by any Smart Device for data collection. The dedicated Cloud platform acts as a tool for data analysis providing extensive support to the decision-making phase.

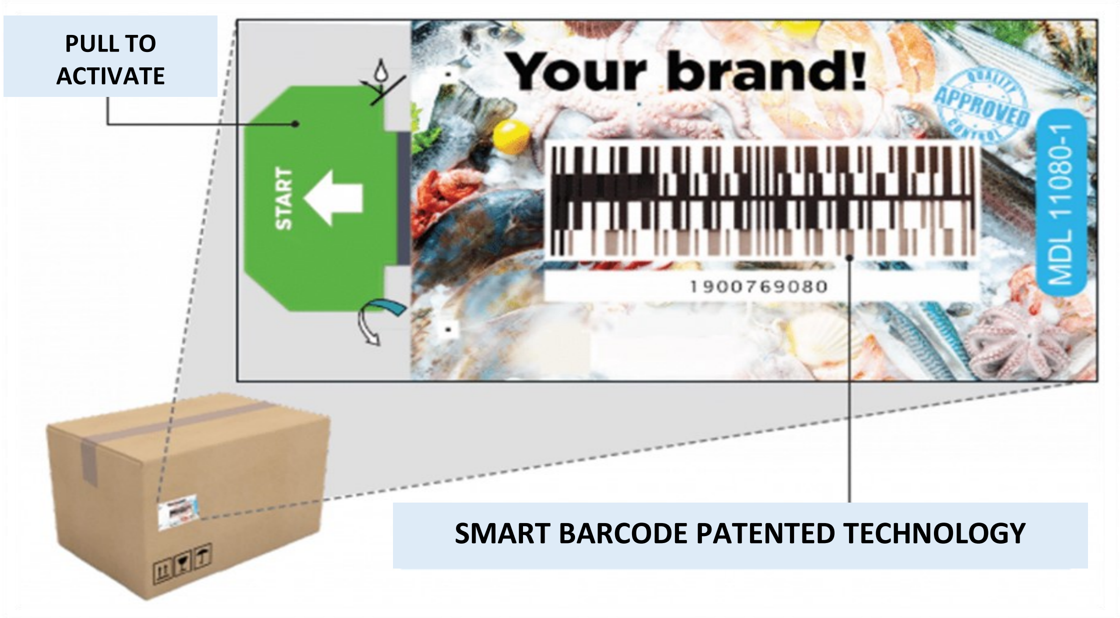

Figure 6.6: Example of Smart Label developed by company D. (Source: Food Sustainability Observatory, 2020)

In *figure 6.6* has been reported the example of the solution. It is a 4.5 x 8 cm label that can be applied to primary, secondary or tertiary packaging and is identified with a unique code. It consists of a barcode printed with chromogenic ink that functions as a temperature indicator. Above a fixed time-temperature threshold, the ink reacts and irreversibly modifies the lines of the barcode. Scanning the barcode (with smartphones or dedicated scanners) allows to verify that the critical temperature has been exceeded, and for how long this happened, recording the information in the cloud platform. The integration with the cloud also allows to read the label of a single product to record information on the entire pallet during handling along the supply chain. Scanning the barcode during the transport, storage and distribution phases, it is therefore possible to trace the temperature history to which the product has been exposed and to understand in which point of the supply chain the threshold temperature has been exceeded, and for how long. It is possible to retrieve information on time, date and place of each scan and integrate them into the management systems of the actors involved.

Company D launched an innovative project in 2020. It consisted in an experimental research conducted with company G and the Food Sustainability Observatory of Politecnico di Milano. The objective was to understand how the adoption of the "talking" Smart Label packaging solution offered by company D could allow company G (manufacturer) to promptly identify and solve any criticalities found along the downstream supply chain of a target product.

During the project, another SC actor was involved. The third company involved was a retailer. The technology of smart label has been used to follow a product manufactured by company G along the supply chain from production centre to point of sale of the selected retailer.

6.1.5 Company E

Company E, within the Italian and European context, is a leading company in fruit and vegetable conserves. It was born in 1976 from the union of 15 fruit, vegetable and tomato processing cooperatives and expanded over the years with a series of acquisitions of other cooperatives and companies. Today company E has seven subsidiaries, which have been founded by the parent company or acquired over the years, and it operates in Italy, Spain, France, Germany, Scandinavian Countries, Great Britain, Ireland, United States, and Argentina. In Italy, it has eight factories, six in Emilia Romagna, one in Tuscany and one in Puglia.

The company produces products with its own brand, and also third party branded products for large-scale retail trade. Through a big network of logistic centres it delivers the finished products to the traditional channels of retail and Ho.re.ca, serving a total of approximately 3000 customers (Company E, 2021).

During the interview phase, respondents made it clear that the technologies covered in this Thesis were not of great value to their company. This is because company E commercializes products with a long shelf life. Each type of canned product, whether it is a fruit jam or a can of beans, does not have a short expiry date, so monitoring the expiry date of the products flows is not of primary importance. Even a dynamic code on the expiry date would be too expensive for their products and the overpricing would not be justified by the benefits gained. However, the interviews had a big value in order to collect more insights, even if the actors were not directly involved in the adoption of communicative packaging technologies. They gave detailed answers on the problems of adopting these technologies and why their company does not use them, so they are a very important part of the case study analysis. The details of the interview can be read in the *Appendix A*.

6.1.6 Company F

Company F, founded in 1994, is a company specialized in the production of mozzarella di bufala campana DOP and ricotta di bufala. In the first years of activity, the company organized the distribution of its products in the local markets of Campania and Lazio; after a few years, the company started commercial relations with the main Italian GDO brands, both with its own brand and with private labels. Today, the company's consolidated experience merges with the desire for innovation and follows the new habits of modern consumers, increasingly attentive to the quality and wholesomeness of food products. In 2019 it announces an important success never reached before in the dairy sector: the entire supply chain of the mozzarella di bufala campana DOP - with its own brand - is visible to all consumers.

Every single package of DOP product with the label 'Blockchain Certificate - Quality' also carries a QR code that, if scanned, allows the consumer to access a landing page with information about the production chain: from the 45 certified farms (located between the Volturno plain and the Agro Pontino) to the processing and packaging phases. By means of the same code and by entering the lot of the product it is possible to verify all the quality standards the company has always followed in order to offer a range of excellence in terms of organoleptic and food safety in compliance with the regulations established by the Consortium for the protection of Mozzarella di Bufala Campana DOP.

6.1.7 Company G

Company G S.p.A. is an Italian food company of bakery products, founded in Verona in 1922. The group has 170 different types of products in its portfolio. The history of the company is a history made of commitment, work and care for quality. Guided by these values, the 2000s were an opportunity for the company to grow and expand, not only in Italy but also abroad. Even today, company G confirms itself as a dynamic company that never renounces innovation and research, remaining faithful to the values of its family history and Italian tradition, to give you new sweet goodness every day, designed to make you feel good.

In the project “Smart Label launched in 2020 by company D in collaboration with Politecnico di Milano regarded one of the most famous product of this company, the chocolate snack.

A smart label has been put on secondary package and on tertiary package of the target product. The labels have been activated in the company G production centre in Castel D'Azzano (VE) and scanned firstly in the retailer distribution centre in Biandrate (NO), then in six different supermarkets located in the west Milan (*figure 6.7*). The path of the product has been entirely traced, from the production plant to the single point of sale.

In this way it was possible to track the condition of the product in every move, monitoring its quality status from production to sale. This has a great potential in terms of waste reduction and can be a solution to the criticalities found for the categories of products sensitive to temperature variations. Thanks to the use of these smart labels on the packages of company G chocolate snacks, it has been possible to prevent criticalities and loss of sales for products sensitive to temperature variations during product scanning were available for each step of the route. If a threshold temperature exceeded, it was possible to visualize at which point of the route it occurred and have the necessary information to intervene.

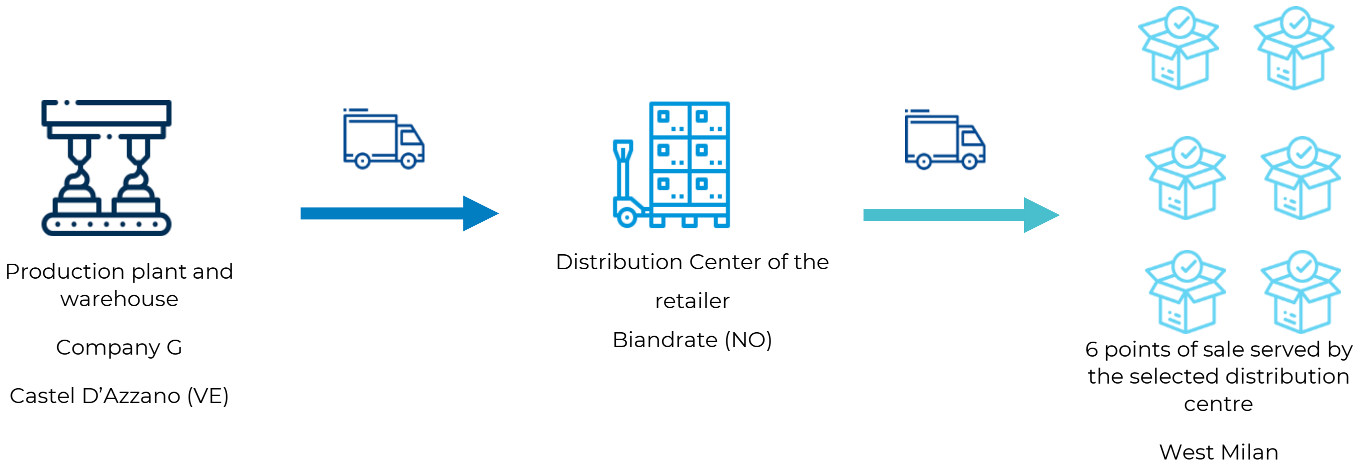

Figure 6.7: Flux of the target product from production to sale (Source: Food Sustainability Observatory, 2020)

6.1.8 Company H

Company H is a system of Italian cooperatives, which manages a network of supermarkets, superstores and hypermarkets. It is a consortium in the form of a cooperative society, meaning that it is directly supported by the social base of consumers. For the company there are five fundamental principles of safety and quality to ensure the health and welfare of consumers: precaution, prevention, control, management of non-conforming product, continuous improvement. The company H Social Balance reports more than 3 mln quality controls have been made on more than 500 suppliers in 2020. In relation to the topic of this Thesis, which deals with the management and minimization of surplus food and the food waste, it should be mentioned that company H pays a lot of attention to social initiatives and education to conscious consumption of food, besides ensuring product safety.

In 2019 the company launched a project dedicated to the application of blockchain technology to the food supply chain and in particular to the production of company H branded eggs. This supply chain was chosen because it was already certified, in fact since 2002 company H has certified this supply chain by focusing on hens not raised in cages, raised exclusively in the Italian territory and following strict controls on animal welfare. For this reason, starting from a good control of the supply chain, it was possible to launch a pilot project on the block chain.

Moreover, it was a complex supply chain and the best selling in the egg category, with a certain degree of risk to be monitored: from microbiological risk to contaminants and counterfeiting.

The project launched in 2019 relied on the technology of QR code *(figure 6.8)*. The consumer had to scan the QR Code printed on the new packaging of eggs and type the specific code of the batch. The code reading included all the history of the product and enabled to track it from the point of sale to the farm, identifying not only the territory where the egg comes from, but also the incubator from which the hen was born.

In this way it could be verified that the eggs have been produced in full compliance with animal welfare requirements, never closed in cages, and without the use of antibiotics. All this is certified by two independent third-party bodies and demonstrates compliance with all legal standards and additional requirements set by company H. This led to a high degree of quality and security along the supply chain.

Even if the code is scanned by final consumers only at the end of the value chain, company H had to deal with many actors in the different supply chain steps to certificate the eggs supply chain and be able to set the project with QR codes. In this specific case it was quite easy to start the project because company H, as a cooperative with a story long more than 30 years, had already in house a high number of controlled and certified supply chains.

Therefore, it has not been necessary a great effort to communicate with the suppliers and to share information, because in these years a relationship of trust had already been established between the actors of many supply chains.
Since the company has many certified supply chains, it has the "governance "of them: they know very well the steps of the supply chain and are able to manage it in a structured way. For this reason, thanks to the great trust in their suppliers, they are able to start several innovative projects, such as the QR code on the egg packaging.

Figure 6.8: QR code applied on company H eggs pack. (Source: company H website)

Another innovative project performed by company H some years ago concerns chromogenic inks. The company experimented with innovative chromogenic labels placed on the packaging of cured meats that can give information about the state of oxidation of the product. Thanks to the change of color on the label it was therefore possible to know the current state of the food and verify if there was any undesirable variation that could alter its organoleptic properties.

Both projects, once the results were analysed after a certain period of testing on the market, were concluded and not proposed again. As for the QR code, the cost benefit analysis was not satisfactory, although it was appreciated by consumers who completed the scanning process.

On the other hand chromogenic labels have not been used anymore for economic issues linked to their high price, but also for the difficulty in reading the labels, due to a possible color change not sharp enough.

6.1.9 Company I

Company I is an Italian company that produces food packaging not only to improve the performance of our packaging, but also to make all our product lines increasingly eco-sustainable. In addition to the research on eco-friendly materials that respect the environment, the company has also chosen to transform its packaging into a real channel of direct communication with the consumer, inserting in the print also a QR Code (*figure 6.9*) that conveys information about the product and how to dispose the package.

Figure 6.9: QR code applied to company I bag. (Source: company I website)

From the dialogue with the experts, it emerged that this new service on their packaging was very much appreciated by customers, especially because, being only a printed addition, there was no extra charge to them.

However, this technology does not fall within our selection, as it only implies a B2C communication and because the information conveyed only concerns the methods of disposal of the product and redirects to the company's website.

Therefore, this information does not concern traceability along the supply chain, nor does it produce a reduction in food waste, which is the main objective pursued by the technologies covered in this Thesis. For this reason, company I has been excluded from the investigation and has not been included in the coding process of interviews. Details of this interview can be seen in *Appendix A*

.

6.2 Primary information

This part is structured by dividing the case study analysis by the three stages of the supply chain: technology providers, manufacturers and retailers.

It includes a first section presenting the coding of the interviews carried out, according to the process described in *chapter 4,* both for barriers to adoption and drivers to overcome them. The coding is presented for each stage of the supply chain analysed, with details of all interviews for the individual stage. For each stage, the experiences of the different companies belonging to that stage of the SC were aggregated into a single sample and reported in a single overall table. It was therefore possible to collect information from:

- a sample of 4 companies for the technology provider stage,
- a sample of 3 companies for the manufacturer stage,
- a sample of 1 company for the retailer stage.

Subsequently, a second part describes the interpretation of the results, which aims at comparing what emerged from the interviews with the results from the literature analysis.

This part therefore enabled to highlight the differences between the conceptual frameworks previously developed and the results of the direct dialogue with the actors of the supply chain. Thanks to the case study analysis it has been possible to underline new barriers that emerged, those that were confirmed and those that were not perceived by the interviewees. By carrying the analysis on a stage-by-stage basis it was also possible to see the relevance of each barrier according to the different actor point of view along the supply chain.

From the literature review, two frameworks have been developed that highlight how it is possible to classify the barriers to communicative packaging adoption and drivers to overcome them. For this reason, the interviews were carried out according to a deductive approach starting from those frameworks. However, if on the one hand the validation of the frameworks was to be achieved through interviews, new elements might have emerged from the experts' discourses. therefore, subsequently the approach for analysing the coding of the interviews was inductive.

In this part, it is presented for each SC stage first the coding of the interviews, then the interpretation of the results. Subsequently, concluding tables representing all stages and technologies analysed are presented in the discussion (*section 6.3)*.

The primary information that emerged from the interview with the SC actors and that has been codified, turned out to be very interesting. Thanks to the analysis of the transcribed text of the interviews, it has been possible to extract additional information, indicating the relevance of the barriers to the adoption of communicative packaging along the agri-food supply chain, according to the experience of the actors directly involved.

Barriers have been prioritized according to the mentions in the interviews and they can be compared with literature findings. In the columns related to interviews the most relevant barriers, i.e., the ones mentioned by 3 or more actors in the same SC stage, have been coloured in red; the barriers with medium importance, i.e., mentioned by 2 actors have been coloured in orange and the barriers with lowest importance ,i.e., mentioned by only 1 actor have been coloured in yellow. Otherwise, if the cell corresponding to the single barrier is empty, it means that it has not been considered relevant or it has been neglected during the interview.

It must be considered that sample of respondents belonging to the three SC stages was not homogenous, so the degree of relevance derived from interviews analysis is not based on samples of equal size. The interpretation of results based on number of mentions in the interviews was a method proposed by the author to analyse in an objective way the case study, but this limitation related to the different sample size must be remembered.

The relevance of barriers highlighted by the actors interviewed has a big importance with respect to literature results, because this enables to have a point of view on the main barriers to adoption perceived by the actors directly involved based to their experience, going beyond the boundaries of academic and grey literature.

For each stage the coding interpretation of barriers addressed all the four selected technologies i.e., chromogenic inks, barcodes, RFID and sensors. All technologies have been analysed in detail taking into account the relative results in the two conceptual frameworks (*figure 5.3* and *5.4*).

After discussing with the companies, the barriers to adoption perceived by the different actors, the interview moved on to possible solutions and drivers that could lead to overcoming these barriers. As explained in *section 2.6*, to answer RQ2 (Which are possible drivers to overcome barriers to adoption of communicative packaging technologies?), it was not enough to analyse the literature.

The only article found in literature regarding possible drivers to overcome barriers to adoption deals with sustainable supply chain innovation and describes drivers to overcome barriers to adoption of these innovations. The discussion can be extended to communicative packaging as a sustainable innovation to be adopted along the supply chain.

The five drivers identified in the literature were the following:

- Regulatory support
- Internal development:
- R&D activities:
- Collaboration and networking:
- Marketing and promotion

The coding process followed for drivers is slightly different to that used for the barriers. Firstly macro-categories of barriers derived from literature have been identified in the transcribed interviews distinguishing between:

- Technological and environmental barriers,
- Economic and financial barriers,
- Regulatory barrier,
- Cultural barrier,
- Organizational barriers,
- Market barrier.

Then, it has been possible to go into detail about possible drivers to overcome them, using the five labels mentioned above as codes. The analysis has been divided also in this case considering the three SC stages: technology providers, manufacturers and retailers.

In the next sections, interpretation of coding process both for strategies and drivers has been explained in detail stage by stage.

6.2.1 Technology providers

Coding of interviews

Table 6.2: Coding of interviews to technology providers: barriers to the adoption (Source: Author's elaboration)

SC STAGE: TECHNOLOGY PROVIDER				
COMPANY	**TECHNOLOGY**	**MACRO-CATEGORY BARRIERS**	**BARRIERS**	**QUOTES FROM INTERVIEWS**
Company A	QR CODES**	• ECONOMIC • CULTURAL	• Lack of mass market and affordable prices • Inertia toward new technology adoption	*"Il cliente vuole sempre risparmiare, ma con le innovazioni è impossibile, si spende di più. Bisogna educare il cliente ai vantaggi che può trarne, (…) tutto si traduce nella frase :<<Abbiamo sempre fatto così >>.'"*
	RFID*	• ECONOMIC • ENVIRONMENTAL	• Lack of mass market and affordable prices • Lack of recyclability for some smart packaging components	*"Per gli RFID si parla di problemi di costo, ma anche problemi di smaltimento perché composti da diverse parti con materiali diversi"*

	SENSORS*	• ECONOMIC	• Lack of mass market and affordable prices	*"Per i sensori è principalmente una questione di costi, perché ad esempio devono essere alimentati e servono microcelle di pannelli fotovoltaici per alimentare le batterie."*
	CHROMOGENIC INKS*	• TECHNOLOGICAL • ECONOMIC	• Difficulty in interpreting information conveyed by technology # • Lack of mass market and affordable prices	*"Gli inchiostri cromogenici ti mostrano che il problema è già successo, non puoi fare niente per prevenirlo, ma lo devi buttare. E inoltre insinuano il dubbio di leggibilità legata al viraggio di colore non troppo chiaro"* *"Il cliente vuole risparmiare tramite l'adozione di innovazioni, ma è impossibile"*
Company B	CHROMOGENIC INK**	• ECONOMIC • REGULATORY	• Lack of mass market and affordable prices • Lack of adequate regulation	*"Il problema di non aver fatto diventare gli indicatori di temperatura una soluzione di massa è una questione puramente economica. Questi dispositivi riscontrano molto interesse, ma dover investire è il primo problema; il secondo è dover toccare macchinari già esistenti e funzionanti."* *"Le aziende alimentari non sono obbligate a fare questo tipo di controlli sui loro prodotti, perciò non c'è una spinta neanche da questo punto di vista."*
	SENSORS**	• ECONOMIC	• Lack of mass market and affordable prices	*"Sono dispositivi molto precisi, ma sono anche anche costosi. Il prezzo si aggira intorno ai 6/7 € al pezzo"*

	RFID*	• ECONOMIC	• Lack of mass market and affordable prices	*"Gli RFID non sono molto utilizzati nel settore food, i problemi economici riguardano i costi legati all'integrazione con il software, poi serve un lettore ad hoc, cambiare i programmi di gestione dei magazzini."*
Company C	QR CODES**	• ECONOMIC • REGULATORY • CULTURAL	• Lack of mass market and affordable prices • Lack of adequate regulation • Inertia toward new technology adoption	*"Anche se negli ultimi anni c'è stata un'impennata sulla tecnologia, c'è sempre una fase di transizione prima di raggiungere l'adozione di massa. E noi siamo ancora nella fase di transizione. Ci sono altri aspetti oltre a quello economico da considerare, ad esempio il quadro legislativo si sta allineando alle richieste del mercato, ma la burocrazia si muove sempre sempre in maniera più lenta rispetto alla tecnologia. Questo rende l'investimento privato un po' sprecato perché non tamponato da un quadro legislativo completo."* *"È un fatto culturale. Non si può saltare in poco tempo dal vecchio al nuovo perché si è abituati a lavorare in un certo modo. È un quadro che prende forma un po' alla volta ed è un processo che richiede tempo."*
COMPANY D	CHROMOGENIC INKS** / BARCODES**	• ECONOMIC • CULTURAL • ORGANIZATIONAL • REGULATORY	• Lack of long-term profitability perspective • Lack of mass market and affordable prices • Inertia toward new technology adoption	*"La barriera principale dal nostro punto di vista è che l'adozione di una nuova tecnologia innovativa viene sempre messa a confronto con un business case di ritorno. Le aziende non vedono un ritorno economico dall'adozione di soluzione innovativa."* *"Poi ci sono i limiti nel comprenderne la validità e il ritorno in termini di vantaggi, non solo economici. Non sono tante le persone che hanno una visione più ampia e più aperta alle innovazioni, alcune persone presenti in azienda bloccano le azioni di innovazione, c'è spesso una*

			• Lack of collaborative processes along the SC • Lack of trust in sharing information with other actors along the SC • Lack of adequate regulation	*non volontà di innovare per mancanza di tempo e di voglia.”* *“Ci sono dei vincoli lungo la filiera. È un problema di organizzazione, barriere che emergono quando si cerca di mettere in comunicazione sistemi differenti, aziende differenti, sistemi informatici diversi.”* *“Nell’alimentare e nella logistica non ci sono enti regolatori a cui riferirsi. Se ci fossero dei regolamenti come ad esempio quelli che dicono “Non bisogna produrre CO2 entro un certo limite, altrimenti devi pagare” sarebbe diverso.”*

**: direct experience (technology adopted or developed by the actor)
*: knowledge (technology not adopted or developed by the actor)
#: new barrier emerged in interviews, not present in literature

Table 6.3: Coding process for drivers for technology providers (Source: Author's elaboration)

SC STAGE: TECHNOLOGY PROVIDERS			
COMPANY	**MACRO-CATEGORY BARRIERS**	**DRIVERS**	**QUOTES**
Company A	ECONOMIC/ CULTURAL	• Marketing and promotion	*"Ci sobbarchiamo noi la spesa fornendo una versione prova. È come dire: provalo e capirai i vantaggi, anche se spendi di più. Capirai che quello che spendi in più, ti tornerà indietro."* *"Bisogna sensibilizzare il cliente. Pensa se butti 200 kg di pomodori quanto butti via, mentre se hai la tracciabilità di tutta la filiera, hai modo di vedere dove si verifica un problema e puoi risolverlo in mariera tempestiva. È questo il tuo vantaggio."*
Company B	REGULATORY	• Regulatory support	*"Le aziende attualmente non sono obbligate a fare dei controlli con questo grado di precisione, manca perciò una spinta da questo punto di vista che ne favorirebbe la diffusione."*
	ECONOMIC/ CULTURAL	• Marketing and promotion	*"La barriera economica si supera solo se si cerca un risultato non immediato. Se si cerca un conto positivo a fine mese è impossibile con l'implementazione di innovazioni. Bisogna far capire che il vantaggio si raggiunge nel lungo termine e che valga la pena investire. (...) Si vede una risposta positiva nelle aziende che hanno un piano di sostenibilità sul lungo termine e sono pronte a lanciarsi in progetti innovativi. Lo si può vedere maggiormente in aziende più grandi, le piccole hanno bisogno di un ritorno economico sul breve termine."*

Company C	CULTURAL	• Marketing and promotion	*"È un fatto culturale, non si può saltare dal vecchio al nuovo in poco tempo. Le istituzioni stanno remando in quella direzione negli ultimi anni, ma è un quadro che prende forma un po' alla volta. Anche noi partecipiamo alla sensibilizzazione sull'argomento e alla divulgazione scientifica per collaborare al processo di adozione di queste tecnologie."*
	REGULATORY	• Regulatory support	*"La comunità europea, ad esempio, propone bandi con cui alloca fondi per progetti innovativi che ruotano attorno a tracciabilità, trasparenza e sostenibilità."*
COMPANY D	REGULATORY	• Regulatory support	*"È come dire: "C'è il limite di velocità, se lo superi ti faccio la multa". Qui nel settore alimentare dovrebbe esserci una regola sullo spreco perché oggi è come dire "Se tu sprechi non succede nulla, non c'è nessuna conseguenza". Questo è l'aspetto principale. Se ci fosse questo regolamento le soluzioni tecnologiche sarebbero mille e se ne svilupperebbero ancora di più."*
	CULTURAL	• Marketing and promotion • Collaboration and networking	*"Si cerca di trovare delle soluzioni affidabili, garantite, di poco costo. Si è cercato nel nostro caso di facilitare l'adozione di questa tecnologia andando incontro al cliente, capire il problema del cliente e trovare soluzioni. E dietro a tutto questo sta il marketing."* *"Noi, da fornitori di tecnologia, abbiamo provato ad andare in comunità scientifiche per curiosità, per fare ricerca nelle aziende, per studiare le soluzioni. È il luogo ideale per capire le esigenze del mercato, studiare le tecnologie e cercare di portare avanti progetti innovativi."*

Coding interpretation

The technology providers stage involved 4 different companies that made a valuable contribution to this Research: *company A, company B, company C* and *company D* (see *section 6.1* for details). Their experience covered all four technologies and made it possible to combine the literature analysis with a real analysis of the barriers encountered in the industrial world.

Experts interviewed expressed the point of view of technology providers on the solutions they market. In particular, the companies interviewed were involved in the development of barcodes, chromogenic inks and sensors.
Unfortunately, none of the four companies had any direct experience with RFID technology, but the interviewees wanted to express their opinion on this technology, as it is well known in the industrial and manufacturing world.
This lack of experience with RFID technology could explain why the case study column of RFID in *Table 6.4* is emptier than the case study columns of other technologies. The interviewed actors had more experience with barcodes and chromogenic inks technologies and therefore the case study columns related to these two technologies are fuller.

In *Table 6.4* comprehensive results for all the four technologies in the specific SC stage of technology providers are reported.
In the next sections the coding interpretation for each single technology is explained in detail, starting from chromogenic inks, then barcodes, RFID and in the end sensors. From *Table 6.5* to *Table 6.8* it is possible to see similarities and differences between literature findings and case study for each specific technology.

Table 6.4: Coding interpretation for barriers, technology provider stage (Source: Author's elaboration)

		CHROMOGENIC INKS		BARCODES		RFID		SENSORS	
	SUB-CATEGORY BARRIERS	LITERATURE	INTERVIEWS	LITERATURE	INTERVIEWS	LITERATURE	INTERVIEWS	LITERATURE	INTERVIEWS
TECHNOLOGICAL AND ENVIRONMENTAL	Lack of proper R&D activities, protocols and standard tests								
	Lack of recyclability for some smart packaging components								
ECONOMIC AND FINANCIAL BARRIERS	Lack of mass market and affordable prices								
	Lack of long-term profitability perspective								
REGULATORY BARRIER	Lack of adequate regulation								
CULTURAL BARRIER	Inertia toward new technology adoption								
ORGANIZATIONAL BARRIERS	Lack of collaborative processes along the SC								
	Lack of Best Practices in the market to follow								
	Lack of solutions for security, privacy, and data ownership issues								
	Lack of a data management system for decision-making/ difficulty in identifying responsibility along the SC								
	Lack of trust in sharing information with other actors along the SC								
MARKET BARRIERS	Lack of smart technology market-competitiveness								
New Barriers from interviews	Difficulty in interpreting information conveyed by technology								

LEGEND for literature	
	LOW RELEVANCE: mentioned by 1-2 articles
	MEDIUM RELEVANCE: mentioned by 3-5 articles
	HIGH RELEVANCE: mentioned 6-8 articles

LEGEND for interviews	
	LOW RELEVANCE: mentioned by 1 actor in that SC stage
	MEDIUM RELEVANCE: mentioned by 2 actors in that SC stage
	HIGH RELEVANCE: mentioned by 3 or more actors in that SC stage

Chromogenic inks

Table 6.5: Detail of the coding interpretation for technology provider SC stage, chromogenic inks (Source: Author's elaboration)

		CHROMOGENIC INKS	
	SUB-CATEGORY BARRIERS	LITERATURE	INTERVIEWS
TECHNOLOGICAL AND ENVIRONMENTAL	Lack of proper R&D activities, protocols and standard tests	[medium – orange]	
	Lack of recyclability for some smart packaging components		
ECONOMIC AND FINANCIAL BARRIERS	Lack of mass market and affordable prices	[high – red]	[high – red]
	Lack of long-term profitability perspective		[low – yellow]
REGULATORY BARRIER	Lack of adequate regulation	[high – red]	[high – red]
CULTURAL BARRIER	Inertia toward new technology adoption		[low – yellow]
ORGANIZATIONAL BARRIERS	Lack of collaborative processes along the SC	[low – yellow]	[low – yellow]
	Lack of Best Practices in the market to follow		
	Lack of solutions for security, privacy, and data ownership issues	[low – yellow]	
	Lack of a data management system for decision-making/ difficulty in identifying responsibility along the SC		
	Lack of trust in sharing information with other actors along the SC		[low – yellow]
MARKET BARRIERS	Lack of smart technology market-competitiveness		
New Barriers from interviews	Difficulty in interpreting information conveyed by technology		[low – yellow]

	LEGEND for literature
[yellow]	LOW RELEVANCE: mentioned by 1-2 articles
[orange]	MEDIUM RELEVANCE: mentioned by 3-5 articles
[red]	HIGH RELEVANCE: mentioned 6-8 articles

	LEGEND for interviews
[yellow]	LOW RELEVANCE: mentioned by 1 actor in that SC stage
[orange]	MEDIUM RELEVANCE: mentioned by 2 actors in that SC stage
[red]	HIGH RELEVANCE: mentioned by 3 or more actors in that SC stage

As far as chromogenic ink technology is concerned, the interviews revealed that the most relevant barriers are *Lack of mass market and affordable prices* and *lack of adequate regulation*. More than three out of four stakeholders perceived this barrier as the most impactful and the most difficult to overcome. It emerged that the client company always wants to save money, but with innovations it is impossible. The problem of not making temperature indicators based on chromogenic ink a mass solution is purely an economic issue. Interviewees said that in the market there is a lot of interest in these devices, but the availability and the allocation of resources to be invested is often an issue in companies. Having to invest is the first big problem to overcome, the second is having to modify existing and functioning machinery. Modifications along the way come at a cost. When implementing systems with chromogenic inks, it is necessary to modify existing lines, there are downtimes and economic losses to consider. Huge investments are needed and, due to scarce resources, often it is preferred to continue using common technologies rather than implement new ones.

Regarding regulations barrier, on the other hand, according to technology providers, is related to the fact that food companies are not obliged to do this kind of control on their products. It is not mandatory to use modern inks to monitor food status and guarantee the best shelf-life to food products. So, there is no push from this point of view either. In the food and logistics areas there are no regulatory entities to refer to. If there were regulations with set limits and fines to pay, it would be different. Enforced limits on the amount of food that can be disposed by each company are necessary. This would give companies an incentive to take certain precautions and use certain technologies such as smart packaging.

Other barriers perceived by technology providers were found to be less relevant, as they were not shared by all companies, such as the *lack of long-term profitability perspective, inertia toward new technology adoption, lack of collaborative processes along the SC* and the *lack of trust in sharing information with other actors along the SC.*

One company testified that a major barrier from their point of view is that the adoption of a new innovative technology is always compared to a return business case. Companies do not see an economic return from adopting an innovative solution and this slows its diffusion on large scale. Then there are the limits in understanding the validity and the return in terms of advantages, not only on an economic level, but also on an image or operational level. There are not many professional figures who have a broader vision and are open to innovation, some people in the company often stop innovation actions, there is often an unwillingness to innovate due to lack of time and desire.

Other perceived barriers are those at organisational level concerning *collaboration between partners along the supply chain* and *trust in sharing sensitive information and data*. Respondents identified constraints along the supply chain related to communication between parties. One actor identified barriers that arise when trying to connect different systems, different companies, different IT systems. All this is a big problem to solve when proposing a solution to a company that therefore not only has to adopt a new technology but has also to consider all the organisational issues that are involved.

In addition to the barriers that emerged from the literature and were confirmed by the supply chain actors, a new barrier that emerged from the direct comparison with the companies concerns the *difficulty in interpreting information conveyed by technology,* since one actor mentioned it.

In the specific case of chromogenic inks, the problem of interpreting the colour change was encountered. It may be that the colour change of a label due to a variation of a certain monitored parameter gives an intermediate colour between those that distinguish between an edible and non-edible product. Such uncertainty is not acceptable because it could lead to further waste. Inaccurate colour change could lead to the rejection of a product that might still be edible. Therefore, this is a problem strictly related to chromogenic inks technology, so it can be considered under the macro category of technological barriers. This is definitely a technological problem that needs to be addressed in order to adopt chromogenic inks as innovative solutions to monitor the state of the food and reduce food waste along the supply chain.

From *Table 6.5* it can be easily seen similarities and differences between what emerged from the literature and what emerged from the case study.
The first thing to notice is the confirmation of the two main barriers, identified by both literature and case study as the most relevant: *Lack of mass market and affordable prices* and *Lack of adequate regulation.* The *Lack of collaborative processes along the SC* was also confirmed by the case study and it is reported in both cases in yellow as it is a barrier of secondary importance with respect to the two previously mentioned.

The barrier *Lack of proper R&D activities, protocols and standard tests*, reported in the literature as medium importance, was not perceived by any technology provider. This may be due to the fact that technologies are improving very quickly in recent years and many technological issues noted in the literature have been resolved by the increasing development activities carried out on these new technologies.

Also the barrier *Lack of solutions for security, privacy, and data ownership issues* found in the literature were not found in the case study. The reason may be related to the fact that already in the literature they were not found to be very relevant as they were only present in 1-2 articles. In the practical case these barriers have either been solved or are not considered so impactful as to prevent the adoption of the new technologies.

On the other hand, some barriers not referred to technology provider in literature, have been perceived by the actors of this SC stage. This is the case of:

- *Lack of long-term profitability perspective*
- *Inertia toward new technology adoption*
- *Lack of trust in sharing information with other actors along the SC*

While literature identified these barriers only with actors in the demand side, i.e., post-harvest, manufacturer, retailer and logistic operator, thanks to the dialogue with technology providers, they have been identified also in the offer side.

Barcodes

Table 6.6:Detaill of the coding interpretation for technology provider SC stage, chromogenic inks (Source: Author's elaboration)

		BARCODES	
	SUB-CATEGORY BARRIERS	LITERATURE	INTERVIEWS
TECHNOLOGICAL AND ENVIRONMENTAL	Lack of proper R&D activities, protocols and standard tests		
	Lack of recyclability for some smart packaging components		
ECONOMIC AND FINANCIAL BARRIERS	Lack of mass market and affordable prices		
	Lack of long-term profitability perspective		
REGULATORY BARRIER	Lack of adequate regulation		
CULTURAL BARRIER	Inertia toward new technology adoption		
ORGANIZATIONAL BARRIERS	Lack of collaborative processes along the SC		
	Lack of Best Practices in the market to follow		
	Lack of solutions for security, privacy, and data ownership issues		
	Lack of a data management system for decision-making/ difficulty in identifying responsibility along the SC		
	Lack of trust in sharing information with other actors along the SC		
MARKET BARRIERS	Lack of smart technology market-competitiveness		
New Barriers from interviews	Difficulty in interpreting information conveyed by technology		

	LEGEND for literature
	LOW RELEVANCE: mentioned by 1-2 articles
	MEDIUM RELEVANCE: mentioned by 3-5 articles
	HIGH RELEVANCE: mentioned 6-8 articles

	LEGEND for interviews
	LOW RELEVANCE: mentioned by 1 actor in that SC stage
	MEDIUM RELEVANCE: mentioned by 2 actors in that SC stage
	HIGH RELEVANCE: mentioned by 3 or more actors in that SC stage

As far as barcode technology is concerned, the two most important barriers encountered by the interviewed companies that confirmed the relevance emerged in literature findings were *Lack of mass market and affordable prices* and *Lack of adequate regulation*. In fact, the technology providers interviewed said that although there has been a boom in barcode technology in recent years, especially for QR codes, there is always a transition phase before mass adoption is achieved. According to them we are still in the transition phase. Moreover, there are other aspects besides economics to consider, for example the legislative framework is aligning with market demands, but the bureaucracy is always moving slower than the technology. This makes private investment a bit wasted because it is not accompanied by a comprehensive legislative framework.

Along with these two barriers, the other highly relevant barrier emerged by case study, but not identified for this specific SC stage by literature was *Inertia toward new technology adoption.*

Technology providers also believe that it is a cultural problem. It in not possible to just jump from the old to the new in a short time because companies are used to work in a certain way. It is a framework that takes shape step by step and it is a process that takes time, to convince companies and to allow them to adapt in times and new needs.

Another barrier that has been validated through the case study regards the *Lack of collaborative processes along the SC.* This barrier had in fact been identified in the literature for this stage of the supply chain, although of lesser importance than the two previously mentioned. It is in fact an surmountable barrier, even if it is still perceived by the actors involved.

The barrier *Lack of solutions for security, privacy, and data ownership issues* found in literature did not emerge from the dialogue with experts, meaning that it is not so impactful as to prevent the adoption of barcodes along the food chain.

On the other hand, a barrier perceived by the actors but not identified by the literature analysis is *Lack of trust in sharing information with other actors along the SC.*
In their experience with barcodes, a technology provider interviewed perceived this as a barrier to the adoption of his technology because business customers are often wary and prefer not to share sensitive data. It takes a lot of trust in supply chain partners to be able to implement such solutions that require the collaboration of many stakeholders.

RFID

Table 6.7::Detail of the coding interpretation for technology provider SC stage, RFID (Source: Author's elaboration)

		RFID	
	SUB-CATEGORY BARRIERS	LITERATURE	INTERVIEWS
TECHNOLOGICAL AND ENVIRONMENTAL	Lack of proper R&D activities, protocols and standard tests		
	Lack of recyclability for some smart packaging components		
ECONOMIC AND FINANCIAL BARRIERS	Lack of mass market and affordable prices		
	Lack of long-term profitability perspective		
REGULATORY BARRIER	Lack of adequate regulation		
CULTURAL BARRIER	Inertia toward new technology adoption		
ORGANIZATIONAL BARRIERS	Lack of collaborative processes along the SC		
	Lack of Best Practices in the market to follow		
	Lack of solutions for security, privacy, and data ownership issues		
	Lack of a data management system for decision-making/ difficulty in identifying responsibility along the SC		
	Lack of trust in sharing information with other actors along the SC		
MARKET BARRIERS	Lack of smart technology market-competitiveness		
New Barriers from interviews	Difficulty in interpreting information conveyed by technology		

	LEGEND for literature
	LOW RELEVANCE: mentioned by 1-2 articles
	MEDIUM RELEVANCE: mentioned by 3-5 articles
	HIGH RELEVANCE: mentioned 6-8 articles

	LEGEND for interviews
	LOW RELEVANCE: mentioned by 1 actor in that SC stage
	MEDIUM RELEVANCE: mentioned by 2 actors in that SC stage
	HIGH RELEVANCE: mentioned by 3 or more actors in that SC stage

As mentioned at the beginning of this section, RFID technology has not been directly used by the interviewed actors. But, even if they did not have direct experience with this technology, they knew very well the solution, as it is widely used in the industrial sector, thus, they were able to give useful insights regarding barriers to adoption of RFID technology along the agri-food supply chain.

The economic problems relate not only to the costs of purchasing the technology, but also to the integration with the warehouse software used by the company. Then an ad hoc reader is needed, which does not always correspond to those used to read common barcodes. In addition, the warehouse management programs must be changed according to the new technology introduced. Also in this case, the economic barrier is therefore not only linked to the purchase of new devices, but also to the integration with production processes and IT systems that already exist and properly function. Therefore, the barrier *Lack of mass market and affordable prices* also in this case confirmed the results coming from the literature and is among the most relevant, also in the case of RFID.

In this specific case the colour related to the case study column is orange and not red, because it is mentioned by two actors on a total of four as a barrier to adoption. This should not be misleading and lead to premature conclusions. It does not mean that the barrier is considered less important than in the literature because, as mentioned above, none of the interviewed actors had direct experience with this technology.

Therefore, there is less information related to RFID than to chromogenic ink and barcode technologies, with which the interviewees had more experience. In fact, in the interviews only two out of four actors mentioned RFID technology according to their knowledge, and both mentioned this economic barrier as the most relevant. This brings us to a different reasoning, and since two out of two actors who talked about RFID mentioned this barrier, it certainly appears to be of high importance compared to the others, even if it has been reported in *Table 6.7* with orange colour.

Another barrier emerged from case study was the *Lack of recyclability for some smart packaging components*. One respondent said that, in addition to cost problems, RFID also has disposal problems because it consists of different parts made of different materials and is not always recyclable. Also in this case the yellow colour does not show a low importance because the sample of actors who mentioned this technology is no more four, as in the case of barcodes and chromogenic inks, but it is two. The colour yellow means that one actor, on a total of two, mentioned this barrier as relevant. All the two barriers identified by case study confirmed literature results. Once again, the method used to show relevance in case study, based on a variable sample size of the respondents, must be always considered.

The other barriers related to RFID adoption emerged from literature has not been confirmed by the case study. This can be due to the lack of experience of the selected companies with this specific technology.

However, it must be noticed that the *Lack of mass market and affordable prices* and the *Lack of recyclability for some smart packaging components*, which were the barriers with highest relevance identified by literature, have been confirmed by interviewees.

Sensors

Table 6.8::Detail of the coding interpretation for technology provider SC stage, sensors (Source: Author's elaboration)

		SENSORS	
	SUB-CATEGORY BARRIERS	LITERATURE	INTERVIEWS
TECHNOLOGICAL AND ENVIRONMENTAL	Lack of proper R&D activities, protocols and standard tests		
	Lack of recyclability for some smart packaging components		
ECONOMIC AND FINANCIAL BARRIERS	Lack of mass market and affordable prices		
	Lack of long-term profitability perspective		
REGULATORY BARRIER	Lack of adequate regulation		
CULTURAL BARRIER	Inertia toward new technology adoption		
ORGANIZATIONAL BARRIERS	Lack of collaborative processes along the SC		
	Lack of Best Practices in the market to follow		
	Lack of solutions for security, privacy, and data ownership issues		
	Lack of a data management system for decision-making/ difficulty in identifying responsibility along the SC		
	Lack of trust in sharing information with other actors along the SC		
MARKET BARRIERS	Lack of smart technology market-competitiveness		
New Barriers from interviews	Difficulty in interpreting information conveyed by technology		

	LEGEND for literature
	LOW RELEVANCE: mentioned by 1-2 articles
	MEDIUM RELEVANCE: mentioned by 3-5 articles
	HIGH RELEVANCE: mentioned 6-8 articles

	LEGEND for interviews
	LOW RELEVANCE: mentioned by 1 actor in that SC stage
	MEDIUM RELEVANCE: mentioned by 2 actors in that SC stage
	HIGH RELEVANCE: mentioned by 3 or more actors in that SC stage

With regard to sensors, as for RFID, the degree of experience of technology providers with this technology is poor. In fact, only one company in four markets sensors, while another mentioned it even without direct experience. Therefore, also in this case the sample of actors who talked about sensors during the interviews is not composed of four, but of two companies. This explains the absence of red colour in the case study column, which would instead show evidence of three actors.

The results recorded in the case study analysis of technology providers with sensors, lead to the same conclusions done for RFID technology. The two barriers that emerged were: *Lack of mass market and affordable prices* and the *Lack of recyclability for some smart packaging components*. Both have been identified by the literature and confirmed by case study.
The other barriers identified in the literature for this specific supply chain stage and technology were also not found by the interviewed actors. This means either that these barriers were not perceived by the interviewees or that they have been overcome. However, it may also mean that the sample size was too small to go into such detail and the limited experience with these technologies does not allow for an accurate picture of the barriers to their adoption.

Drivers

Thanks to the coding process of the interviews, it was possible to extract data in an objective manner. The dialogues with the experts revealed a lot of common points in all the three stages on possible drivers to overcome the barriers to adoption.

First, thanks to the codes on the macro-barriers, it was possible to identify which were the levers to make companies move towards finding solutions. Certainly, from the technology providers' point of view, it emerged that economic and cultural barriers were the main ones to be overcome, along with regulatory barriers.

One way identified by respondents to overcome economic and cultural barriers was through *Marketing and promotion*. One strategy proposed by the interviewees is to bear the expense by providing a trial version of their technology to the client company. In this way the provider makes the client try a new technology to understand its advantages, even if it is more expensive than those currently in use. Thanks to this promotion, the customer will be able to understand that what he spends more, will get back. Experts stated that the economic barrier can only be overcome if companies will look for a result that is not immediate. The mission of technology providers is to make clients understand that the advantage is achieved in the long term and that it is worth investing in technological sustainable innovations because they enable reduction of food waste and traceability of the whole chain.

Respondents noticed a positive response in companies that have a long-term sustainability plan and are ready to launch innovative projects. This is more common in larger companies, while the smaller ones need a short-term economic return. However, as every technological innovation, it is impossible to jump from the old to the new in a short time. Institutions have been pulling in that direction in recent years, but it is a picture that takes shape little by little and it is fundamental to raise awareness of this subject in scientific research to help the process of adopting these technologies.

Remaining on the cultural issue, another way suggested by technology providers was *Collaboration and networking*. In fact, they often relate to the scientific community out of curiosity, to do research in client companies, to study solutions and they collaborate with institutions to understand market needs, study new technologies and try to develop innovative projects.

Alongside this strategy of marketing, raising customer awareness and collaboration with scientific community, *Regulatory support* has been considered of considerable importance by the interviewees. The European community, for example, offers initiatives with which it allocates funds for innovative projects concerning traceability, transparency and sustainability. This is a great incentive for companies to launch innovative projects, to test new technologies with a view to sustainability and to understand the substantial benefits they can gain from using these systems. However, these incentives are often not enough to convince companies to innovate and, above all, not to limit themselves to short but long-lasting projects. Companies are not currently obliged to carry out in-depth controls with this degree of precision, monitoring parameters throughout the supply chain to optimise processes and limit food waste. So, there is a lack of encouragement from this point of view that would favour their spread. In the food sector there should be a rule on waste because today even if a company wastes a certain amount of food there is no consequence. While, if there were limits set by law, beyond which a fine has to be paid, these solutions would be much more popular and used, according to technology providers.

From *Table 6.9* can be seen also the degree of relevance of the proposed drivers. Dark green shows the most cited drivers, mentioned by two or more actors, in this case *Marketing and promotion* and *Regulatory support.* In light green there is *Collaboration and networking*, meaning that one actor has mentioned it. Also in this case, as the interpretation for barriers, it must be considered that this way to define relevance is based on samples with different size. In fact, the sample of respondents belonging to the three SC stages was not homogenous, but it was made up of 4 respondents for the technology providers stage, 3 for the manufacturers and only 1 for the retailers stage.

Table 6.9:Coding interpretation for drivers to overcome adoption barriers proposed by technology providers (Source: Author's elaboration)

TECHNOLOGY PROVIDERS	
MACRO-CATEGORY BARRIERS	**DRIVERS**
Technological/Environmental	-
Economic/Financial	***Marketing and promotion***
Regulatory	***Regulatory support***
Cultural	***Marketing and promotion***
	Collaboration and networking
Organizational	-
Market	-

LEGEND	
(dark green)	HIGH RELEVANCE: mentioned by 2 or more actors
(light green)	MEDIUM RELEVANCE: mentioned by 1 actor

6.2.2 Manufacturers

Coding of the interviews

Table 6.10: Coding of interviews to manufacturers: barriers to the adoption (Source: Author's elaboration)

SC STAGE: MANUFACTURERS				
COMPANY	**TECHNOLOGY**	**MACRO-CATEGORY BARRIERS**	**BARRIERS**	**QUOTES FROM INTERVIEWS**
COMPANY E	BARCODES*	• ECONOMIC • REGULATORY	• Lack of mass market and affordable prices • Lack of adequate regulation	*"Marcare con codice a barre una linea molto veloce non è semplice. Ci sono delle complessità di struttura dell'impianto di produzione e confezionamento che rendono difficile uno stampaggio così veloce. Se c'è qualcuno che paga il problema si risolve, ma allo stato attuale è complicato perché il consumatore dovrebbe pagare qualche decimo di euro in più per avere questo servizio."* *"L'applicazione normativa aiuta a far le cose. Non è obbligatorio usare i QR code dinamici e finchè non lo sarà non ci sarà una spinta in questo senso per spingere l'adozione di queste tecnologie su larga scala."*

	RFID*	• ECONOMIC	• Lack of mass market and affordable prices	*"Non usiamo l'RFID perché nessuno lo leggerebbe nella nostra filiera. Si tratta di un cambio di tecnologia che comporta degli investimenti lungo tutta la filiera".*
	SENSORS* / CHROMO. INKS*	• REGULATORY • MARKET • ECONOMIC • ENVIRONMENTAL	• Lack of adequate regulation • Lack of smart technology market-competitiveness • Lack of mass market and affordable prices • Lack of long-term profitability perspective • Lack of recyclability for some smart packaging components	*"Per sensori e inchiostri cromogenici le barriere sono le medesime. Le cose le facciamo se qualcuno ce lo impone o se il mercato lo richiede. Sono queste le due spinte necessarie che spingono l'adozione di queste tecnologie. E noi non le adottiamo perché non c'è stata ancora nessuna delle due. Oppure dobbiamo vedere un grande ritorno economico, ma neanche questo è uno stimolo che sentiamo perché non vediamo un grande ritorno dall'utilizzo di smart packaging dal momento che trattiamo alimenti a lunga conservazione. (...) per chi tratta alimenti a scadenza breve, una migliore gestione del prodotto basata sulle scadenze avrebbe un ritorno maggiore perché ridurrebbe gli sprechi legati allo scarto di prodotti freschi vicini alla data di scadenza."* *"Se faccio smart packaging per limitare gli sprechi e non sono riciclabili mi infilo in un altro tunnel e per quanto riguarda i sensori sono molto costosi"*

COMPANY F	QR CODES **	• ORGANIZATIONAL • CULTURAL • MARKET	• Lack of collaborative processes along the SC • Lack of trust in sharing information with other actors along the SC • Inertia toward new technology adoption • Lack of smart technology market-competitiveness	*"Abbiamo provato un gap di digitalizzazione notevole, non tanto degli allevamenti, quanto in uscita. Grandi player della GDO non sono ancora pronti con i loro mezzi a garantire una blockchain logistica in linea con quella dei fornitori."* *"Noi abbiamo avuto grandissime difficoltà con gli allevatori, perché non concepivano l'idea di rendere condivisibili i loro dati."* *"Adottare queste tecnologie è un grande rischio. Noi siamo una DOP e abbiamo la filiera già rigidamente controlata, ma se mi metto nei panni di altre aziende, capisco che non tutti vogliano rischiare di esporre dei dati e dicano "Perché devo rischiare di avere segnalazioni per delle cose che se non comunico, mai nessuno verrà a chiedermi?".* *"L'Italia ancora non è pronta, rispetto ad altre nazioni europee in cui la blockchain è molto più nota al consumatore. Il riscontro del cliente non è stato quello che ci si aspettava, ma è tutta una questione di marketing: il trend per il bio, il vegan, il sostenibile, ha portato tante aziende a cambiare, anche se non era qualcosa di obbligatorio. La stessa cosa potrebbe succedere per queste tecnologie. Bisogna credere nello strumento e nelle sue potenzialità."*

COMPANY G	BARCODES** / CHROMOGENIC INKS**	• ECONOMIC • CULTURAL • ORGANIZATIONAL • REGULATORY	• Lack of mass market and affordable prices • Lack of long-term profitability perspective • Inertia toward new technology adoption • Lack of trust in sharing information with other actors along the SC • Lack of solutions for security, privacy, and data ownership issues • Lack of collaborative processes along the SC • Lack of adequate regulation	*“Non avendo ancora raggiunto un mercato di massa, il prezzo rimane ancora d'élite.”* *“Uno fa una cosa che costa tanto se ne ha un certo guadagno. Spesso ci sono degli efficientamenti di flusso che hanno dei ricavi nascosti, difficili da far emergere, che non andranno mai a coprire i costi che invece sono ben visibili, palesi e certi. So quanto mi costa ma non so quale sarà il ritorno sulla mia filiera, in termini di guadagno effettivo ed efficientamento.”* *“Oggi scambiare informazioni con i nostri clienti è davvero difficile, sia per la questione di fiducia e tutela dei dati da un lato, sia per una questione economica: ti danno i dati ma vogliono essere pagati.”* *“C'è la questione della sicurezza dei dati e dell'apertura alla rete. Parlando con un operatore logistico con cui collaboriamo, è emerso che uno dei problemi più grossi è che ormai ogni device è connesso alla rete, e questo può portare a problemi di cyber security.”* *“Oggi ci sono tante tecnologie molto diverse tra loro che riguardano il monitoraggio di parametri diversi. Bisognerebbe riuscire ad essere più collaborativi con l'altro per capire quale sia il dato più importante da monitorare e trovare degli standard di riferimento per regolamentare le cose. Perché altrimenti c'è una proliferazione di diversi strumenti che diventano di difficile applicazione. Se una cosa si riesce a sviluppare su larga scala riuscirà a raggiungere prezzi più accessibili a tutti, mentre se invece rimane una cosa più di nicchia non riesce a svilupparsi.”*

**: direct experience (technology adopted or developed by the actor)

*: knowledge (technology not adopted or developed by the actor)

#: new barrier emerged in interviews, not present in literature

Table 6.11:Coding process for drivers proposed by manufacturers (Source: Author's elaboration)

SC STAGE: MANUFACTURERS			
COMPANY	**MACRO-CATEGORY BARRIERS**	**DRIVERS**	**QUOTES**
COMPANY E	REGULATORY	• Regulatory support	*"Sono le leggi che fanno cambiare la situazione. Il click avviene soltanto attraverso una sorta di obbligo. Altrimenti ciascuno avrà sempre un motivo per non investire in una tecnologia nuova, diversa, che comporta un certo grado di complessità anche in termini organizzativi. (…) Quando c'è un salto di questa natura servono gli incentivi e gli aiuti finanziari, ma serve un intervento pubblico che evidenzi il problema e ponga degli obiettivi (es. diminuire gli sprechi) istaurando un vero e proprio meccanismo virtuoso."*
COMPANY F	CULTURAL/ ECONOMIC	• Marketing and promotion	*"Abbiamo puntato su tutti i tipi di marketing: promozione digitale, eventi, stampa di settore (articoli su editoriali dedicati alla GDO), progetti con università per farci conoscere e diffondere i benefici della blockchain."*
COMPANY G	CULTURAL	• Collaboration and networking	*"Quello che si può fare e che abbiamo fatto è quello di coinvolgere istituti molto influenti su questo aspetto. Riuscire a portare a bordo dei nostri progetti la comunità scientifica, le istituzioni, le associazioni di categoria. Creare una sorta di collaborazione per il dialogo tra attori molto diversi. Il lavoro della comunità scientifica è molto importante per portare idee innovative nel mondo delle aziende, perché hanno una cassa di risonanza enorme in determinati contesti."*

Coding interpretation

The manufacturer stage involved 3 different companies that made a valuable contribution to this Research: *company E, company F,* and *company G* (see *section 6.1* for details).
Experts interviewed expressed the point of view of manufacturers on the solutions they use in their company. In particular, the companies interviewed had direct experience with barcodes and chromogenic inks.
Unfortunately, none of the three companies had any direct experience with RFID and sensors, but some interviewees wanted to express their opinion on these technologies, as they are well known in the industrial and manufacturing world. This lack of experience with RFID and sensors could explain why the case study columns of these technologies (see *Table 6.12*) are emptier than the case study columns on the other two technologies and yellow is the only colour, meaning that only one actor mentioned that barrier.
The interviewed actors had more experience with barcodes and chromogenic inks technologies and therefore the case study columns related to these two technologies are fuller.

In *Table 6.12* comprehensive results for all the four technologies in the specific SC stage of manufacturers are reported.

In the next sections the coding interpretation for each single technology is explained in detail, starting from chromogenic inks, then barcodes, RFID and in the end sensors. From *Table 6.13* to *Table 6.16* it is possible to see similarities and differences between literature findings and case study for each specific technology.

Table 6.12: Coding interpretation for barriers, manufacturers stage (Source: Author's elaboration

		CHROMOGENIC INKS		BARCODES		RFID		SENSORS	
	SUB-CATEGORY BARRIERS	LITERATURE	INTERVIEWS	LITERATURE	INTERVIEWS	LITERATURE	INTERVIEWS	LITERATURE	INTERVIEWS
TECHNOLOGICAL AND ENVIRONMENTAL	Lack of proper R&D activities, protocols and standard tests								
	Lack of recyclability for some smart packaging components					HIGH		HIGH	LOW
ECONOMIC AND FINANCIAL BARRIERS	Lack of mass market and affordable prices	HIGH	MEDIUM	HIGH	MEDIUM	HIGH	LOW	HIGH	LOW
	Lack of long-term profitability perspective	LOW	MEDIUM	LOW	LOW	LOW		LOW	LOW
REGULATORY BARRIER	Lack of adequate regulation		MEDIUM		MEDIUM				LOW
CULTURAL BARRIER	Inertia toward new technology adoption	MEDIUM	LOW	MEDIUM	MEDIUM	MEDIUM		MEDIUM	
ORGANIZATIONAL BARRIERS	Lack of collaborative processes along the SC	LOW	LOW	LOW	MEDIUM	LOW		LOW	
	Lack of Best Practices in the market to follow	LOW		LOW		LOW		LOW	
	Lack of solutions for security, privacy, and data ownership issues	LOW	LOW	LOW	LOW	LOW		LOW	
	Lack of a data management system for decision-making/ difficulty in identifying responsibility along the SC	LOW		LOW		LOW		LOW	
	Lack of trust in sharing information with other actors along the SC	LOW	LOW	LOW	MEDIUM	LOW		LOW	
MARKET BARRIERS	Lack of smart technology market-competitiveness	LOW	LOW	LOW	LOW	LOW		LOW	LOW
New Barriers from interviews	Difficulty in interpreting information conveyed by technology		LOW						

LEGEND for literature	
(yellow)	LOW RELEVANCE: mentioned by 1-2 articles
(orange)	MEDIUM RELEVANCE: mentioned by 3-5 articles
(red)	HIGH RELEVANCE: mentioned 6-8 articles

LEGEND for interviews	
(yellow)	LOW RELEVANCE: mentioned by 1 actor in that SC stage
(orange)	MEDIUM RELEVANCE: mentioned by 2 actors in that SC stage
(red)	HIGH RELEVANCE: mentioned by 3 or more actors in that SC stage

Chromogenic inks

Table 6.13: Detail of the coding interpretation for manufacturer SC stage, chromogenic inks (Source: Author's elaboration)

	SUB-CATEGORY BARRIERS	CHROMOGENIC INKS LITERATURE	CHROMOGENIC INKS INTERVIEWS
TECHNOLOGICAL AND ENVIRONMENTAL	Lack of proper R&D activities, protocols and standard tests		
	Lack of recyclability for some smart packaging components		
ECONOMIC AND FINANCIAL BARRIERS	Lack of mass market and affordable prices		
	Lack of long-term profitability perspective		
REGULATORY BARRIER	Lack of adequate regulation		
CULTURAL BARRIER	Inertia toward new technology adoption		
ORGANIZATIONAL BARRIERS	Lack of collaborative processes along the SC		
	Lack of Best Practices in the market to follow		
	Lack of solutions for security, privacy, and data ownership issues		
	Lack of a data management system for decision-making/ difficulty in identifying responsibility along the SC		
	Lack of trust in sharing information with other actors along the SC		
MARKET BARRIERS	Lack of smart technology market-competitiveness		
New Barriers from interviews	Difficulty in interpreting information conveyed by technology		

LEGEND for literature	
(yellow)	LOW RELEVANCE: mentioned by 1-2 articles
(orange)	MEDIUM RELEVANCE: mentioned by 3-5 articles
(red)	HIGH RELEVANCE: mentioned 6-8 articles

LEGEND for interviews	
(yellow)	LOW RELEVANCE: mentioned by 1 actor in that SC stage
(orange)	MEDIUM RELEVANCE: mentioned by 2 actors in that SC stage
(red)	HIGH RELEVANCE: mentioned by 3 or more actors in that SC stage

As far as chromogenic ink technology is concerned, the interviews revealed that the most relevant barriers are

- *Lack of mass market and affordable prices,*
- *Lack of long-term profitability perspective,*
- *Lack of adequate regulation,*

Two out of three manufacturers perceived these barriers as the most impactful and the most difficult to overcome.

Respondents confirmed that because these technologies have not yet reached a mass market, the price still remains for the elite. Moreover, experts believe that a company will only do something that costs a lot of money if it makes a certain profit. Often there are flow efficiencies that have hidden revenues, which are difficult to reveal and which will never cover the costs, that, on the other hand, are clearly visible and certain. Companies know how much it costs but they do not know what the return will be, in terms of actual profit and efficiency gains.

Today there are so many different technologies involved in monitoring different parameters. Interviewees believe that companies should be able to be more collaborative with each other in order to understand what is the most important data to monitor and to find reference standards to regulate things, otherwise there would be a proliferation of different tools that become difficult to apply. If something can be developed on a large scale, it will be able to reach prices that are more accessible to everyone, whereas if it remains a niche product, it cannot develop.
In addition, one interviewee stated that his company does things only if someone imposes them or if the market demands it. Those are the two necessary pushes that drive the adoption of new technologies and none of them has happened yet.
Therefore, these statements respectively correspond to the regulatory barrier and the market barrier identified by literature: *Lack of adequate regulation,* and *Lack of smart technology market-competitiveness.*

Also cultural barrier has been perceived by manufacturers, as well as many organizational barriers.

From *Table 6.13* it can be easily seen which organizational barriers identified by literature have been confirmed by the case study:

- *Lack of collaborative processes along the SC,*
- *Lack of solutions for security, privacy and data ownership issues,*
- *Lack of trust in sharing information with other actors along the SC.*

Interviewed manufacturing companies said that today exchanging information with retail customers is really difficult, both because of the issue of trust and data protection, and because of an economic issue since they give you the data but they want to be paid. In addition, there is the issue of data security and access to the net. A manufacturer said that talking to a logistics operator he works with, it turns out that one of the biggest problems is that today every device is connected to the net, and this can lead to cyber security problems.

On the other hand, a barrier which emerged from the direct dialogue with expert but not from literature is *Difficulty in interpreting information conveyed by technology*. The same barrier has been perceived by the technology providers who sell chromogenic inks. At the same way, manufacturers encountered the problem of interpreting the colour change. The colour change of a label due to a variation of a certain monitored parameter can give an intermediate colour between those that distinguish between an edible and non-edible product. Such uncertainty is not acceptable because it could lead to further waste.

Making a comparison between what emerged from literature and from case study, it must be noticed that almost all the barriers derived from literature have been confirmed by interviews. Only the *Lack of best practices in the market to follow* and the *Lack of a data management system for decision making/difficulty in identifying responsibility along the SC* have not been confirmed, meaning that they are not perceived by manufacturers.

If on the one side almost all barriers have been confirmed, on the other side only one barrier emerged from case study differently from literature: *Lack of adequate regulation.* From the case study this barriers emerged to be of medium relevance, meaning that also technology providers perceive the lack of regulations as an obstacle to the adoption of these technologies.

Barcodes

Table 6.14: Detail of the coding interpretation for manufacturer SC stage, barcodes (Source: Author's elaboration)

		BARCODES	
	SUB-CATEGORY BARRIERS	LITERATURE	INTERVIEWS
TECHNOLOGICAL AND ENVIRONMENTAL	Lack of proper R&D activities, protocols and standard tests		
	Lack of recyclability for some smart packaging components		
ECONOMIC AND FINANCIAL BARRIERS	Lack of mass market and affordable prices		
	Lack of long-term profitability perspective		
REGULATORY BARRIER	Lack of adequate regulation		
CULTURAL BARRIER	Inertia toward new technology adoption		
ORGANIZATIONAL BARRIERS	Lack of collaborative processes along the SC		
	Lack of Best Practices in the market to follow		
	Lack of solutions for security, privacy, and data ownership issues		
	Lack of a data management system for decision-making/ difficulty in identifying responsibility along the SC		
	Lack of trust in sharing information with other actors along the SC		
MARKET BARRIERS	Lack of smart technology market-competitiveness		
New Barriers from interviews	Difficulty in interpreting information conveyed by technology		

LEGEND for literature	
	LOW RELEVANCE: mentioned by 1-2 articles
	MEDIUM RELEVANCE: mentioned by 3-5 articles
	HIGH RELEVANCE: mentioned 6-8 articles

LEGEND for interviews	
	LOW RELEVANCE: mentioned by 1 actor in that SC stage
	MEDIUM RELEVANCE: mentioned by 2 actors in that SC stage
	HIGH RELEVANCE: mentioned by 3 or more actors in that SC stage

The results of case study analysis for the specific case of barcodes in the SC stage of manufacturers are similar to the ones for the case of chromogenic inks. Also in this case the most relevant barriers perceived by the interviewees correspond to the most relevant ones identified by literature:

- *Lack of mass market and affordable prices,*
- *Inertia toward new technology adoption,*

In addition to these, the other barriers considered as the most relevant, even more than what emerged from literature are:

- *Lack of collaborative processes along the SC,*
- *Lack of trust in sharing information with other actors along the SC.*

All these barriers coloured in orange in the case study column of *Table 6.14* show that two actors on a total of three mentioned them as relevant.

Another barrier perceived as the most relevant, coloured in orange, is *Lack of adequate regulation*. As in the case of chromogenic ink, this barrier has not been reported by literature as relevant for manufacturer SC stage. But, manufacturing companies interviewed perceived this obstacle as well as technology providers.

Also in this case, making a comparison between what emerged from literature and from case study, it must be noticed that almost all the barriers derived from literature have been confirmed by interviews. Only the *Lack of best practices in the market to follow* and the *Lack of a data management system for decision making/difficulty in identifying responsibility along the SC* have not been confirmed, meaning that they are not perceived as impactful by manufacturers or that they have been overcome.

Also in this case it must be remembered the sample size. Differently from the technology providers stage, with was made up of a sample of 4 companies, the manufacturers stage was composed of 3 companies. This means that for this SC stage is more difficult to obtain red barriers because it would require unanimity of the respondents, i.e. 3 actors out of a total of 3. This limitation related to the heterogeneity of respondents sample size must always be kept in mind, when analysing results of interpretation of interviews.

RFID

Table 6.15:Detail of the coding interpretation for manufacturer SC stage, RFID (Source: Author's elaboration

		RFID	
	SUB-CATEGORY BARRIERS	LITERATURE	INTERVIEWS
TECHNOLOGICAL AND ENVIRONMENTAL	Lack of proper R&D activities, protocols and standard tests		
	Lack of recyclability for some smart packaging components		
ECONOMIC AND FINANCIAL BARRIERS	Lack of mass market and affordable prices		
	Lack of long-term profitability perspective		
REGULATORY BARRIER	Lack of adequate regulation		
CULTURAL BARRIER	Inertia toward new technology adoption		
ORGANIZATIONAL BARRIERS	Lack of collaborative processes along the SC		
	Lack of Best Practices in the market to follow		
	Lack of solutions for security, privacy, and data ownership issues		
	Lack of a data management system for decision-making/ difficulty in identifying responsibility along the SC		
	Lack of trust in sharing information with other actors along the SC		
MARKET BARRIERS	Lack of smart technology market-competitiveness		
New Barriers from interviews	Difficulty in interpreting information conveyed by technology		

	LEGEND for literature
	LOW RELEVANCE: mentioned by 1-2 articles
	MEDIUM RELEVANCE: mentioned by 3-5 articles
	HIGH RELEVANCE: mentioned 6-8 articles

	LEGEND for interviews
	LOW RELEVANCE: mentioned by 1 actor in that SC stage
	MEDIUM RELEVANCE: mentioned by 2 actors in that SC stage
	HIGH RELEVANCE: mentioned by 3 or more actors in that SC stage

As mentioned at the beginning of this section, RFID technology has not been directly used by the interviewed manufacturing companies. But, even if they did not have direct experience with this technology, they knew very well the solution, as it is widely used in the industrial sector.
Specifically, one actor was able to give useful insights regarding barriers to adoption of RFID technology along the agri-food supply chain.

The main barrier stated by the interviewee regarded economic problems relate not only to the costs of purchasing the technology, but also to the integration with the warehouse software used by the company. There is the need an ad hoc reader, which does not always correspond to those already used to read common barcodes. In addition, the warehouse management programs must be changed according to the new technology introduced.

In this specific case the colour related to the case study column is yellow and not red, because it is mentioned only by one actor on a total of three as a barrier to adoption. This should not be misleading and lead to premature conclusions. It does not mean that the barrier is considered less important than in the literature because, as mentioned above, none of the interviewed actors had direct experience with this technology.
Therefore, there is less information related to RFID than to chromogenic ink and barcode technologies, with which the interviewees had direct experience.

Since the experience with this technology was poor for the interviewees in this SC stage, it has not been possible to deeply analyse barriers from the actors' point of view. It has only been possible to confirm once again that most impactful barrier is the *Lack of mass market and affordable prices.*

Sensors

Table 6.16:Detail of the coding interpretation for manufacturer SC stage, sensors (Source: Author's elaboration)

	SUB-CATEGORY BARRIERS	SENSORS	
		LITERATURE	INTERVIEWS
TECHNOLOGICAL AND ENVIRONMENTAL	Lack of proper R&D activities, protocols and standard tests		
	Lack of recyclability for some smart packaging components		
ECONOMIC AND FINANCIAL BARRIERS	Lack of mass market and affordable prices		
	Lack of long-term profitability perspective		
REGULATORY BARRIER	Lack of adequate regulation		
CULTURAL BARRIER	Inertia toward new technology adoption		
ORGANIZATIONAL BARRIERS	Lack of collaborative processes along the SC		
	Lack of Best Practices in the market to follow		
	Lack of solutions for security, privacy, and data ownership issues		
	Lack of a data management system for decision-making/ difficulty in identifying responsibility along the SC		
	Lack of trust in sharing information with other actors along the SC		
MARKET BARRIERS	Lack of smart technology market-competitiveness		
New Barriers from interviews	Difficulty in interpreting information conveyed by technology		

	LEGEND for literature
	LOW RELEVANCE: mentioned by 1-2 articles
	MEDIUM RELEVANCE: mentioned by 3-5 articles
	HIGH RELEVANCE: mentioned 6-8 articles

	LEGEND for interviews
	LOW RELEVANCE: mentioned by 1 actor in that SC stage
	MEDIUM RELEVANCE: mentioned by 2 actors in that SC stage
	HIGH RELEVANCE: mentioned by 3 or more actors in that SC stage

As far as sensors are concerned, as for RFID, the degree of experience of manufacturers with this technology is poor. In fact, none of the interviewees had direct experience with sensors, while only one company expressed its point of view with adoption of this technology.

Therefore, also in this case the sample of actors who talked about sensors during the interviews is not composed of three, but of only one company. This explains the absence of red and orange colour in the case study column.

Barriers corresponding to yellow colour in case study column does not mean that the barrier is of low relevance because it has been mentioned by only one actor. This means that the only one actor who talked about sensors identified that barrier as relevant. Therefore, considering him as reference sample, barriers mentioned are the ones of highest relevance.

However, the barriers that emerged from the dialogue with manufacturers basically confirmed what emerged from literature.

The comparison between literature and case study column in *Table 6.16* shows how barriers emerged in literature and confirmed by case study are:

- *Lack of recyclability for some smart packaging components,*
- *Lack of mass market and affordable prices,*
- *Lack of long-term profitability perspective,*
- *Lack of smart technology market-competitiveness.*

On the other hand, a barrier not perceived by literature but mentioned by the interviewees is *Lack of adequate regulation*. This one has been reported by manufacturers also with regard to the other technologies. This means that, even if academic and grey literature did not report this obstacle for manufacturers SC stage, it is perceived by them as well as technology providers.

The other barriers present in literature but not mentioned by the manufacturer are cultural and organizational. Since they have not been mentioned by the interviewee, it can be deducted that they are not so impactful as economic and environmental are, confirming literature point of view.
In fact, as it can be easily seen by looking at the red coloured cells of the literature column, the most perceived barriers were *Lack of recyclability for some smart packaging components* and *Lack of mass market and affordable prices,* which have been confirmed by case study. It must be noticed that these barriers have been perceived also by the technology providers SC stage meaning that they are certainly the most impactful barriers and the first ones that need to be addressed during the implementation of innovative technologies, either for the offer point of view (technology providers) and for the demand point of view (actors in the supply chain, such as manufacturers).
On the other hand, cultural and organizational barriers are yellow coloured in the literature column, meaning that they had a low relevance according to the other ones.

Drivers

The Respondents belonging to manufacturing provided similar insights regarding drivers to overcome barriers to adoption with respect to technology providers'ones. Manufacturing companies often have to convince partners such as suppliers, logistics operators and retailers to adopt this technology to complete the supply chain of their products. Since they are the producers of the final product that reaches the shelves, they have a key role in the supply chain because they need to convince all the other actors in the supply chain to properly monitor their product in order to reach common sustainable goals and decrease the generation of surplus food and food waste along the supply chain. It is not surprising that the drivers proposed by manufacturers include *Marketing and promotion* and *Collaboration and networking* as for the precious SC stage. The companies interviewed focused on all kinds of marketing: digital promotion, events, trade press (articles in editorials dedicated to large-scale retail), projects with universities to raise awareness and spread the benefits of sustainable innovations.

In addition to marketing, there is also collaboration with the scientific community. A driver to overcome adoption barriers is involving very influential institutes sensible on aspects such as technology, innovation and sustainability, and being able to bring the scientific community and institutions on board our projects. In this way a field of dialogue for experimentation is created. The work of the scientific community is very important for bringing innovative ideas into the corporate world, because they have a huge resonance in certain contexts.

The other driver proposed by the manufacturers, as technology providers did, is *Regulatory support.* Respondents stated that laws are able to change the situation and changes are only achieved through some sort of obligation.

Otherwise, everyone will always have a reason not to invest in a new, different technology, which involves a certain degree of complexity in terms of organisation and new and unknown risks. When there is a change of this nature, incentives and financial aids are certainly needed, as has already been said by technology providers. But in addition to this, public intervention is needed to highlight the problem of food waste and set the same targets for everyone, with defined limits, establishing a real virtuous mechanism of collaboration to pursue sustainability objectives common to all stakeholders in the food supply chain.

In conclusion, the drivers that emerged from the discussion with the supply chain actors were the same on both the offer and demand sides, demonstrating that, in order to overcome the barriers to the adoption of these technologies, it is necessary to move together and collaborate with all the supply chain partners in order to achieve the common goal of reducing surplus food and food waste. This is only possible through awareness-raising achievable thanks marketing and promotions, through collaboration with the scientific community and institutions, and through the support of legislation that should define guidelines and limits to be respected in order to reduce waste.

In *Table 6.17* drivers proposed and referred to the barriers perceived by manufacturers are reported. Also in this case, different colours show the different relevance: *Marketing and promotion* was the most mentioned in the interviews, while *Collaboration and networking* and *Regulatory support* were mentioned by 1 actor on a total of 3.

Table 6.17:Coding interpretation for drivers to overcome adoption barriers proposed by manufacturers (Source: Author's elaboration)

MANUFACTURERS	
MACRO-CATEGORY BARRIERS	**DRIVERS**
Technological/Environmental	-
Economic/Financial	***Marketing and promotion***
Regulatory	***Regulatory support***
Cultural	***Marketing and promotion***
	Collaboration and networking
Organizational	-
Market	-

LEGEND	
(dark green)	HIGH RELEVANCE: mentioned by 2 or more actors
(light green)	MEDIUM RELEVANCE: mentioned by 1 actor

6.2.3 Retailers

Coding of interviews

Table 6.18: Coding of interviews to retailers: barriers to the adoption (Source: Author's elaboration)

SC STAGE: RETAILERS				
COMPANY	**TECHNOLOGY**	**MACRO-CATEGORY BARRIERS**	**BARRIERS**	**QUOTES FROM INTERVIEWS**
COMPANY H	QR CODES**	• ECONOMIC • REGULATORY	• Lack of mass market and affordable prices • Lack of long-term profitability perspective • Lack of adequate regulation	*"La barriera economica riguarda la modifica dei materiali, gli impianti per poter utilizzare nuovi imballaggi, il database. I prezzi per le innovazioni hanno sempre cifre folli. Va bene avere degli ammortamenti iniziali, ma i differenziali di prezzo sono molto importanti e, anche se il sovraprezzo fosse distribuito lungo la catena del valore, anche al consumatore finale arriva un sovraprezzo di minima e questo è un periodo molto delicato per il consumatore."* *"A livello regolamentare le procedure sono sempre lente e complicate, sono sempre in ritardo, perciò è una barriera molto difficile da superare".*

	CHROMOGENIC INKS**	• ECONOMIC • TECHNOLOGICAL • ORGANIZATIONAL	• Lack of mass market and affordable prices • Lack of long-term profitability perspective • Difficulty in interpreting information conveyed by technology# • Difficulty in identifying responsibility along the SC	*"Gli investimenti per le etichette cromogeniche erano troppo sostanziosi. Inoltre c'erano problemi di resa tecnologica: il prodotto poteva essere ancora edibile anche se l'etichetta mostrava un viraggio di colore. Era difficile per il cliente interpretarne il significato."* *"A livello organizzativo è complicato, perché potresti essere considerato il responsabile di qualcosa che tu non governi pienamente: la variazione di qualità infatti legata allo stato di ossidazione del prodotto non è detto che sia avvenuta per colpa della nostra azienda."*

**: direct experience (technology adopted or developed by the actor)

***:** knowledge (technology not adopted or developed by the actor)

#: new barrier emerged in interviews, not present in literature

Table 6.19:Coding process for drivers proposed by retailers (Source: Author's elaboration)

SC STAGE: RETAILERS			
COMPANY	**MACRO-CATEGORY BARRIERS**	**DRIVERS**	**QUOTES**
COMPANY H	ECONOMIC	• None	*"Se non si rompono le barriere economiche, non ci sarà mai un mercato di massa. Gli investimenti necessari sono ancora troppo sostanziosi (...). L'analisi costi-benefici del nostro progetto con i QR code non è stata molto favorevole. I costi erano molto elevati, non per il pack in sé, ma per tutto ciò che c'è dietro: impianto, database, integrazione."*

Coding interpretation

The analysis of the retailer's stage in our case study involved only one actor: *company H* (see *section 6.1.8* for details).

It has not been possible to organise interviews with other companies, so the sample size is very small. This explains why only yellow is shown in the case study columns of the *Table 6.20.* This means that the single barrier was mentioned by the only actor interviewed.

In *Table 6.20* comprehensive results for all the four technologies in the specific SC stage of retailers are reported. The presence of only one company at this stage did not allow to analyse the barriers for RFID and sensor technologies as the company had no experience nor did it want to express a judgement on these technologies as they were far from its field of action.
For this reason case study columns related to RFID and sensors have the label "not mentioned".

In the next sections the coding interpretation for the remaining two technologies is explained in detail, From *Table 6.21* to *Table 6.22* it is possible to see similarities and differences between literature findings and case study for each specific technology.

Table 6.20: Coding interpretation for barriers, retailers stage (Source: Author's elaboration)

		CHROMOGENIC INKS		BARCODES		RFID		SENSORS	
	SUB-CATEGORY BARRIERS	LITERATURE	INTERVIEWS	LITERATURE	INTERVIEWS	LITERATURE	INTERVIEWS	LITERATURE	INTERVIEWS
TECHNOLOGICAL AND ENVIRONMENTAL	Lack of proper R&D activities, protocols and standard tests						Not mentioned		Not mentioned
	Lack of recyclability for some smart packaging components								
ECONOMIC AND FINANCIAL BARRIERS	Lack of mass market and affordable prices								
	Lack of long-term profitability perspective								
REGULATORY BARRIER	Lack of adequate regulation								
CULTURAL BARRIER	Inertia toward new technology adoption								
ORGANIZATIONAL BARRIERS	Lack of collaborative processes along the SC								
	Lack of Best Practices in the market to follow								
	Lack of solutions for security, privacy, and data ownership issues								
	Lack of a data management system for decision-making/ difficulty in identifying responsibility along the SC								
	Lack of trust in sharing information with other actors along the SC								
MARKET BARRIERS	Lack of smart technology market-competitiveness								
New Barriers from interviews	Difficulty in interpreting information conveyed by technology								

LEGEND for literature
LOW RELEVANCE: mentioned by 1-2 articles
MEDIUM RELEVANCE: mentioned by 3-5 articles
HIGH RELEVANCE: mentioned 6-8 articles

LEGEND for interviews
RELEVANCE: mentioned by the actor

Chromogenic inks

Table 6.21:Detail of the coding interpretation for retailer SC stage, chromogenic inks (Source: Author's elaboration)

		CHROMOGENIC INKS	
	SUB-CATEGORY BARRIERS	LITERATURE	INTERVIEWS
TECHNOLOGICAL AND ENVIRONMENTAL	Lack of proper R&D activities, protocols and standard tests		
	Lack of recyclability for some smart packaging components		
ECONOMIC AND FINANCIAL BARRIERS	Lack of mass market and affordable prices	[red]	[yellow]
	Lack of long-term profitability perspective	[yellow]	[yellow]
REGULATORY BARRIER	Lack of adequate regulation		
CULTURAL BARRIER	Inertia toward new technology adoption	[orange]	
ORGANIZATIONAL BARRIERS	Lack of collaborative processes along the SC	[yellow]	
	Lack of Best Practices in the market to follow	[yellow]	
	Lack of solutions for security, privacy, and data ownership issues	[yellow]	
	Lack of a data management system for decision-making/ difficulty in identifying responsibility along the SC	[yellow]	[yellow]
	Lack of trust in sharing information with other actors along the SC	[yellow]	
MARKET BARRIERS	Lack of smart technology market-competitiveness	[yellow]	
New Barriers from interviews	Difficulty in interpreting information conveyed by technology		[yellow]

	LEGEND for literature
[yellow]	LOW RELEVANCE: mentioned by 1-2 articles
[orange]	MEDIUM RELEVANCE:mentioned by 3-5 articles
[red]	HIGH RELEVANCE: mentioned 6-8 articles

	LEGEND for interviews
[yellow]	RELEVANCE: mentioned by the actor

The interviewed company had direct experience with chromogenic inks as a few years ago they started a project of chromogenic labels that measured the oxidation status of the product. The first barriers that were perceived by the interviewee were the economic ones: *Lack of mass market and affordable prices* and *Lack of long-term profitability perspective.* The investment in the chromogenic labels was too high compared to the economic return for their company.

In addition, with chromogenic inks, there were technological yield problems: the product could still be edible even if the label showed a colour change. It was difficult to interpret the meaning of the colours shown on the label because there were often intermediate and uncertain colours, which could lead to rejecting a product even if it was still in good condition. This barrier was not perceived in the literature, but was found by this actor, as well as it has been reported by a technology provider previously mentioned. Therefore, a new barrier has been added to the conceptual framework developed by the literature analysis: *Difficulty in interpreting information conveyed by technology*.

On an organisational level, the interviewee admitted that he sees a golden and privileged situation, because his company has many controlled supply chains and it is easier to manage different partners, from suppliers to processors, because there are already many controls and rules to respect along their controlled and certified supply chains. For this reason, most of the organisational barriers reported in literature for this supply chain stage were not perceived by the interviewed company.
The only one found was: *Difficulty in identifying responsibility along the SC*. The respondent explained how his company could be held responsible for something that it does not fully govern and this is a risk that many companies, including the respondent itself, do not want to take. Therefore, it is perceived as one of the barriers to adopting this technology.

Another barrier reported in literature but not perceived by the interviewee is the cultural one: *Inertia toward new technology adoption*. In fact, the company perceives a growing awareness and informatization and does not believe that there are cultural barriers to the adoption of innovative technologies.

In conclusion, from *Table 6.21* it can be easily seen as the barriers confirmed by case study are:

- *Lack of mass market and affordable prices,*
- *Lack of long-term profitability perspective,*
- *Difficulty in identifying responsibility along the SC*.

On the other hand, some barriers did not emerge from the case study because of the context in which the company is. As mentioned before, controlled and certified supply chains do not suffer from organisational problems and also the cultural barrier is not perceived at this stage.

Barcodes

Table 6.22:Detail of the coding interpretation for retailer SC stage, barcodes (Source: Author's elaboration)

		BARCODES	
	SUB-CATEGORY BARRIERS	LITERATURE	INTERVIEWS
TECHNOLOGICAL AND ENVIRONMENTAL	Lack of proper R&D activities, protocols and standard tests		
	Lack of recyclability for some smart packaging components		
ECONOMIC AND FINANCIAL BARRIERS	Lack of mass market and affordable prices		
	Lack of long-term profitability perspective		
REGULATORY BARRIER	Lack of adequate regulation		
CULTURAL BARRIER	Inertia toward new technology adoption		
ORGANIZATIONAL BARRIERS	Lack of collaborative processes along the SC		
	Lack of Best Practices in the market to follow		
	Lack of solutions for security, privacy, and data ownership issues		
	Lack of a data management system for decision-making/ difficulty in identifying responsibility along the SC		
	Lack of trust in sharing information with other actors along the SC		
MARKET BARRIERS	Lack of smart technology market-competitiveness		
New Barriers from interviews	Difficulty in interpreting information conveyed by technology		

	LEGEND for literature
	LOW RELEVANCE: mentioned by 1-2 articles
	MEDIUM RELEVANCE:mentioned by 3-5 articles
	HIGH RELEVANCE: mentioned 6-8 articles

	LEGEND for interviews
	RELEVANCE: mentioned by the actor

Regarding the retailer's experience with barcodes, the interviewee told us about his experience with a QR code project implemented on one of his controlled and certified supply chains. The most relevant barriers once again turned out to be the economic ones: *Lack of mass market and affordable prices* and *Lack of long-term profitability perspective*.

The economic barrier does not only concern the purchase of innovative technology, but the costs also concern the modification of materials, the equipment to use new packaging, the database to be implemented or modified. The interviewee said that prices for innovations are always crazy. It is fine to have initial amortization and support from technology providers, but price differentials are very important and have to be considered. Even if the overpricing was distributed along the value chain, the end consumer also gets a minimum overpricing and this is a very sensitive time for the consumer. It was the interviewee from this stage who raised the issue of the price differential reaching the final consumer, while the actors from other stages bypassed this issue.

Concerning the long-term economic return, the interviewee specified that the QR code project had been a pilot project to conduct a cost-benefit analysis of the implementation of this innovative technology. With this project the company wanted to assess the economic and management sustainability in terms of time and costs. The result was not very satisfactory because the costs were too high, not so much for the packaging itself, but for everything behind it: the system, the database, the integration. The company therefore decided not to adopt this technology of QR codes any more and concluded that the economic barrier is still too impactful and until it is overcome, there will never be a mass market for these innovative technologies.

These two economic barriers validated results obtained by literature review, while a barrier not reported in the literature for this stage of the supply chain, but perceived by the interviewee has been the regulatory one. To the barrier *Lack of adequate regulation* the respondent answered that at the regulatory level, the procedures are always slow and complicated. They are always late, so it is a very difficult barrier to overcome.

All the other barriers identified by literature concerned organizational and cultural problems. As said in the section of chromogenic inks, this retailer sees a golden situation since controlled and certified supply chains do not suffer from organisational problems.
At the same time the cultural barrier is not perceived at this stage, but retailer perceives a growing interest in sustainability issues and does not believe in this obstacle for the adoption of innovative technologies along the supply chain.

Drivers

As far as the retailer stage is concerned, no drivers have been identified by the company to overcome barriers to adoption. For this reason, in *Table 6.23* no driver was identified to overcome the barriers which were perceived by retailers.

In fact, the interviewee stated that if the economic barriers are not broken, there will never be a mass market for innovative technologies. The investments needed are still too substantial. The cost-benefit analysis of their project with smart packaging was not favourable because their experience with innovative technologies under exam had led to high investments. The costs were very high because they involved plant modifications, new databases, and integration with existing systems.

From the point of view of the retailer, no solutions were proposed. However, there is interest in the topic of sustainability and understanding of advantages, as the company is interested in innovative projects and is large enough to be able to experiment in the application of new technologies and innovations. Anyway, the interviewee from was not able to find solutions and identify drivers to overcome the barriers to adoption, unless lowering the costs. In his view, therefore, economic barriers are still too substantial for a large-scale diffusion of smart packaging, and he is waiting for prices to come down in order to adopt these types of systems in the future.

Table 6.23:Coding interpretation for drivers to overcome adoption barriers, retailers (Source: Author's elaboration)

RETAILERS	
MACRO-CATEGORY BARRIERS	**DRIVERS**
Technological/Environmental	Not mentioned
Economic/Financial	
Regulatory	
Cultural	
Organizational	
Market	

6.3 Discussion of results

In this section, the final considerations related to the findings derived both from the case study and from the re-elaboration of the literature are illustrated with reference to the research questions presented in *Chapter 3*:

From the evidence derived from the case study, it can be confirmed that the structure of the conceptual frameworks proved to be adaptable also to the case study. In fact, the same barriers and drivers deriving from literature have been mentioned by the interviewed, with the only add of the barrier *Difficulty in interpreting information conveyed by technology* related to the chromogenic ink technology.

This specific barrier was perceived in the same way by actors belonging to all three stages of the supply chain with regard to chromogenic ink technology. This is the reason why it can be considered under the macro category of technological barriers. It is difficult to interpret the colour change, which is characteristic of ink technology. Experts say that there can often be inaccurate colourations and colour shifts that do not allow to distinguish the range between edible and non-edible. This is definitely a technological problem that needs to be improved in order to adopt chromogenic inks as innovative solutions to monitor the state of the food and reduce food waste along the supply chain.

Comparison between literature findings and the evidence from case study enabled to answer to both the research questions.

First it is discussed the first research question, regarding **barriers to adoption**. Discussion has been carried considering the different points of view of the three SC stages analysed with the different four technologies.

Then, it is discussed the second research question, regarding **drivers to overcome adoption barrier**s. In this case all the technologies were treated at the same way, since drivers proposed are referred at the same way to all the four technologies.

First Research Question (RQ1)

Thanks to the extensive review of the academic and grey literature and subsequent re-elaboration of findings, the barriers perceived by the single SC actor with the specific technology have been classified in an exhaustive manner through the conceptual frameworks introduced in *Chapter 5*. In this way RQ1 is answered from the literature point of view:

> *Which are the barriers to adoption of communicative packaging technologies perceived by the actors of the supply chain?*

Moreover, from the purely literary point of view, it was possible to identify the degree of relevance of the barriers based on the citations in the articles. *Table 6.24* reports the prioritization of barriers based on literature findings. In this way, the specificity of the barriers related to the single actor and to the single technology is lost, but the prioritisation serves to give a global idea of the barriers perceived by all SC stages, by aggregating the results coming from the selected articles.

Table 6.24:Prioritization of barriers based on literature findings (Source: Author's elaboration)

	SUB-CATEGORY BARRIERS	RELEVANCE
TECHNOLOGICAL AND ENVIRONMENTAL BARRIERS	Lack of proper R&D activities, protocols and standard tests	[orange]
	Lack of recyclability for some smart packaging components	[red]
ECONOMIC AND FINANCIAL BARRIERS	Lack of mass market and affordable prices	[red]
	Lack of long-term profitability perspective	[yellow]
REGULATORY BARRIER	Lack of adequate regulation	[red]
CULTURAL BARRIER	Inertia toward new technology adoption	[orange]
ORGANIZATIONAL BARRIERS	Lack of collaborative processes along the SC	[yellow]
	Lack of Best Practices in the market to follow	[yellow]
	Lack of solutions for security, privacy, and data ownership issues	[yellow]
	Lack of a data management system for decision-making/ difficulty in identifying responsibility along the SC	[yellow]
	Lack of trust in sharing information with other actors along the SC	[yellow]
MARKET BARRIERS	Lack of smart technology market-competitiveness	[yellow]

LEGEND	
[yellow]	LOW RELEVANCE: mentioned by 1-2 articles
[orange]	MEDIUM RELEVANCE: mentioned by 3-5 articles
[red]	HIGH RELEVANCE: mentioned by 6-8 articles

Secondly, thanks to the case study it has been possible to obtain an empirical refinement of the results. In fact, thanks to the dialogue with the experts it has been possible to refine barriers for each stage of the supply chain, considering the specific technology involved.

However, peculiarities and differences emerged in the comparison between literature and case study. A matrix has been built to summarize the findings of the case study, comparing them with the literature results. The matrix is shown in *Table 6.25* and it can be read as follows: on the y-axis there are the three SC stages analysed i.e., technology providers, manufacturers and retailers; on the x-axis there are the four technologies under exam i.e., chromogenic inks, barcodes, RFID and sensors.
The barriers written in bold and with two asterisks show the correspondence between literature and case study, meaning that the specific barrier has been identified for the specific actor and for the specific technology both by literature and by case study. Other barriers without asterisks refer to the ones emerged only in case study.

With different colour it is possible to distinguish barriers according to their relevance from the case study point of view: in red the ones mentioned by 3 or more actors in that specific SC stage, in orange the ones perceived by 2 actors and in yellow by only 1 actor. It must be considered that sample of respondents belonging to the three SC stages was not homogenous, so the degree of relevance derived from interviews analysis is not based on samples of equal size. The interpretation of results based on number of mentions in the interviews was a method proposed by the Author to analyse in an objective way the case study, but this limitation related to the different sample size must be remembered.

To answer the first research question in a more targeted manner, for each SC stage, the main barriers are listed below, comparing literature and case study findings, and highlighting those barriers confirmed of primary importance both by the conceptual framework and by the case study.
Through the following table it is possible to see which barriers have confirmed the literature and which ones have emerged only from the interviews. It is possible to see the results for all three supply chain stages and all four technologies and see common points and differences.

Table 6.25:Matrix of barriers perceived by the three SC stage for the four technologies (Source: Author's re-elaboration of case study results)

	CHROMOGENIC INKS	BARCODES	RFID	SENSORS
TECHNOLOGY PROVIDER	Lack of mass market and affordable prices **	Lack of mass market and affordable prices **	Lack of mass market and affordable prices **	Lack of mass market and affordable prices **
	Lack of adequate regulation**	Lack of adequate regulation **	Lack of adequate regulation **	Lack of recyclability for some smart packaging components **
	Lack of collaborative processes along the SC**	Inertia toward new technology adoption**	Lack of recyclability for some smart packaging components **	
	Difficulty in interpreting information conveyed by technology	Lack of long-term profitability perspective		
	Lack of long-term profitability perspective	Lack of trust in sharing information with other actors along the SC		
	Lack of trust in sharing information with other actors along the SC	Lack of collaborative processes along the SC		
	Inertia toward new technology adoption			
MANUFACTURER	Lack of mass market and affordable prices**	Lack of mass market and affordable prices**	Lack of mass market and affordable prices**	Lack of mass market and affordable prices**
	Lack of long-term profitability perspective**	Lack of smart technology market-competiveness**		Lack of recyclability for some smart packaging components**
	Lack of smart technology market-competitiveness**	Inertia toward new technology adoption**		Lack of long-term profitability perspective**
	Lack of adequate regulation	Lack of collaborative processes along the SC**		Lack of adequate regulation
	Inertia toward new technology adoption**	Lack of trust in sharing information with other actors along the SC**		
	Lack of collaborative processes along the SC**	Lack of adequate regulation		
	Lack of solutions for security, privacy, and data ownership issues	Lack of long-term profitability perspective**		
	Lack of trust in sharing information with other actors along the SC**	Lack of solutions for security, privacy, and data ownership issues**		
	Difficulty in interpreting information conveyed by technology			
RETAILER	Difficulty in indentifying responsibility along the SC**	Lack of mass market and affordable prices**	Not Mentioned	Not Mentioned
	Lack of mass market and affordable prices **	Lack of long-term profitability perspective **		
	Lack of long-term profitability perspective **	Lack of adequate regulation		
	Difficulty in interpreting information conveyed by technology			

LEGEND

**	correspondence between literature and case study
(yellow)	LOW RELEVANCE: mentioned by 1 actor in that SC stage
(orange)	MEDIUM RELEVANCE: mentioned by 2 actors in that SC stage
(red)	HIGH RELEVANCE: mentioned by 3 or more actors in that SC stage

The case study analysis showed that for all four technologies, considering the stage of the **technology providers** (see details in *Table 6.26*), the most perceived barrier relates to the economic issue. In fact, the *Lack of mass market and affordable prices* is present in all the columns with red and orange colours, meaning that it is the most mentioned barriers in interviews.

It is important to remember that the degree of experience with RFID and sensors for the interviewed companies was low with respect.to chromogenic inks and barcodes. This explains the lack of red colour in RFID and sensors column.

Then, the most perceived barrier is the *Lack of adequate regulation,* perceived by technology providers for all technologies except sensors. This means that it is not something strictly related to the technology under exam, but all of them equally need an external push to facilitate their adoption. As explained before, ad hoc incentives and regulations are needed to facilitate the large-scale adoption of innovative and sustainable technologies such as communicative packaging.

Table 6.26 shows the barriers that emerged from the interviews with technology providers, specifically with two asterisks those that confirm the literature, without asterisks those that were mentioned by the respondents, but were not identified by the literature for this stage of the supply chain and for the specific technology.

Table 6.26: Barriers perceived by technology providers for the four technologies (Source: Author's re-elaboration of case study results)

	CHROMOGENIC INKS	BARCODES	RFID	SENSORS
TECHNOLOGY PROVIDER	Lack of mass market and affordable prices **	Lack of mass market and affordable prices **	Lack of mass market and affordable prices **	Lack of mass market and affordable prices **
	Lack of adequate regulation**	Lack of adequate regulation **	Lack of adequate regulation **	Lack of recyclability for some smart packaging components **
	Lack of collaborative processes along the SC**	Inertia toward new technology adoption**	Lack of recyclability for some smart packaging components **	
	Difficulty in interpreting information conveyed by technology	Lack of long-term profitability perspective		
	Lack of long-term profitability perspective	Lack of trust in sharing information with other actors along the SC		
	Lack of trust in sharing information with other actors along the SC	Lack of collaborative processes along the SC		
	Inertia toward new technology adoption			

LEGEND	
**	correspondence between literature and case study
(yellow)	LOW RELEVANCE: mentioned by 1 actor in that SC stage
(orange)	MEDIUM RELEVANCE: mentioned by 2 actors in that SC stage
(red)	HIGH RELEVANCE: mentioned by 3 or more actors in that SC stage

It can be said that the literature has identified the barriers actually perceived by the actors in the supply chain, but has not been able to distinguish them correctly according to the stage at which they are most encountered because they were not made explicit in the articles. In fact, the other barriers in the table without the two asterisks refer to the barriers reported by the interviewees, but which do not correspond to the literature results. These ones, according to literature, were faced by the demand side rather then the offer side. Thanks to the case study it was therefore possible to refine the conceptual frameworks elaborated in *chapter 5* based on the empirical research carried out through the interviews.

As far as **manufacturers** are concerned barriers emerged through case study substantially confirmed literature findings. In *Table 6.27* barriers referred to the four technologies for the specific case of manufacturers SC stage have been reported. The only the addition is *Lack of adequate regulation* and *Difficulty in interpreting information conveyed by technology*, barriers that were reported in literature only for technology providers.

Table 6.27: Barriers perceived by manufacturers for the four technology (Source: Author's re-elaboration of case study results)

	CHROMOGENIC INKS	BARCODES	RFID	SENSORS
MANUFACTURER	Lack of mass market and affordable prices**	Lack of mass market and affordable prices**	Lack of mass market and affordable prices**	Lack of mass market and affordable prices**
	Lack of long-term profitability perspective**	Lack of smart technology market-competitiveness**		Lack of recyclability for some smart packaging components**
	Lack of smart technology market-competitiveness**	Inertia toward new technology adoption**		Lack of long-term profitability perspective**
	Lack of adequate regulation	Lack of collaborative processes along the SC**		Lack of adequate regulation
	Inertia toward new technology adoption**	Lack of trust in sharing information with other actors along the SC**		
	Lack of collaborative processes along the SC**	Lack of adequate regulation		
	Lack of solutions for security, privacy, and data ownership issues	Lack of long-term profitability perspective**		
	Lack of trust in sharing information with other actors along the SC**	Lack of solutions for security, privacy, and data ownership issues**		
	Difficulty in interpreting information conveyed by technology			

LEGEND	
**	correspondence between literature and case study
(yellow)	LOW RELEVANCE: mentioned by 1 actor in that SC stage
(orange)	MEDIUM RELEVANCE: mentioned by 2 actors in that SC stage
(red)	HIGH RELEVANCE: mentioned by 3 or more actors in that SC stage

Specifically, the *Lack of adequate regulations* was mentioned by manufacturers for three out of four technologies. However, it must be remembered that the respondents' experience with RFID was small so the sample may not be sufficient to state that this barrier does not apply to RFID

Moreover, it should be noted that this barrier, according to the conceptual frameworks, was only reported for the technology providers SC stage, but all the manufacturers interviewed agreed to consider it. This is certainly an important piece of information that comes from empirical research rather than literature.

The last barrier without asterisks concerns a completely new obstacle, which had not emerged from the literature and was therefore not present in the two conceptual frameworks. The *difficulty in interpreting information conveyed by technology* was encountered by the manufacturers, just as it was experienced by the technology providers in the specific case of chromogenic inks. In fact, the problem of unclear colour variation was particularly perceived and turned out to be a very impactful barrier that does not allow the large-scale diffusion of this specific technology.

As far as **retailers** are concerned, it must be remembered that the sample of interviewees was made up of only one actor, so results are poor with respect to the other two supply chain stages examined. However, the case study confirmed economic barriers found in the literature in the case of chromogenic inks and barcodes, as well as the *Difficulty in identifying responsibility along the SC*. Also in this case the obstacle of *Lack of adequate regulation* was perceived by this SC stage and not only by technology providers as stated by literature. In addition, the new barrier of *Difficulty in interpreting information conveyed by technology* emerged for chromogenic inks as for technology providers and manufacturers. For this reason, this specific barrier has been considered as a valuable addition derived by empirical research.

Table 6.28: Barriers perceived by retailers for the four technologies (Source: Author's re-elaboration of case study results)

	CHROMOGENIC INKS	BARCODES	RFID	SENSORS
RETAILER	Difficulty in indentifying responsibility along the SC**	Lack of mass market and affordable prices**	Not Mentioned	Not Mentioned
	Lack of mass market and affordable prices **	Lack of long-term profitability perspective **		
	Lack of long-term profitability perspective **	Lack of adequate regulation		
	Difficulty in interpreting information conveyed by technology			

LEGEND	
**	correspondence between literature and case study
(yellow)	LOW RELEVANCE: mentioned by 1 actor in that SC stage
(orange)	MEDIUM RELEVANCE: mentioned by 2 actors in that SC stage
(red)	HIGH RELEVANCE: mentioned by 3 or more actors in that SC stage

Then, it was possible to synthetize the results of all the four technologies and all the three supply chain stages and understand what the overall perceived barriers were according to the case study. The mentions of barriers by respondents for different technologies were aggregated and ranked according to the number of times they appeared in the matrix in *Table 6.25*. As a result, *Table 6.29* was built to show the results of this analysis and a ranking of the barriers from the most relevant to the less relevant. In addition, in the column "mentions" it is possible to see the number of times the barrier appears in the *table 6.25*. It can be easily seen that the most mentioned barriers were *Lack of mass market and affordable prices, Lack of long-term profitability perspective* and *Lack of adequate regulation* and are coloured in red, while the barrier with lowest relevance is *Difficulty in identifying responsibility along the SC,* since it was mentioned only one time in the interviews.

Table 6.29: Ranking of barriers according to case study findings (Source: Author's elaboration)

RELEVANCE	mentions
Lack of mass market and affordable prices	10
Lack of long-term profitability perspective	7
Lack of adequate regulation	7
Inertia toward new technology adoption	4
Lack of collaborative processes along the SC	4
Lack of trust in sharing information with other actors along the SC	4
Difficulty in interpreting information conveyed by technology	3
Lack of recyclability for some smart packaging components	3
Lack of smart technology market-competitiveness	2
Lack of solutions for security, privacy, and data ownership issues	2
Difficulty in identifying responsibility along the SC	1
Lack of proper R&D activities, protocols and standard tests	0
Lack of Best Practices in the market to follow	0

	LEGEND
(red)	mentioned 7-10 times in interviews
(orange)	mentioned 4 times in interviews
(yellow)	mentioned 2-3 times in interviews
(light yellow)	mentioned 1 time in interviews
(white)	not mentioned in interviews

Table 6.30 Comparisons between literature and case study results (Source: Author's elaboration)

SUB-CATEGORY BARRIERS	MACRO-CATEGORY BARRIERS	CONVERGENCE WITH LITERATURE	NOVELTY
Lack of mass market and affordable prices	Economic/Financial	Confirmed	NO
Lack of long-term profitability perspective	Economic/Financial	Rejected	**YES**
Lack of adequate regulation	Regulatory	Confirmed	NO
Inertia toward new technology adoption	Cultural	Confirmed	NO
Lack of collaborative processes along the SC	Organizational	Partially confirmed	NO
Lack of trust in sharing information with other actors along the SC	Organizational	Partially confirmed	NO
Difficulty in interpreting information conveyed by technology	New from literature	New	**YES**
Lack of recyclability for some smart packaging components	Technological/Environmental	Rejected	**YES**
Lack of smart technology market-competitiveness	Market	Confirmed	NO
Lack of solutions for security, privacy, and data ownership issues	Organizational	Confirmed	NO
Difficulty in identifying responsibility along the SC	Organizational	Partially rejected	NO
Lack of proper R&D activities, protocols and standard tests	Technological/Environmental	Rejected	**YES**
Lack of Best Practices in the market to follow	Organizational	Rejected	**YES**

	LEGEND
(red)	mentioned 7-10 times in interviews
(orange)	mentioned 4 times in interviews
(yellow)	mentioned 2-3 times in interviews
(light yellow)	mentioned 1 time in interviews
(white)	not mentioned in interviews

After the ranking of barriers according to number of mentions in the interviews, a new analysis has been done in order to see if the case study confirmed literature results and to highlight the novelty of case study with respect to literature. Specifically, *Table 6.30* can be read starting from left:

- **Sub-category barriers:** the single barrier ranked from to the most mentioned to the less mentioned in the interviews;
- **Macro-category barriers:** the macro-category to which each sub-category barrier refers;
- **Convergence:** this shows the convergence between literature and case study results. If there is a double confirmation both in the case study side and in literature side it is used the word "confirmed". If case study do not identify a barrier or if it considers a barrier of high relevance, while literature considers it of low relevance or if it considers a barrier of low relevance, while literature considers it of high relevance, it is used the word "rejected". If case study considers a barrier of medium relevance, while literature considers it of low relevance it is used the word

"partially confirmed". If case study considers a barrier of low relevance, while literature considers it of higher relevance it is used the word "partially rejected". For the case of new barriers not present in literature but deriving from literature it is used the word "new";

- **Novelty:** it was used the word "YES" whether the case study revealed something new compared to the literature, otherwise the word "NO".

It can be seen that two of the three barriers in red, i.e. the most frequently mentioned in the case study, confirmed the degree of relevance obtained from the literature: *Lack of mass market and affordable prices* and *Lack of adequate regulation.* On the other hand, the other barrier that is perceived to be of high importance by the case study, i.e. *Lack of long-term profitability perspective,* is a novelty compared to the literature. In fact, according to the theoretical results, it was considered to be of low importance (see *Table 6.24*). This result should not come as a surprise, since the case study, by analysing the companies experience, has certainly brought out what the barriers are from a practical point of view. Closely linked to the cost barrier is the lack of long-term profitability, explaining that it is not easy to understand what the economic return is from adopting new and innovative technologies which involve huge initial investments.

Then, *inertia toward new technology adoption*, was also matched by case studies and literature. In both cases they were found to be of medium importance, meaning that, in addition to economic issues, there are cultural factors to be considered. For this reason in the convergence column it is reported "confirmed".

Some differences in degree of relevance appear with the barriers *Lack of trust in sharing information with other actors along the SC* and *Lack of collaborative processes along the SC.* They have been identified both by literature and case study, but interviews gave a higher relevance with respect to literature results. This explains the word "partially confirmed" in the convergence column.

Moreover, other organisational, technological and market barriers, were found to be of secondary importance for both literature and case studies. In fact, thanks to the discussion with the experts, it was possible to understand how these barriers are easier to overcome and come after to the economic, regulatory and cultural issues. Companies stated that there are already collaboration solutions that can be implemented, but the main problem is always the cost. There are many ways already in place to start collaborations, manage data, ensure security and privacy and so on, but they come at a cost.

Finally, the last consideration to be made concerns barriers which have been rejected by the case study: *Lack of recyclability for some smart packaging components, Lack of proper R&D activities, protocols and standard tests,* and *Lack of Best Practices* This may be due to the fact that the technologies under consideration are developing a lot in recent years and many technological problems are being solved fast.

A special attention must be given to the barrier which derives from case study, and that was not identified by literature: *Difficulty in interpreting information conveyed by technology*. Obviously this is a novelty that must be considered because it is a valuable adding to the identification of barriers to adoption of communicative packaging technologies.

Second Research Question (RQ2)

Differently from RQ1, the literature review on drivers to overcome barriers to the adoption of communicative packaging did not yield valuable results and it has not been possible to build detailed frameworks as in the case of barriers to adoption. As explained in *chapter 3*, a substantial gap emerged because of the extreme novelty of the topic and only one scientific paper, deriving from search for drivers has been analysed. The article deals with supply chain sustainable innovation and describes the drivers to overcome barriers to the adoption of these innovation. The discussion has been extended to communicative packaging, as a sustainable innovation but it has been deepened through case study and dialogue with companies. Given the lack of academic articles on the topic of strategies and drivers, it was preferred to keep the drivers on sustainable innovation only as a starting point, but the second Research Question (RQ2) was answered through the experiences of the actors directly involved:

> *Which are possible drivers to overcome barriers to adoption of communicative packaging technologies?*

It has not possible to make an analysis distinguishing between individual technologies, but the actors interviewed talked about possible drivers for all four technologies under consideration in a generic manner. Drivers identified can be related to all of them indifferently. Furthermore, after interpreting the results of the case study in *section 6.2*, the information of the different stages was aggregated to see in an overall way which are the most relevant drivers, as done previously with the barriers. The result is shown in *Table 6.31,* where the drivers derived from literature are presented with different colours, according to the relevance given by case study. In the "mentions" column it is possible to see how many times in interviews the single drives has been mentioned by the actors. The drivers coloured in dark green are the ones mentioned 4 or 5 times, in light green the driver mentioned 2 times, and in white the ones highlighted in literature, but not confirmed by case study.

Table 6.31: Results of case study analysis for drivers to overcome adoption barriers (Source: Author's elaboration)

RELEVANCE	mentions
Marketing and promotion	5
Regulatory support	4
Collaboration and networking	2
Internal development	0
R&D activities	0

LEGEND	
	mentioned 4-5 times in interviews
	mentioned 2 times in interviews
	not mentioned in interviews

The first aspect that can be seen from the above table is that three of the five drivers present in the literature have been mentioned in the interviews:

- *Marketing and promotion.*
- *Regulatory support,*
- *Collaboration and networking,*

Then, it can be seen the relevance of these drivers from the point of view of the case study. Also in this case, thanks to the colours, it is possible to visually understand which drivers were mainly proposed and which were not. The respondents largely confirmed the importance of marketing and promotion by identifying this driver as the main one. According to the interviewees, there are many ways of doing *marketing and promotion*, such as digital promotion, events, trade press (articles in editorials dedicated to large-scale retail), projects with academic world and research centres to raise awareness and spread the benefits of sustainable innovations. Thanks to this, the customer will be able to understand that what he spends more, will get back. Experts stated that the economic barrier can only be overcome if companies will look for a result that is not immediate. Thus, the mission is to make people understand that the advantage is achieved in the long term and that it is worth investing in technological sustainable innovations because they enable huge advantages such as reduction of food waste and traceability of the whole chain.

Of equal importance to *marketing and promotion*, was *regulatory support*. The lack of legislation and guidelines in the food sector in terms of reducing food waste was one of the perceived barriers in all interviews. It emerged how incentives are necessaries for companies to launch innovative projects, to test new technologies with a view to sustainability and to understand the substantial benefits they can gain from using these systems. However, these incentives are often not enough to convince companies to invest and innovate. Through the case study it has been possible to understand how regulatory support is necessary not only in the form of funds and incentives, but it is necessary a precise legislation aimed at reducing food waste, because it could quickly push companies to change their way of acting and make them all conform to certain set standards, so that sustainability goals are understood and shared by the whole community. What must emerge is that regardless of the supply chain stage this is a key driver in overcoming barriers to the adoption of communicative packaging along the agri-food the supply chain.

Along with these drivers the last driver which emerged from the case study and which confirms the literature, but which plays a secondary role to the two previously explained is *collaboration and networking*. Organisational barriers concerning collaboration between partners have been mentioned several times in the interviews. There is a lot of difficulty in collaborating with other companies and sharing information and resources. Interviewees confirmed the importance of relationships with the scientific community to do research in client companies, to understand market needs, to study new technologies and to try to develop innovative projects. According to the interviewees a driver to overcome adoption barriers is involving very influential institutes sensible on aspects such as technology, innovation and sustainability, and being able to bring the scientific community and institutions on board innovative projects. The collaboration with the scientific community is fundamental to share new ideas because they have a huge resonance in certain contexts.

On the other hand, the driver related to *R&D activities* was not found in case study, probably because these technologies are developing exponentially, and the interviewees think that enough R&D work has already been done. This is not surprising since the technological barriers were not perceived by the respondents either, meaning that they have already been addressed and resolved in recent years. On the contrary, the case study showed that in the practical case it is more relevant to resolve economic and cultural barriers. Hence the importance of marketing and promotion.

Finally, the *internal development* driver was not mentioned by the interviewees. This is because there is a shared belief that there is a need for an external push, coming from the outside and not from the single company. To overcome the economic barrier all actors agreed that regulatory support is necessary rather than allocating separate funds within the company to develop innovative projects. External help is needed at the legislative level to speed up the adoption process and really push companies to start innovative actions with the sustainable aim of reducing food waste along the supply chain. In conclusion, it can be said that the drivers that emerged from the literature review, although related to sustainable innovations in general, were confirmed by the case study. In fact, 3 out of 5 drivers were confirmed by all respondents, demonstrating that they are applicable to the specific case of communicative packaging in the food supply chains as a sustainable innovation.

7. Conclusions

The present Thesis focuses on barriers to adoption of communicative packaging technologies along the agri-food supply chain and possible drivers to facilitate their diffusion on a large scale. It addresses two main research questions, namely RQ1 *Which are the barriers to adoption of communicative packaging technologies perceived by the actors of the supply chain?* and RQ2 *Which are possible drivers to overcome barriers to adoption of communicative packaging technologies?*

After conducting a literature review on barriers and drivers, two conceptual frameworks have been elaborated. The frameworks have been enriched and validated through the case study, composed of actors belonging to three different supply chain stages, which allowed to answer research questions more comprehensively.

This concluding chapter includes three main sections. *Section 7.1* presents summary of the theoretical and managerial implications obtained by the literature and the case study analysis. *Section 7.2* comprehends possible limitations of the study. Finally, *section 7.3* includes suggestions about further research.

7.1 Theoretical and managerial implications

The aim of the Research conducted was to answer the Research Questions in the most exhaustive way possible. Starting from the **theoretical level**, the conceptual frameworks presented in this Thesis are a comprehensive systematization of literature. Moreover, the innovative point of the Research stands on the parallel evaluation of the subject at the theoretical and managerial levels, considering either the state of the art of the topic and solutions currently on the market, developed or adopted by the interviewed companies. Thanks to the case study it was possible to deepen this topic, to confirm the main barriers identified by literature such as the *Lack of mass market and affordable prices*, and the *Lack of adequate regulations*, but also to add novelty such as the rejection of some barriers like *Lack of R&D activities,* that was highlighted in literature, but not confirmed by the interviews. In this way, this Research provides a significant enrichment of literature regarding barriers to adoption. Moreover, it deepens the theme of the drivers that would push the diffusion of communicative packaging along the agri-food supply chain. Specifically, thanks to the case study, it has been confirmed that the literature findings on drivers for sustainable innovations can be applied to the specific case of communicative packaging. In *figure 7.1*, it is possible to see in conclusion which are the drivers confirmed by the case study. Certainly, there is to consider the great value of *marketing and promotion* that companies need to raise awareness and make understand the many benefits that can be gained in the long term. Alongside this, there is the driver of *regulatory support*, to speed up the process of adoption and push companies to pursue common sustainable goals, through proper incentives and with the setting of specific laws. Finally, there is the driver of *collaboration and networking* with the scientific community and institutions to launch innovative projects, study market trends and continue the process of raising awareness on issues such as sustainability and waste reduction.

Figure 7.1: Summary of the drivers identified by the case study (Source: Author's elaboration)

The results of this Research are not just a theoretical tool, but, at a **managerial level**, they could serve as an instrument to analyse and visualize future technological breakthrough related to the adoption of innovative sustainable technologies such as communicative packaging. Results can represent indications and guidelines for the actors involved agri-food supply chain to evaluate technological innovations. Specifically, the evidence of the main barriers perceived by the different stages of the supply chain, could provide help for managers and decision makers operating within the relative stages in identifying the critical steps to be met when adopting communicative packaging technologies, and understand how to face them. For example, economic barriers were the most critical, followed by regulatory and cultural barriers. This provides a clear view of what priorities need to be addressed to drive the adoption of innovative technologies to reduce food waste along the agri-food supply chain. Once the critical points have been identified, it is possible to understand how to solve them and, thanks to the case study, it has been possible to understand which driver should be activated to overcome adoption barriers.

In conclusion, the present Thesis has also the aim to increase managerial knowledge of this topic, the relevance of technological innovation and possible applications of new communicative packaging technologies for reducing food waste along the agri-food supply chain.

7.2 Possible limitations

Communicative packaging is a new topic which is spreading in recent years. Due to the novelty of the object under analysis and the way in which the Research was conducted, some limitations emerged. As far as the methodology is concerned, the case study did not cover all steps of the supply chain, but only three, not considering post-harvest and logistic operators. This may be related to the low interest in this type of innovation. Moreover, the samples of companies interviewed for each SC stage were different: 4 companies for the technology providers stage, 3 for the manufacturers and 1 for the retailers. The retailer stage was less present (only one company), so the results coming from the first two stages have a higher value than the last stage because the sample was larger. This limitation related to the different sample size must be remembered, but in spite of this, it can be concluded that the results obtained can cover the supply chain at a comprehensive level, identifying barriers and drivers shared by the actors in the different stages. In the end, given the lack of specific literature, results on drivers could be less robust than those related to barriers.

7.3 Suggestions for future research

The research limitations presented in *section 7.2* could be considered as a point to continue the study. As regards the qualitative research focused on investigating the barriers to adoption and possible drivers to overcome them, the results could be further validated and enriched through other case studies including the stages not analysed in this work: post-harvest and logistic operator. Moreover, also an enrichment of the sample size for the three analysed stages (technology providers, manufacturers and retailers) could give and added value to the research and lead to more detailed conclusions based on a larger sample of analyses.

As emerged in this Thesis, integrating innovative communicative packaging technologies along the supply chain implies investments for companies. In this perspective, it would be interesting to better understand what the real opportunities for a company in the implementation of such solutions are. There is currently small market for these products, so more specific analyses, such as cost-benefit analysis, should be done to ensure that the actors in the agri-food supply chain could implement these technologies overcoming economic barriers.

Finally, since the objective of this Research was to reduce food waste generated along the agri-food supply chain, it is possible to think that further research can be carried out to understand how actors at the most advanced stages of the SC, who have already had experience with these technologies and are aware of their potential, can encourage other stages to adopt them, communicating the benefits that could be gained.

A. Appendix A

Transcription of interviews

a) COMPANY A

RUOLO: Digital Printing Business Development Manager

SC STAGE: technology provider

Usano QR code perchè gli inchiostri cromogenici ti mostrano che il problema è già successo, non puoi fare niente per prevenirlo, devi buttare. Inoltre insinuano il dubbio di leggibilità.

RFID problema di costo e problema di smaltimento. Sensori problemi di costi (es. se devono essere alimentati i servono microcelle di pannelli fotovoltaici per alimentare microbatterie).

Mettono QR code sui sacchi asettici (dai 5 ai 1500kg) che servono per un prodotto non finito, che non va sul mercato; permette di conoscere tutto quello che è successo lungo la filiera.

Ogni confezione ha il suo numero univoco (QRcode alfanumerico) che contiene tutte le info del loro processo interno, ma possibilità di dare al cliente spazio nello stesso database per mettere tutte le altre info che ritengono necessarie. Questa tecnologia avrebbe un grande valore anche nella grande distribuzione, ad esempio sulle insalate fresche: permetterebbe di sapere: quanta merce sta scadendo, fare azioni promozionali, gestire real time ed in maniera organica il magazzino NB: devi fare codici univoci, non sui lotti

BARRIERE PERCEPITE:

BARRIERA: ECONOMICA: il cliente vuole risparmiare tramite l'adozione di innovazioni, ma è impossibile. Si spende di più. Bisogna educare il cliente ai vantaggi che possono trarre.

CULTURALE Si traduce in "Abbiamo sempre fatto così"

ORGANIZZATIVE: database. I clienti grossi vogliono il loro database o uno neutrale. È una questione di tempo e si arriverà ad una sorta di blockchain integrata.

DI MERCATO: è la soluzione più diffusa tra le quattro tecnologie, ma c'è ancora stata da fare. Bisogna spingere sui benefici che si possono trarre. Spendere un po' di più per questa tecnologia, ma per avere un ritorno economico non indifferente. Meno sprechi, meno

BARRIERE NON PERCEPITE:

TECNOLOGICO: QR code esiste da tanti anni, le stampanti sono già sviluppate.

Loro riescono a stamparli interposti, cioè stamparli tra due materiali, non c'è quindi la questione REGOLAMENTARE di sostanze da porre a contatto con gli alimenti.

STRATEGIE:

Promozionale: COMPANY A si sobbarca la spesa, fornendo una versione prova. "Provalo, capirai i vantaggi, anche se spendi di più. Capirai che quello che spendi in più ti ritorna indietro."

Marketing: Hanno spinto sulla sensibilizzazione del cliente, nei produttori di alto livello è stato recepito. Pensa se butti 200kg di pomodoro quanto butti via, mentre se hai una tracciabilità su tutta la filiera, hai modo di vedere dove si verifica un problema e puoi risolverlo in maniera tempestiva. È questo il tuo vantaggio.

b) COMPANY B

RUOLO: General sales manager

SC STAGE: technology provider

RFID: problemi di sviluppo del mercato; integrazione con software, serve un lettore, cambiare programmi dei magazzini

LETTURA CON UN OCCHIO DI CO2 o O2 (TEX SENSE)_Austria:

Si tratta di un inchiostro sul film che permette ad un occhio di leggere la concentrazione di CO2 o O2. Un possibile difetto nella saldatura dell'imballo o se è successo qualcosa durante il processo produttivo che ha portato ad una concentrazione di gas diversa dal prestabilito, viene visto da questo occhio e segnalato immediatamente già in fase di imballo. Così può anche essere reimballato. Minori sprechi. Controllo al 100% sul prodotto.

NB: adesso si testa a campione con degli interventi invasivi i prodotti che escono dalla produzione. Quindi c'è solo un controllo statistico di una minima parte, non del 100%.

BARRIERA ECONOMICA: è un investimento iniziale che si ammortizza in breve tempo se si tiene conto del risparmio che si può generare e della qualità che si può produrre. Si controlla il 100% del materiale, cosa che ora non si fa. Riscontrano molto interesse, ma dover investire è un primo problema, il secondo è dover toccare macchinari già esistenti e funzionanti. Anche se è integrabile a volte può necessitare di modifiche: l'occhio è fisso. Se lo metto su un impianto che fa solo un tipo di pack è ok, se lo metto su una linea che fa diversi formati devo riorientarlo.

REGOLAMENTAZIONI: non sono obbligati a fare questi controlli, perciò non c'è una spinta neanche da questo punto di vista.

INDICATORI DI TEMPERATURA: una volta attivati segnalano se la T è superata per un certo tempo indicativo (esposizione per breve – medio- prolungata). C'è un liquido viscoso che diventa più liquido se la T viene superata. Non sono abbastanza precisi: se il prodotto è esposto a T 30° la fluidità sarà molto più veloce che se fosse a 12°.

Applicazioni: non si usano ad esempio nel pesce perché diventa troppo costoso, incidenza sul cliente finale, non lo utilizzano per un monitoraggio continuo, ma per un monitoraggio sul last mile. Loro considerano che il processo sia controllato, dal cambio frigo, o da altri registratori. La problematica più grande era stata riscontrata solo sull'ultimo tratto di consegna. Es. Ferrero l'ha riscontrato quando avveniva la consegna nei piccoli supermercati, perché qualcuno lascia il camioncino troppo aperto. Allora un solo indicatore sullo sportello del camioncino.

Il problema di non averlo fatto diventare una soluzione di massa è proprio una questione puramente economica. Il prezzo va tra i 70cent e i 2 euro (a seconda dei quantitativi)

REGISTRATORI ELETTRONICI Emerson Loggers: Monitorano sempre la catena del freddo. Non dicono solo se è stata interrotta, ma dove e in che momento (perché registrano tutti i superamenti delle soglie critiche di temperatura, tempo ogni 4-8-12min) Metti la USB nel PC e ti dà un pdf con tutti i dati. + informazione visiva rossa lampeggiante se si è verificato un problema (poi se stampi il pdf vedi dove).

Soluzioni ancora più precise ed affidabili GO REAL TIME Sono delle scatole nere che misurano temperatura, umidità luce ed ha anche una geolacalizzazione: per identificare il responsabile Costano ancora di più (6/7 euro) ma sono più richiesti. Perché molto più precisi. Il cliente preferisce identificare il responsabile e pagare un po' di più piuttosto che avere solo un'informazione

La barriera economica si supera solo se si cerca un risultato non immediato. Se si cerca un conto positivo a fine mese è impossibile con le implementazioni di innovazioni. Se l'azienda si prende il tempo di investire nel progetto e vedere i risultati si renderà conto del vantaggio.

Si vede una risposta positiva nelle aziende che hanno un piano di sostenibilità sul lungo termine e sono pronte a lanciarsi in progetti innovativi. Lo si può vedere maggiormente in aziende più grandi; le piccole hanno bisogno di un ritorno economico sul breve termine.

Barriera del tempo: causa covid, c'è stato un rallentamento negli sviluppi tecnologici. Si pensa al quotidiano.

R&D non è una strategia per gli indicatori tramite liquido viscoso perché esistono da più di 20anni.

c) COMPANY C

RUOLO: Project Manager

SC STAGE: technology provider

Blockchain - QR code

Lavoriamo su larga scala sui QRCODE: Generano un QRcode stampato su un'etichetta. I codici riportati su soluzioni più complesse come l'interfaccia con tag NFC o RFID invece richiede uno studio ad hoc con il cliente dei loro sistemi verso la nostra piattaforma.

Company Y: (2015) Hanno perfezionato la tecnologia seguendo i feedback dal caso pratico. Il cliente non aveva sistemi informatici complessi, perciò ha scelto quello che noi vendiamo "as a service" cioè tramite una subscription annuale hanno accesso alla loro soluzione, senza un grosso sforzo da parte del cliente. Ogni transazione che avviene viene riportato nella blockchain che funge proprio da validatore per tutte le transazioni effettuate ed alla fine genera un codice univoco racchiuso all'interno del QRcode stampabile. Si possono vedere tutti i dati inseriti nell'upstream della filiera. Questo viene molto apprezzato dal cliente perché il codice elimina la possibilità di manomissione del dato, dando informazioni simbolo di alta qualità, valorizzazione del prodotto

Produzione di nicchia: soluzione semplice e poco complessa. Ideale per startup e piccole aziende, per chi non ha un team di esperti o piattaforme complesse alle spalle. Basta una subscription per poter accedere al servizio.

Company W: Volumi prodotti maggiori rispetto al Company Y. Azienda produttrice di frutta e verdura che ha come cliente la grande distribuzione. Soluzione più incentrata sui benefici all'interno dell'operatività piuttosto che dello storytelling con il cliente finale. Il primo caso del caffè invece era più incentrato sull'importanza di comunicare con il cliente e quindi ottenere un ritorno economico grazie al valore aggiunto legato allo storytelling sulla produzione del caffè. Nel secondo caso invece le informazioni veicolate tramite la blockchain erano più operative (es gestione tempi morti, tempi legati allo scambio di info con tecnologie vecchie e non efficaci): la velocità con cui si scambiano le informazioni riesce proprio a dare un guadagno dal punto di vista dell'operatività

Quali strategie utilizzate per risolvere la questione economica (personalizzazione costosa)? Hanno una gamma di soluzioni variabile in base alla disponibilità economica dell'azienda. Es. soluzione "as a service" è la più economica. Si concede una licenza con cui è possibile utilizzare questa tecnologia, senza conoscenze tecnologiche elevate (circa 5000Euro, accessibile anche a startup)

Questione organizzativa, lato technology provider: Se la somma di investimento è maggiore, andiamo verso filiere più complesse in cui si studia un modello con il cliente per soddisfare i suoi bisogno di business.

Dal 2016 c’è stata un’impennata sulla tecnologia , c’è sempre una fase di transizione prima di raggiungere l’adozione di massa. Ancora siamo nella fase di transizione. Ci sono altri aspetti oltre a quello economico da considerare, per esempio tecnologia emergente, il quadro legislativo si sta allineando alle richieste del mercato, ma la burocrazia si muove sempre in maniera più lenta rispetto alla tecnologia. Questo rende l’investimento privato un po’ sprecato, perché non tamponato dal quadro normativo completo. La comunità europea propone dei bandi (Horizon 2020) con cui alloca dei fondi per progetti a cui noi partecipiamo. Spendere dei soldi in blockchain che ruotano attorno a tracciabilità, trasparenza e sostenibilità.

È un fatto culturale. Non si può saltare in poco tempo dal vecchio al nuovo. è un processo che richiede tempo. Le istituzioni stanno remando in quella direzione dal 2016 ad oggi. C’è un’accelerazione verso l’adozione di queste tecnologie che poi si va a fondere con quelle complementari (artificial intelligence, IoT,5G, telecomunicazioni). È un quadro che prende forma un po’ alla volta.

Strategia culturale: partecipiamo alla sensibilizzazione sull’argomento e alla divulgazione scientifica per collaborare al processo di adozione di queste tecnologie.

d) COMPANY D

RUOLO: General manager

SC STAGE: technology provider

Barcodes + chromogenic ink: La barriera principale dal nostro punto di vista è che l’adozione di una nuova tecnologia innovativa viene sempre messa a confronto con un business case di ritorno. Le aziende non vedono un ritorno economico dall’adozione di soluzione innovativa.

Qui è anche un problema culturale: lo si vuole solo per ritorno all’investimento. Poi ci sono i limiti nel comprenderne la validità e il ritorno in termini di vantaggi, non solo economico. In alcune aziende non si riesce a parlare con il top manager. Non sono tante le persone che hanno una visione più ampia e più aperta alle innovazioni, alcune persone presenti in azienda bloccano le azioni di innovazione di un'azienda, c'è spesso una non volontà di innovare per mancanza di tempo e di voglia.

Ci sono dei vincoli lungo la filiera: mancanza di processi collaborativi. È un problema di organizzazione, barriere che emergono quando si cerca di mettere in comunicazione sistemi differenti, aziende differenti, sistemi informatici diversi.

Barriera Regolamentare: Nel campo dell'alimentare non ci sono enti regolatori a cui tutti si devono adattare (es. nel campo finanziario). Nell'alimentare e nella logistica non ci sono enti regolatori a cui riferirsi, intendo un regolatorio organizzativo della comunità. Servirebbe qualcuno che definisse le linee guida per mettere d'accordo i vari attori della filiera.

DRIVER: Servirebbe qualcuno che stendesse delle linee guida per facilitare la comunicazione tra gli attori della filiera.

Se ci fossero dei regolamenti che dicessero qualcosa come ad esempio ci sono quelli che dicono "Non bisogna produrre CO_2 entro un certo limite, altrimenti devi pagare" sarebbe diverso. Servirebbe qualcosa del tipo "Se tu sprechi una certa percentuale di prodotto alimentare allora prendi una multa" perché stai buttando prodotti che hanno un certo valore e sono una risorsa dell'umanità. Se ci fosse una regola di questo tipo tutti seguirebbero la cosa e sarebbero sensibili all'argomento.

Barriera di mercato: non percepita. Se un'azienda vuole innovare non cerca di imitare i competitor, ma cerca un valore unico. La nostra azienda, come fornitore di tecnologia cerca proprio di vendere innovazioni per diversificare le aziende, ma forse non tutte le aziende la vedono così.

Mancanza di fiducia: sì

Mancanza sistemi di gestione, sicurezza: No. Sono barriere che sono state superate, ci sono tanti sistemi già implementati. Sono barriere organizzative perché magari un'azienda non vuole implementare soluzioni innovative, ma non perché non ci sono queste barriere.

Barriera economica: le innovazioni hanno un prezzo e nel nostro caso la nostra soluzione ha un prezzo accettabile per i vantaggi che offre. È un investimento che chi vuole innovare deve affrontare.

DRIVERS:

Obbligo regolamentare: È come dire "c'è il limite di velocità, se lo superi ti faccio la multa". Qui nel settore alimentare dovrebbe esserci una regola sullo spreco perché oggi è come dire " se tu sprechi non succede nulla, non c'è nessuna conseguenza". Questo è l'aspetto principale. Se ci fosse questo regolamento le soluzioni sarebbero mille e se ne svilupperebbero ancora di più.

Ricerca e rapporto con comunità scientifica: Noi da fornitori di tecnologia abbiamo provato ad andare in comunità scientifiche per curiosità, per fare ricerca nelle aziende, per studiare le soluzioni. È il luogo ideale per capire le esigenze del mercato, studiare le tecnologie e cercare di portare avanti progetti innovativi.

Marketing: si cerca di trovare delle soluzioni affidabili, garantite, di poco costo. Si è cercato nel nostro caso di facilitare l'adozione di questa tecnologia andando incontro al cliente, capire il problema del cliente e trovare soluzioni. E dietro a tutto questo sta il marketing.

e) COMPANY E

RUOLO: R&D director – Information systems director

SC STAGE: manufacturer

BARCODES

QRcode: La tracciabilità partecipa al fatto del contenimento degli errori di produzione che producono scarto alimentare. Noi misuriamo quello che succede e sappiamo che gli errori identificati portano a produrre dei prodotti che non possono essere commercializzati tramite canali primari, che sono per noi scarto.

Non facciamo l'EAN dinamico (data di scadenza dinamica) perché la complessità è molto alta. Se noi avessimo prodotti a bassa scadenza, saremmo molto più sensibili all'argomento. I nostri prodotti non hanno una shelflife breve, per cui la pressione su queste cose non c'è. Però esistono progetti sia per marcare in databar, sia per QR code con tante informazioni tra cui la data di scadenza. Per noi questa è una cosa di poco conto, attribuire un codice dinamico sulla data di scadenza.

Un'altra modalità tecnologica è quella di serializzare il codice a barre. Attraverso quel numero posso sapere qual è la scadenza dello specifico prodotto. Miliardi di prodotti, c'è complessità. Marcare una linea così veloce non è semplice, è proprio un problema di stampaggio. IL QR code è un codice complesso da stampare. Se sei in linea ci sono delle complessità di struttura dell'impianto di produzione e confezionamento che rendono difficile uno stampaggio così veloce. Se c'è qualcuno che paga (barriera economica) il problema si risolve, ma allo stato attuale è complicato. Il consumatore dovrebbe spendere qualche decimo di euro in più per avere questo servizio in più.

Company X: Le scadenze brevi sono quelle che possono essere gestite con un differenziale di prezzo, se scade domani alla cassa lo paghi meno. Questo serve per togliere dallo scaffale i prodotti a scadenza breve. Per questo tipo di problema può essere applicato il barcode dinamico

Barriera normativa: l'applicazione normativa aiuta a far le cose. Se diventa imperativo fosse basso scarto, allora tutti metterebbero questo tipo di codice sui prodotti. Servirebbe una legge, una norma che ti obbliga a mettere un codice che ti faccia fare l'abbattimento del prezzo in funzione alla data di scadenza. Nel momento in cui diventa obbligatorio, tutti quanti si devono adeguare e gli scarti diminuiscono. Vale per tutto, es. norme di scrivere sulle etichette le modalità di smaltimento. Sono quelle le cose che fanno cambiare la situazione. (strategia) Il QR code potrebbe diventare obbligatorio.

Si sta andando verso il digitale? Sì ma la trasformazione digitale viene fatta da persone che ignorano il processo che bisogna seguire per farlo. Il digitale è pervasivo nel senso dell'uso, ma non nel senso della conoscenza. Per questo motivo alcune cose si fanno e alcune no. Se ci fosse una norma che obbligasse all'RFID sui pallet, questo garantirebbe un controllo sulla merce che viaggia assolutamente migliore di quello che c'è adesso. L'ispezione del carico sarebbe immediata. È una cosa semplice, i produttori di pallet non sono tantissimi, spesso sono riciclati e riutilizzati. Questo determinerebbe una gestione migliore anche degli scarti, perché tutti dovrebbero dichiarare esattamente cosa c'è in ogni carico.

Il click avviene soltanto attraverso una sorta di obbligo. Altrimenti ciascuno avrà sempre un motivo per non investire in una tecnologia nuova, diversa, che comporta un certo grado di complessità anche in termini organizzativi. Dare una dimensione al problema non è un costo per la società. Definire che è un obiettivo di natura pubblica, si fa una norma e un po' alla volta si risolve. Diversamente, se si rimane entro i confini del marketing, tutto ruota attorno a due fattori: uno che è il prezzo del prodotto, l'altro che è il valore aggiunto (cioè il prezzo variabile in funzione della scadenza). Bisogna capire quanto questo valore aggiunto sia competitivo su mercato. È da vent'anni che diciamo che la tracciabilità è un valore aggiunto, che se comunicato in maniera opportuna sviluppa un grande mercato, ma se guardiamo i numeri non è così (barriera culturale). Perché il nostro cliente diretto (distribuzione) ti chiede la tracciabilità se è obbligato, ma non ti paga di più (es. 0.5$ in più se fai una tracciabilità corretta). Anzi ti chiede un contributo perché mostra alla cassa una nuova tecnologia che segnala la data di scadenza dinamica.

Degli incentivi da parte delle istituzioni o del governo può essere una soluzione? L'incentivo ci deve essere, ma se ricevi un incentivo o un premio per una cosa che poi diventa obbligatoria è un conto, se invece non diventa obbligatoria la questione cambia. Se alle spalle c'è un motivo sociale, come può essere quello di diminuire gli sprechi alimentari, questo è una valida leva che deve far scattare una mobilitazione da parte delle istituzioni. Ma finché non diventa obbligatorio non sarà mai abbastanza forte per far cambiare davvero le cose.

RFID: non utilizzato perché nessuno leggerebbe l'RFID nella loro filiera. Si tratta di un cambio di tecnologia e quando c'è un cambio di tecnologia ci sono degli investimenti da fare. Il riconoscimento ottico è migliorato molto e si sta sviluppando maggiormente ma per potersi diffondere bisogna trovare dei buoni motivi per adottarlo. Ad esempio il riconoscimento ottico permette una lettura di un pallet da distanze superiori senza averlo a vista, cosa che non e possibile fare con altre tecnologie. Ma non è tanto richiesto oggi. I logistici si stanno evolvendo molto in questo senso grazie a diverse tecnologie (pistola laser per leggere il codice, apparecchi acustici per sentire l'ordine). Dipende anche dalle dimensioni dell'azienda: se il magazzino è molto automatizzato si sente la necessità dell'RFID, perché il maneggiamento di una pistola da parte di una persona consente una certa precisione, ma se parliamo di una linea automatizzata non è esattamente uguale, l'RFID anche se l'oggetto è distante e non a vista, consente la lettura. Però problemi come la collisione non vengono risolti del tutto, può capitare che la lettura dell'RFID non permetta di identificare il singolo prodotto, quando si legge un insieme di RFID non è semplice identificarli uno per uno. Gli algoritmi sono stati migliorati, ma sono ancora da perfezionare.

STRATEGIE: la strada da seguire ce la sta insegnando il PNRR (Piano Nazionale di Ripresa e Resilienza). SI parla di dover fare infrastrutture di un certo tipo eccetera. A chi tocca farlo? Chi mette i soldi? Chi ci guadagna? Occorre una spinta di natura pubblico-sociale perché è un obiettivo di comunità, non di singola impresa. Quando c'è un salto di questa natura, servono gli incentivi e gli aiuti finanziali, ma serve un intervento di tipo pubblico che evidenzia il problema e pone un obiettivo (es. obiettivo di diminuire gli scarti perchè diventano rifiuti ecc.). Questo diventa uno stimolo importante per l'economia perché si devono costruire cose che non ci sono e quindi un mercato grande. Questo fa sì che ci sia un vero sviluppo. Si tratta di istaurare un meccanismo virtuoso per cui la trasformazione digitale è un elemento fondamentale, perché gestire gli scarti senza informazione è difficile. L'informazione dà ritorno di dati su ciò che accade.

INCHIOSTRI CROMOGENICI E SENSORI:

Le barriere sono le medesime. Le cose le facciamo se qualcuno ce le impone o se il mercato ce lo richiede. Sono queste le due spinte necessarie che spingono all'adozione di queste tecnologie. E noi non le adottiamo perché non c'è stata ancora nessuna delle due. Oppure dobbiamo vedere un grande ritorno economico. Ma neanche questo è uno stimolo che sentiamo perché non vediamo un grande ritorno dall'utilizzo di smart packaging. Dal momento che noi abbiamo prodotti con lunga vita non ci tocca tanto lo scarto alimentare. Per chi tratta alimenti a bassa scadenza probabilmente una miglio gestione del prodotto basata sulle scadenze può portare a sentire maggiormente questo tema e sicuramente avrebbe un ritorno economico maggiore perché ridurrebbe gli sprechi legati allo scarto di prodotti freschi (es. insalata) vicini alla scadenza. Problema della pianificazione dei prodotti da movimentare: chiaramente si cerca di produrre solo i quantitativi che il mercato assorbe, ma questa cosa ha le sue complicazioni, ma nell'ambito della gestione delle eccedenze è importante. Ad esempio un servizio molto veloce provoca anche molto scarto (vedi caso Am*zon che consegna subito: tantissime emissioni dovute alla distribuzione, basterebbe consegnare dopo tre giorni invece che il giorno dopo); necessaria educazione del consumatore

Forte è la barriera tecnologica e ambientale (riciclabilità): se faccio smart packaging per limitare gli sprechi e non sono riciclabili mi infilo in un altro tunnel, e per quanto riguarda i sensori sono molto costosi.

Tramite sensori si può gestire in modo dinamico la shelflife (dinamic expyring date) Nel fresco i sensori potrebbero essere utilizzati (es. salmone, caviale, carni pregiate). Nel nostro caso di prodotti che valgono pochi euro al chilo non è una tecnologia che potremmo utilizzare.

f) COMPANY F

RUOLO: Marketing manager

SC STAGE: manufacturer

COMPANY F si occupa di produzione di mozzarella di bufala da più di 75 anni. Dal 2000 è entrata in GDO ed ha iniziato ad avere dei partner nazionale ed internazionali più conosciuti. Essendo un prodotto DOP, tutto ciò che riguarda la sua produzione è tracciato. Si seguono rigidissimi disciplinari su come trattare il prodotto: Temperatura di pastorizzazione, forma da dare ecc. Ovviamente anche la materia prima deve essere controllata e tracciata. L'area di produzione essendo DOP è delimitata e gli allevamenti devono per forza trovarsi entro questi confini e devono avere delle precise razze di bufala ed ogni singola bufala ha un proprio codice fiscale. Quindi da sempre tracciano la loro filiera: quanto latte da ogni allevamento prende, in quali giorni viene lavorato (entro 72h dalla mungitura per essere DOP), dove viene lavorato e le analisi sul latte in entrata e sul prodotto finito. Tutti questi dati vengono comunicati quotidianamente al Ministero delle Politiche Agricole. A questo punto, intorno al 2018, vedendo i trend di mercato, la crescente attenzione alla sicurezza alimentare, alla necessità di maggiori informazioni da parte del cliente. Poiché la filiera esiste ed è controllata perché non diamo al cliente la possibilità di vedere quei dati che noi comunque già raccogliamo e comunichiamo al ministero?

NO BARRIERA TECNOLOGICA: non hanno dovuto integrare nuove figure che seguissero la filiera, né inserire nuove tecnologie complesse. Hanno digitalizzato la filiera inserendo una nuova piattaforma, senza assumere nuove persone.

SCANSIONE DEL QR CODE: scansionando il codice e inserendo il lotto si può vedere:

- Data di produzione: tutte le confezioni prodotte, nei diversi formati
- Contribuzione al lotto: del singolo allevamento (es.25% da azienda A, 15% da azienda B ecc.)
- Data di mungitura
- Dettagli di mungitura: macchina o a mano
- Dettagli di trasporto: automezzo utilizzato, orario d'arrivo
- Certificato Blockchain per ogni fase: trasporto, trasformazione ecc.
- Dettagli di trasformazione: pastorizzazione, macerazione, cagliatura ecc.
- Analisi del prodotto finito: parametri chimici e organolettici

IL QRcode è stato un elemento per garantire la qualità e la sicurezza degli alimenti. La questione della riduzione degli sprechi sarebbe raggiungibile se la blockchain fosse agganciata con la distribuzione: nel realizzare questa filiera tracciata abbiamo avuto difficoltà sia con i partner in entrata che in uscita. Abbiamo provato un gap di digitalizzazione notevole, non tanto degli allevamenti, quando in uscita. Grandi player della GDO non sono ancora pronti con i loro mezzi a garantire una blockchain logistica in linea con quella dei fornitori. (barriera organizzativa)

C'è ad esempio un retailer che ha voluto che molti suoi prodotti fossero tracciati, ma in quel caso è il distributore che crea la blockchain con i prodotti a suo marchio. Nel nostro caso siamo noi produttori a proporre una blockchain con i nostri prodotti, che non riesce ad agganciarsi con i distributori con cui la nostra blockchain si completerebbe (cioè dati sulla distribuzione, quando la merce raggiunge gli scaffali, quando viene venduta e quando non viene venduta). Da qui la gestione delle eccedenze e evitare sprechi alimentari. Con una tracciabilità del genere si avrebbe traccia di tutti i prodotti e si potrebbero gestire in maniera adeguata.

L'Italia ancora non è pronta, rispetto ad altre nazioni europee, in cui la blockchain è molto più nota al consumatore. (barriera culturale: mancanza di conoscenza, consapevolezza del consumatore). Il riscontro del cliente non è stata quella che ci si aspettava. Tuttavia crediamo molto nel potenziale della blockchain e crediamo che in futuro possa prendere sempre più piede anche per la collaborazione con i vari attori della filiera. Noi abbiamo avuto grandissime difficoltà con gli allevatori, perché non concepivano l'idea di rendere condivisibili i loro dati. Noi gli abbiamo fatto capire che loro sono già controllati, sono soggetti a continui controlli di qualità e benessere animale. Tutti i documenti cartacei venivano semplicemente digitalizzati. Nonostante questa resistenza iniziale, si tratta di una barriera facilmente superabile, perché abbiamo notato che con le seconde generazioni sono entusiasti di collaborare e stanno costruendo sempre di più allevamenti 4.0 dove il cartaceo non esiste più. Sono le macchine mungitrici stesse a raccogliere il dato e a comunicarlo ai camion che trasporta il latte. Ed una volta arrivato nello stabilimento lo comunica ai nostri computer. Tutto questo tramite un codice da scansionare sull'automezzo. Ma tutto questo verrà raggiunto effettivamente forse a fine 2022, 2023. Stiamo costruendo un nuovo stabilimento 4.0. con delle colonnine che leggono i camion e tutti i dati che trasportano. Tutto ciò che ora inseriamo manualmente, diventerà automatico.

Barriera regolamentare? Noi non ne abbiamo risentito tanto perché in qualità di DOP siamo già dentro ad una regolamentazione molto rigida, quindi non abbiamo riscontrato grossi cambiamenti.

Drivers:

-MARKETNG: abbiamo partecipato a fiere di settore dove la tematica era sponsorizzare la blockchain. Abbiamo puntato su tutti i tipi di marketing: promozione digitale, eventi, stampa di settore (articoli su editoriali dedicati alla GDO), progetti con università per farci conoscere e diffondere i benefici della blockchain.

Bisogna credere nello strumento. La tecnologia veramente potrebbe favorire la trasparenza nel consumatore. Forse noi siamo facilitati, perché come DOP siamo sempre stati tracciati, anche se abbiamo tantissimi standard da rispettare.

C'è un grande rischio, quindi se io mi metto nei panni di altre aziende capisco che non tutti vogliano rischiare di esporre dai dati e dicano "perché devo rischiare di avere segnalazioni per delle cose che se non comunico, mai nessuno verrà a chiedermi?".

È tutta una questione di marketing: il trend per il bio, il vegan, il sostenibile, ha portato tante aziende a cambiare, anche se non era qualcosa di obbligatorio

g) COMPANY G

RUOLO: Logistic director

SC STAGE: manufacturer

Barcodes-inchiostri cromogenici – Progetto *Smart Label*

Credo che tutte le barriere che avete elencato siano quelle riscontrate in questo progetto, ma che si riscontrano in tutti i progetti. Un pack con etichette intelligenti serve per efficientare il network logistico all'interno dell'azienda e con il cliente principale che è la GDO. Ciè una parte di packaging che serve a parlare con il cliente, prima che con il consumatore. Parlare con la GDO ha un certo tipo di barriere:

- Economiche: non avendo ancora raggiunto un mercato di massa, il prezzo rimane ancora d'élite. Uno fa una cosa che costa tanto se ne ha un certo guadagno. Spesso ci sono degli efficientamenti di flusso che hanno dei ricavi nascosti, difficili da far emergere, che non andranno mai a coprire i costi che invece sono ben visibili, palesi e certi. So quanto mi costa ma non so quale sarà il ritorno sulla mia filiera, in termini di guadagno effettivo ed efficientamento.
- culturali
- apertura a dare informazioni dall'altra parte.

Oggi scambiare informazioni con i nostri clienti è davvero difficile, sia per la questione di fiducia e tutela dei dati da un lato, sia per una questione economica (ti danno i dati ma vogliono essere pagati). C'è la questione della sicurezza dei dati e dell'apertura alla rete. Parlando con un operatore logistico con cui collaboriamo, è emerso che uno dei problemi più grossi è che ormai ogni device è connesso alla rete, e questo può portare a problemi di cyber security.

Con un retailer invece abbiamo riscontrato un altro tipo di barriere. Abbiamo proposto una tecnologia di barcode che andava letta con i comuni smartphone. Ma il retailer non poteva richiedere agli operatori di utilizzare il loro cellulare, non avevano il lettore a radiofrequenza perciò non erano dotati dei dispositivi necessari. Da qui poi sarebbe arrivato il limite delle regolamentazioni sui lavoratori, e questo sarebbe un rischio nuovo.

Oggi ci sono tante tecnologie molto diverse tra loro che riguardano il monitoraggio di parametri diversi. Bisognerebbe riuscire ad essere più collaborativi con l'altro per capire quale sia il dato più importante da monitorare e trovare degli standard di riferimento per regolamentare le cose. Perché altrimenti c'è una proliferazione di diversi strumenti che diventano di difficile applicazione perché non si può fare tutto ovviamente e quindi si decide di portarne avanti solo alcuni. Se una cosa si riesce a sviluppare su larga scala riuscirà a raggiungere prezzi più accessibili a tutti, mentre se invece rimane una cosa più di nicchia non riesce a svilupparsi. Da qui quindi ci si collega alla barriera di mercato.

Con il consumatore finale le barriere sono meno. L'azienda è molto più libera di creare QR code. È strano da dire ma è molto più facile che sia il consumatore finale a chiedere una cosa e poi la filiera è costretta a farlo e si deve adeguare per forza, per rimanere nel mercato. Invece che un'azienda riesca ad imporre alla GDO determinati standard è molto più difficile.

Drivers:

L'obbligo è una strada pericolosa. Non è detto che abbia i benefici che pensava di ottenere.

Quello che invece si può fare e che abbiamo fatto è quello di coinvolgere istituti molto influenti su questo aspetto. Riuscire a portare a bordo dei nostri progetti la comunità scientifica, le istituzioni, le associazioni di categoria. Creare una sorta di collaborazione per il dialogo tra attori molto diversi. Il lavoro della comunità scientifica è molto importante per portare idee innovative nel mondo delle aziende, perché hanno una cassa di risonanza enorme in determinati contesti.

h) COMPANY H

RUOLO: Responsible for sustainability and value innovation

SC STAGE: retailer

NON RICICLABILITÀ: attenzione alla riciclabilità dell'RFID, devi vedere l'intero LCA. Anche se rende l'imballaggio meno riciclabile, devi allargare gli orizzonti. L'imballaggio in sé per sé magari va buttato, però se allargo i confini dell'LCA devo considerare una shelf life del prodotto maggiore ottenuta grazie a questa soluzione di packaging. Non è detto che l'impatto ambientale complessivo sia negativo.

CODICI A BARRE: tutti i prodotti lo hanno (è un B2B, non tocca il consumatore finale).

BARRIERE PERCEPITE:

TECNOLOGICA Gestione spazio sull'etichetta

ECONOMICA:

- modifica dei materiali, quindi degli impianti per poter usare i nuovi imballaggi. Il costo può essere distribuito lungo la filiera o polarizzato, ma sicuramente è molto percepita.

- I prezzi per le innovazioni sono sempre alti. Cifre folli. Okay ci sono ammortamenti iniziali, però i differenziali di prezzo sono molto importanti. Anche se il sovraprezzo fosse distribuito lungo la catena del valore, anche al consumatore finale arriva un sovrapprezzo di minima, e questo è un momento molto delicato per il consumatore.

REGOLAMENTARE: sono sempre in ritardo, le procedure sono sempre lente e complicate. Barriera difficilmente superabile

NON PERCEPITE:

CULTURALE: il consumatore finale è sempre più sensibile e informatizzato (uso di smartphone, lettore QR code, internet)

DI MERCATO: non è la barriera più rilevante. È più il risultato di tutte le barriere precedenti.

ORGANIZZATIVE: COMPANY H vede una situazione dorata, privilegiata, perché hanno tante filiere certificate perciò hanno il "governo" della filiera. Hanno una grande conoscenza della filiera e comprano i prodotti in ottica di filiera. Riescono a gestirle in maniera abbastanza strutturata e riescono a far partire diverse sperimentazioni innovative, perché c'è già tanta fiducia nei fornitori (vedi caso uova).

La filiera nasce più di 30 anni fa per agevolarsi nella gestione dei rischi e pericoli nei vari punti critici. Prodotti in cui si controlla tutta la filiera. Prima frutta e verdura, poi le carni (anabolizzanti, ormoni ecc). Hanno gettato le basi per un sistema di gestione complessivo di filiera, questo ha permesso una gestione ottimizzata per rischi di sicurezza e frode. Ma anche per definire requisiti volontari (trasparenza, etica, rispetto ambientale). I requisiti volontari possono essere anche una sperimentazione.

Progetto pilota: QR code uova bio: Filiera certificata – filiera a rischio (microbiologico – contraffazione – contaminanti – benessere animale) – filiera mediamente complessa – le più altovendenti nella categoria uova

Dal 2002 hanno lavorato sulla filiera, non allevato in gabbia, territorio italiano, controllo benessere animale. Avevano un buon controllo della filiera per poter fare una sperimentazione della block chain.

Obiettivo: analisi di fattibilità (per fare analisi costi-benefici) e sostenibilità economica e gestionale (in termini di tempi e costi). Volevano valutare l'effort di integrazione, le tempistiche dei fornitori (trade-off sostenibile: tra raccolta informazioni, lo sforzo ed il risultato prodotto) e poi capire l'impatto sul consumatore.

Risultati: scarsa penetrazione, pochi hanno scannerizzato. Quelli che però lo hanno provato erano molto soddisfatti, hanno capito l'importanza della trasparenza, della filiera, della fiducia in COMPANY H. Erano incentivati al ri-acquisto.

BARRIERA ECONOMICA ANCORA TROPPO IMPATTANTE: L'analisi costi-benefici non è stata molto favorevole. I costi erano elevati, non per il pack, ma tutto ciò che c'è dietro (impianto, database, integrazione)

Etichette cromogeniche: Misurava lo stato di ossidazione del prodotto. Problemi a livelli di impianto,

CULTURALE: difficile interpretare i risultati

TECNOLOGICI: c'era variabilità di prodotto. Problemi di resa tecnologica; inoltre il prodotto potrebbe ancora essere edibile ma è stato registrato un viraggio: spreco

ORGANIZZATIVE: RESPONSABILITA' LEGALE: potresti essere il responsabile di qualcosa che tu non governi pienamente: la variazione di qualità potrebbe non essere legata all'unica variabile che vai a monitorare (stato di ossidazione)

ECONOMICO: ancora investimenti troppo sostanziosi

Se non riescono a rompere le barriere tecnologiche-economiche non ci sarà mai un mercato di massa.

i) COMPANY I

RUOLI: Quality Manager, Marketing Responsible

SC STAGE: technology provider-packagers

Tecnologia: QR code

QRcode rivolta alla comunicazione B2C. Sarebbe bello inserire tecnologie che diano informazioni dinamiche sul prodotto. Essendo packaging da banco servito c'è tutto l'interesse possibile a prolungare la shelflife il più possibile. Il cliente ha accolto molto bene questo strumento offerto perché non c'è stato nessun sovrapprezzo volto al cliente finale. Il packaging è un prodotto povero, non si può rincarare il prezzo. Si è trattato solo di un'aggiunta stampata.

Barriera Tecnologica/ambientale: non percepita

Barriera Regolamentare: molto sentita nel settore packaging alimentare.

Barriera Culturale: è stata accolta molto bene la loro tecnologia proposta, anche perché non ha aggiunto costi

Barriera organizzativa: non risentita perché veicolano informazioni semplici. Se si vuole veicolare informazioni legate a dati sensibili sicuramente ci saranno problemi di privacy da considerare

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Acknowlegments

Ringrazio i miei genitori che in questi anni mi hanno osservato da lontano, senza mai perdermi di vista. Per primi avete creduto in me e non avete mai smesso di farlo, neanche nei momenti più difficili. Grazie a voi non mi sono mai sentita sola, neanche a mille chilometri di distanza. Vi ringrazio per aver investito nel mio futuro e per avermi permesso di realizzare tutti i miei sogni.

Ringrazio Lorenzo, il mio punto di riferimento e la persona che più mi sprona e mi spinge a dare il meglio di me. Mi hai insegnato a lottare per ciò che desidero, ad aver fiducia in me stessa ed a non arrendermi mai. Il tuo aiuto è stato prezioso e non avrei mai raggiunto tutti i miei obiettivi se tu non fossi stato al mio fianco a fare il tifo per me.

Ringrazio Angela, Roberto e Tommaso per essere stati la mia famiglia a Milano, per avermi accolta nella loro casa e per tutti i pranzi, che mi hanno riportato con il cuore alle domeniche dalla nonna, alleggerendomi la nostalgia di casa.

Ringrazio le mie coinquiline Margherita, Giulia e Natalie per avermi distratto dalle ansie dell'università. In questi anni mi avete vista spesso disperata, ma siete state fondamentali per renderli indimenticabili, tra una serata in discoteca ed una festa in Casa Kaos.

Ringrazio i miei amici di giù che hanno portato un po'di Puglia a Milano. La distanza ed il tempo non ci hanno allontanati, ma alla fine questa città ci ha riuniti tutti e ci ha fatto crescere insieme. Siete stati una boccata di Sud in questo mare di nebbia e mi avete regalato serate piene di risate e di allegria.

Ringrazio infine tutti i miei compagni di corso ed i professori che ho incontrato durante questi cinque anni al Politecnico, le professoresse Garrone e Del Curto e la dottoressa Silvestro che mi hanno accompagnato in questo periodo finale. Ognuno di voi è stato necessario per farmi crescere e diventare la giovane donna che sono adesso.