CUSTOMER AWARENESS REGARDING THE ROLE OF INTELLIGENT PACKAGING IN THE PREVENTION OF FOOD WASTE

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‘πολλῶν δ’ ἀνθρώπων ἴδεν ἄστεα καὶ νόον ἔγνω’

Ομήρου Οδύσσεια, ραψωδία α΄(3)

‘Many were the men whose cities he saw and whose mind he learned’

Homer, The Odyssey, Book I, Line 3

Table of abbreviations

DIT	Diffusion of Innovation Theory
e.g.	exempli gratia
et al.	et alia
FIs	Freshness Indicators
GLIs	Gas Leakage Indicators
GS1	Global System of supply chain standards
Inc.	Incorporated
NDIR	Non-Dispersive Infrared
pH	potential of Hydrogen
p.	page
pp.	pages
QR	Quick Response
RFID	Radio Frequency Identification
RSS	Reduced Space Symbology
TTIs	Time Temperature Indicators
UPC	Universal Product Code
UK	United Kingdom
vol.	volume
XM	eXperience Management

Abstract

Intelligent packaging is a relatively recent innovation that aligns with sustainable development. By employing active and interactive technologies it manages to monitor food quality, improve food safety, and record product information across the supply chain. By incorporating intelligent tools, such as barcodes, time temperature indicators, and gas sensors, intelligent packaging transforms conventional packaging conspicuously.

Previous studies have tried to investigate how customers perceive and understand intelligent packaging. However, not many studies have examined the factors that affect the adoption of intelligent packaging. This study fills the gap and examines the factors that affect the adoption of intelligent packaging by deploying the Diffusion of Innovation theory. Based on the Diffusion of Innovation theory and the data collected from 106 supermarket customers, it is found that relative advantage, compatibility, observability, and trialability have a positive effect on the adoption of intelligent packaging. On the contrary, complexity and perceived value pricing have a negative effect on the adoption of this innovation.

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1. Introduction

Food supply chains begin from the agricultural phase, continue with manufacturing and retail, and end with consumption in households. Because of technological, economic, and societal reasons food is wasted during this cycle (Galanakis *et al.*, 2015, p. 4). *'Food waste can be defined as any food, and inedible parts of food, removed from the food supply chain to be recovered or disposed'* (Aschemann-Witzel *et al.*, 2015, p. 6458). Limitations in financial, managerial, and technical skills in harvesting are the main reasons for food waste. Also, storage and cooling facilities in extreme weather conditions, as well as packaging and marketing systems imply large quantities of wastage (Girotto *et al.*, 2015, p. 33). Companies are not always able to control their inventories efficiently and they do not comply with market packaging requirements (Irani *et al.*, 2018, p. 368).

Traditional packaging is no more sufficient. Products have become more complex, customer expectations increase continuously, and national and international initiatives are taking place to foster a circular economy and minimize the carbon footprint of product manufacturing (Schaefer and Cheung, 2018, p. 1022). Traditional food packaging is mostly petroleum-based plastics. The fundamental dangers and issues are associated with non-sustainable production, insufficient mechanical and barrier properties, as well as lack of recyclability. In addition, the materials used are not biodegradable. Many food producers must deal with challenges, like water vapour and gases, while in the meantime they must achieve an adequate shelf life for food products (Kocetkovs *et al.*, 2019, p. 223).

Various emerging approaches have been introduced to prevent food waste. Among them, the concept of intelligent packaging can perform a significant role in the food packaging sector. Intelligent packaging can improve food quality and value by monitoring the quality and safety of products in their environment, tracing the movement of the products across the supply chain, or recording important product information (Kalpana *et al.*, 2019, p. 146). It identifies, quantifies, and reposts changes in the atmosphere and temperature within the package during transfer and storage, and informs the consumers about food quality (Pereira de Abreu *et al.*, 2012, p. 174).

However, the development and the implementation of intelligent packaging is strongly depending upon consumers' awareness (Nosáľová *et al.*, 2018, p. 144). Consumers are sometimes suspicious regarding innovations in food technologies and their safety. They are sceptic or misunderstand the concept of such technologies. The feeling of fear, concern, and distrust are critical factors for the implementation of intelligent packaging (Barska and Wyrwa, 2016, p. 154).

Although there is literature concerning intelligent packaging and how successful it can be in the prevention of food waste, little research currently exists regarding the variables that influence the adoption of intelligent packaging. Therefore, the objective of this Thesis is to seek answers to the following research questions: *Based on the Diffusion of Innovation theory, which attributes influence the adoption of intelligent packaging? Is the cost of intelligent packaging a consumer barrier to adopting this innovation?* Following these questions, an additional question is posed: *Are customers willing to pay double the price of conventional packaging for intelligent packaging?*

The main contribution of this research is to investigate the variables that influence the adoption of intelligent packaging. More precisely, the objective of this research is to investigate the facilitators and inhibitors of intelligent packaging adoption under the Diffusion of Innovation theory. According to the Diffusion of Innovations theory, five attributes determine the adoption of an innovation: Relative Advantage, Compatibility, Complexity, Trialability, and Observability (Al-Jabri and Sohail, 2012, pp. 379-380). These attributes, in addition to perceived value pricing, are examined with regard to intelligent packaging adoption.

This research is structured as follows: Section two outlines the literature review and hypotheses formulation. Section three describes the research methodology that is used in this analysis. Section four presents the results, followed by Section five with the discussion. Finally, the research ends with a conclusion in Section six based on the findings from the study.

2. Literature review

Previous studies had focused on understanding customer awareness and attitudes towards intelligent packaging aiming to examine customer expectations and their ability to understand intelligent packaging (Kocetkovs *et al.*, 2019, pp. 223, 225) based largely on the theory of Planned Behaviour (Cammarelle *et al.*, 2021, p. 3). However, customer awareness regarding intelligent packaging technologies requires deeper investigation (Nosáľová *et al.*, 2018, p. 148). The Diffusion of Innovation Theory (DIT) is one of the most popular theories that attempt to explore the factors that influence individuals to adopt a new technology. *'It explains how, why, and at what rate new ideas and technology spread through cultures'* (Young *et al.*, 2020, p. 19).

2.1 Intelligent packaging

Active, smart, interactive, and clever are only a few terms that have been used to describe Intelligent packaging (Han *et al.*, 2005, p. 138). Particularly, *Active Packaging*, *Smart Packaging*, and *Intelligent Packaging* have become popular with the terms often used interchangeably and misinterpreted. They are all packaging systems, which are used for food and drinks, pharmaceuticals and cosmetics, and other perishable goods. Although they share common characteristics, a distinction between the terms is necessary (Schaefer and Cheung, 2018, pp. 1022-1023).

Intelligent Packaging is *'a packaging system that is capable to carry out intelligent functions (such as detecting, sensing, recording, tracing, communicating, and applying scientific logic) to facilitate decision making to extend the shelf life, enhance safety, improve quality, provide information, and warn about possible problems'* (Yam *et al.*, 2005, p. 2). In other words, intelligent packaging detects, senses, and records changes in the environment of the product, either internal or external (Huff, 2008, p. 3). It must have the ability to track the product, sense the internal and external environment of the package, and communicate with humans (Otles and Yalkin, 2008, p. 2).

Intelligent packaging refers to a package that can understand the environmental changes and, in the meantime, it can inform the users of those changes (Han *et al.*, 2005, p. 139). It monitors food conditions by providing information about the packaged food during its storage and distribution (De Kruijf *et al.*, 2002, p. 150). What makes a package intelligent is its ability to communicate food conditions throughout the supply chain. It senses the environment both inside and outside the package and processes information and, thus, enhances food protection (Yam *et al.,* 2005, p. 2). It controls the status and the quality of the packaged food from the package and, hence, prevents food wastage and spoilage (Kalpana *et al.*, 2019, p. 146).

Information technology has created a powerful environment in which intelligent packaging rises successfully. It facilitates the flow of materials and information in the food supply chain from one location to another by performing its main function which is product protection. Moreover, intelligent packaging facilitates the flow of information, as it carries information related to the direction of material flow (truck, train, ship), which can transmit throughout the supply chain either visually by using an indicator or electronically by using barcodes (Yam *et al.*, 2005, pp. 2-3). This information establishes a resilient food supply chain in terms of storage, transport, distribution, and sale of products (Fuertes *et al.*, 2016, p. 2).

Active Packaging is the *'incorporation of certain additives into packaging systems with the aim of maintaining or extending product quality and shelf-life'* (Kerry *et al.*, 2006, p. 114). In active packaging, the package, the product, and the environment interact in a positive way so that they can protect the quality of products and in the meantime, they can extend their shelf life and enhance their safety (Prasad and Kochhar, 2014, p. 1). It is a heterogeneous concept that can be seen as an alternative to the use of preservatives. It controls product deterioration and helps manufacturers to reduce processing costs, process the product inside the package, and control the quality of the product (Singh *et al.*, 2011, p. 250).

Smart Packaging is a broader concept that includes both intelligent and active packaging. It provides a total packaging solution that monitors changes in products or the environment (intelligent packaging) and acts upon these changes (active packaging). In the smart packaging system, various sensors are used to monitor the quality and safety of a product and they vary according to the actual product that is being packaged, like food and beverages, pharmaceuticals, or household products. They analyse freshness, leakages, oxygen, carbon dioxide, as well as the time and temperature (Schaefer and Cheung, 2018, p. 1023).

2.2 Systems of intelligent packaging

Intelligent packaging improves the quality characteristics of the food inside the package (Sohail *et al.*, 2018, p. 2652). It is manufactured by incorporating an external component in the package, such as a two-dimensional film or three-dimensional objects (Ghaani *et al.*, 2016, p. 2). The use of such intelligent tools monitors the quality of the packaged food, and they can be found either inside or outside the package to inform consumers about safety issues of the product (Sohail *et al.*, 2018, p. 2652). Three main technologies are used for intelligent packaging systems: *Indicators, Data carriers, and Sensors*

(Müller and Schmid, 2019, p. 3). An Indicator provides convenience and information about the quality of the product. Data carriers, like Radio Frequency Identification tags and Barcodes, are used for storage, distribution, and traceability purposes. Sensors rapidly quantify food analytes (Ghaani *et al.*, 2016, p. 2).

2.2.1 Indicators

'Indicators determine the presence or absence of a substance, the extent of a reaction between different substances or the concentration of a particular substance' (Müller and Schmid, 2019, p. 5). They are devices that transmit information to consumers regarding the food quality, microbial activity, the presence of chemical or other biological substances, reactions between substances, as well as the concentration of chemicals in food via changes in colour (Kalpana *et al.*, 2019, p. 146). Indicators must be easily activated and display changes that depend on time and temperature and are easy to measure. Moreover, they must not be reversed, and they must be correlated to food quality (De Kruijf *et al.*, 2002, p. 150). They inform about changes in a product or product's environment, such as a change in temperature or a change in the pH level (Schaefer and Cheung, 2018, p. 1023). The indicators that monitor food quality are *Time-Temperature Indicators*, *Freshness Indicators*, and *Gas Leakage Indicators* (De Kruijf *et al.*, 2002, p. 150).

2.2.1.1 Time Temperature Indicators

Time Temperature Indicators (TTIs) are small measuring devices that show irreparable changes depending on time and temperature (De Jong *et al.*, 2005, p. 977). They record the thermal history of perishable products and indicate their remaining shelf life across their storage, distribution, and consumption (Wang *et al.*, 2015, p. 839). They are mostly applied in chilled and frozen products, like meat, dairy, fish products, and other seafood (Kalpana *et al.*, 2019, p. 147). The basic idea behind TTIs is food safety. As temperature increases, the quality of the food deteriorates. By maintaining low storage temperatures TTIs are able to control and protect food quality. They are placed outside single packages or in bigger containers and trays (De Jong *et al.*, 2005, p. 977). They should be small, low-priced, and reliable, and they should be easily integrated inside the package. Also, they should be flexible to different temperatures, and they should pose no toxicological threat or other safety issues (Kerry *et al.*, 2006, p. 124).

TTIs are based on mechanical, chemical, electrochemical, enzymatic, or microbiological changes and they are expressed as a visible response in the form of mechanical deformation, colour development and movement. They are small tags or labels, which keep a record of the time and temperature of perishable products from the point of manufacture to the end consumer. For instance, TTIs can be used in meat and poultry products, where they monitor the cold distribution chain, microbial safety, and quality (Kerry *et al.*, 2006, p. 124).

Although TTIs play an important role in the food supply chain, there are several issues that hinder their application. *Firstly*, TTIs can pose a safety threat. They contain organic and inorganic compounds which can be toxic and may migrate into food and pollute it. *Secondly*, they cannot really monitor the actual temperature of food. Instead, they only monitor the outer surface temperature of a food package. In other words, the colour change of TTIs depends on the environmental conditions rather than reflecting the thermal history of food and estimating the food shelf life. *Thirdly*, TTIs are expensive. Their price is relatively high and because of this food manufacturers are not always eager to apply TTIs to their products (Wang *et al.*, 2015, pp. 861-863).

2.2.1.2 Freshness Indicators

Freshness Indicators (FIs) supervise the quality of products during storage and transportation (Müller and Schmid, 2019, p. 6). They consider not only the quality of the products but also the supply chain mistakes. Spoilage detectors react immediately during a deterioration reaction in the food and for this reason, they are placed inside the packages (De Jong *et al.*, 2005 p. 978). They store information regarding microbiological growth and the presence of microbiological metabolites (Smolander, 2003, p. 127). They analyze chemical reactions by targeting micro-organisms and their metabolites, which cause food spoilage. The concept behind them is that the growth of micro-organisms can cause variations in pH and therefore directly affect the food quality inside the package. FIs are applied to various products, such as fresh foods, seafood, and fruits. Intelligent tools include ripe sensors, which are able to indicate the quality and the freshness of the food (Kalpana *et al.*, 2019, pp. 147-149).

They are developed by using different organic acids, like acetic or lactic acid, ethanol, glucose, carbon dioxide, volatile nitrogen compounds, such as trimethyl amine for packages that contain fish, biogenic amines for chicken and beef, as well as sulfuric compounds which determine the freshness of packaged products (Sohail *et al.*, 2018, p. 2655). FIs include an indicator card and an indicator film. They provide either qualitative or semi-quantitative information about changes in food quality that are caused naturally or because of microbial growth and in the meantime, they preserve the package helping customers to determine food quality (Shao *et al.*, 2021, p. 286).

Despite being a great tool for tackling food waste, FIs face a number of obstacles. First of all, they can cause food safety problems which consequently affect their application. Particularly, they can migrate chemical dyes, printed ink, film adhesives, and synthetic materials into food. For this reason, FIs are placed in the headspace of the package. In this way, the safety of the FIs is improved and migration issues are avoided successfully (Shao *et al.*, 2021, pp. 291-292).

FIs require high energy consumption as well as a long drying time. The production of FIs is difficult to be scaled up and especially for natural polymers as carrier films, as they are not controlled in industrial production. Moreover, due to their large size and strong stiffness, FIs cannot be easily combined with the traditional packaging system which is more flexible. Also, the speed of reaction and the sensitivity of FIs is strongly challenged by differences in packaging conditions, like the quantity, heat, pH, light, or water activity. Furthermore, the cost of using FIs is very high, because they are very complex and highly specialized. In addition, different countries apply different laws and regulations for such materials which also increases the cost considerably (Shao *et al.*, 2021, pp. 292-293).

2.2.1.3 Gas Leakage Indicators

Respiration of fresh fruits and vegetables, changes in gas concentration and leakage inside or outside the package, as well as gas production from microbial growth inside the package, are the reasons that led to the development of Gas Leakage Indicators (GLIs). GLIs provide information about the existence of oxygen or carbon dioxide gas in the packaging material by changing their colour as a result of chemical or enzymatic reactions (Sohail *et al.*, 2018, p. 2654). With the aid of GLIs, any damage to individual packages can be easily determined without opening the package. (Han *et al.*, 2005, p. 148). They contact the gaseous environment inside the package and therefore they are in contact with the food (De Jong *et al.*, 2005, p. 977). They have direct contact with the food materials and thus they inform about the existence of gas. GLIs are usually labels, tablets, or printed or laminated layers in a polymer film (Sohail *et al.*, 2018, p. 2654).

GLIs can indicate food quality conditions depending on the atmosphere within the package. Packages include a sensor which detects and reacts to any change that takes place, while the actual indicator displays food quality. On the one hand, the atmosphere is modified according to the food activity as result of enzymatic or chemical reactions, and on the other hand according to current environmental conditions as result of gas production by microbial growth (Müller and Schmid, 2019, p. 7). Apart from oxygen and carbon dioxide, more gas indicators have been introduced, including ethanol, hydrogen sulfide, and water vapour (Fang *et al.*, 2017, p. 67).

2.2.2 Data carriers

Data carriers, which are also known as automatic identification devices, are systems that facilitate the flow of information within the supply chain in favour of food quality and safety. They provide traceability, automatization, theft prevention, and counterfeit protection. They are placed on tertiary packaging, such as shipping crates, pallets, paperboard packages, or multi-box containers (Ghaani *et al.*, 2016, p. 3). *Barcode labels* and *Radio Frequency Identification tags* are the most important data carrier devices (Müller and Schmid, 2019, p. 3).

2.2.2.1 Barcode labels

Barcode labels *'are a pattern of bars and spaces of varying width that represent digits, letters or other punctuation symbols to identify an item or object'* (Singh and Sharma, 2015, p. 1). They are an arrangement of white and black bars that are placed alternatively and store product information (Kalpana *et al.*, 2019, p. 151). Each barcode contains a piece of information, allowing for an accurate and rapid collection of real-time data (Singh and Sharma, 2015, p. 1). To collect the information, an optical reader is used. The optical reader scans the bars and directs the data to a unique identification that is consisted of an alphanumeric code (Kalpana *et al.*, 2019, p. 151).

Barcodes encode data related to food packaging date, weight, batch number, cooking instructions, nutritional information, and the address of the product manufacturer. They can be read via smartphones providing great convenience for retailers and consumers (Fang *et al.*, 2017, p. 65).

When combined with application software they improve performance and productivity, as well as profitability. Barcodes reduce overall cost, improve operational efficiency, offer accuracy, and better stock verification (Singh and Sharma, 2015, pp. 1-2). They facilitate inventory control and checkout and record the stock. They are cheap and easy to use with different storage capacities (Müller and Schmid, 2019, p. 4). Barcodes assess individual identification numbers by monitoring the inventory control and thus they are able to trace product history (Kalpana *et al.*, 2019, p. 151). They can be either *one-dimensional* which are linear barcodes formed by black and white bars or *two-dimensional* barcodes which are formed by a geometric figure (Shao *et al.*, 2021, p. 290).

Figure 1 illustrates different barcodes used in the food sector. The *Universal Product Code (UPC)* appears as a pattern of lines and spaces, and it was the first commercialized barcode label. It was introduced in the 1970s and is widely used to facilitate inventory control, checkout, and stock reordering (Fang *et al.*, 2017, p. 65). The demand for reduced space usage led to the development of the *Reduced Space Symbology (RSS)*. Likewise, other forms of linear barcodes with patterns and symbols were also developed to incorporate product-related information in a smaller space, such as the *Aztec code* and *Global System of supply chain standards (GS1)* (Kalpana *et al.*, 2019, p. 151).

Figure 2. 1: Barcode labels used in intelligent food packaging sector (Kalpana *et al.*, 2019).

2.2.2.2 Radio Frequency Identification tags

Radio Frequency Identification tags (RFID) are an auto-identification technology that uses radio waves to identify individual objects (Angeles, 2005, p. 52). RFID tags can store a large number of various codes in the tags, and they can also transfer and communicate information at a long-distance offering more traceable operations and improved automatic product identification. They include an active tag and a passive tag (Ghaani *et al.*, 2016, p. 4). The active tag relies on a battery to power the circuitry of the microchip and to broadcast signals to the readers. On the contrary, passive tags do not rely on a battery and they are powered by the energy which is supplied by the readers (Fang *et al.*, 2017, p. 66).

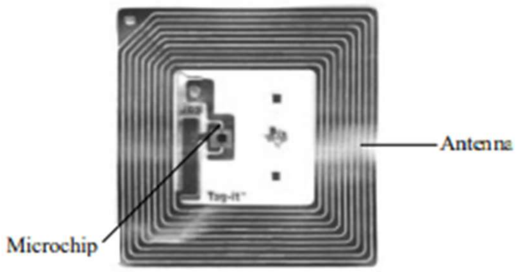

Figure 2. 2: Radio Frequency Identification tag (Khan *et al.*, 2009).

Compared to barcodes, RFID tags are more expensive and require a more powerful electronic information network (Müller and Schmid, 2019, p. 4). Yet they should not be considered as a substitute for barcodes. RFID tags include a microchip and an antenna (Ghaani *et al.*, 2016, pp. 4-5). The microchip stores product information. The antenna enables the microchip to transmit the information to a reader, which transforms them into a format able to be understood by a computer (Angeles, 2005, p. 52). In this way, RFID technology can trace all the products in the production system. It offers better inventory control, improves asset tracking, and manages better stock and shelf inventory (Higberg and Goran, 2016, p. 13). Furthermore, it offers cold chain control, shelf-life prediction, and livestock management (Ghaani *et al.*, 2016, p. 5)

Many important developments have taken place in the food supply chain by applying the RFID technology. Cost-saving, improved traceability and safety control are only a few examples (Shao *et al.*, 2021, p. 290). Namely, the development of a pH sensor embedded in an RFID transmitter without relying on batteries, for in situ control of the deterioration level of fish products. RFID tags that monitor meat freshness, RFID tags with a temperature sensor, a gas sensor, a reader, and a server that constitute a tracking system to check the freshness of pork. Moreover, RFID tags with sensors that can effectively measure the temperature and humidity, as well as the presence of volatile amine compounds, to estimate cod fish freshness. RFID tags that monitor the freshness of vegetables along with oxygen and carbon dioxide. Lastly, RFID tags that provide a real-time evaluation of the freshness of packaged milk (Fuertes *et al.*, 2016, p. 4).

The production and distribution of goods across the world increased the logistics and safety challenges and developed applications, such as the RFID tags to increase the efficiency of the production process. In terms of meat products, the European Union imposes the use of RFID tags in meat production. At present, RFID tags on meat products are not available to consumers. The only exemption is the use of RFID tags on meat cuts to the pig processing industry. It monitors the quality and precision of cutting without providing information about the animal itself and the final product (Costa *et al.*, 2013, p. 360).

Regarding dairy products, different RFID tags have been proposed in favour of traceability along the dairy supply chain, such as an electronic tracing system for an Italian cheese that is made out of buffalo milk. Both the tracing and quality information are put together into an online platform that is defined as *'info tracing system'*. The system stores two information categories, chemical and spectrophotometric, regarding the product shelf-life on a web platform and provides tools for each information category. The categories are divided into manufacturers, wholesalers, resellers, retailers, and consumers who contribute correspondingly on different levels to provide data for each product, that end up in a centralized database (Costa *et al.*, 2013, p. 361).

As for fishery products, RFID sensors are combined with detectors, like TTIs or GPS to improve the conditions and control the working environment across the cold chain. In this way, fresh and perishable items are preserved and distributed to the market safely and in good condition. RFID tags can also be successfully applied to bakery products, which are highly perishable and temperature sensitive. Storage temperature strongly affects the quality of baked products during their shipment and handling. RFID technology can protect baked products against chemical and microbiological spoilage during their processing and packaging. It can also provide data remotely and resistance during heat (Costa et al., 2013, p. 362).

2.2.3 Sensors

'Sensors are electronic devices that detect and convert one form of signal to other form using a transducer' (Kalpana *et al.*, 2019, p. 152). Sensors have the ability to change the colour of the food package and in this way, they inform both the retailers and consumers that the product must not be consumed (Fang *et al.*, 2017, p. 68). They are

classified into active types and passive types. *Chemical sensors* and *Biosensors* are used in intelligent packaging to control humidity, pH, and colour (Kalpana *et al.*, 2019, p. 152). They are instruments that are capable to detect, locate, and quantify a problem and then sending signals so that the physical and chemical characteristics of that problem can be measured. Sensors have the ability to detect any events or changes in the environment (Sohail et al, 2018, p. 2652).

2.2.3.1 Biosensors

Biosensors are small smart devices that have the ability to detect, record, and transmit information related to biochemical reactions. They are specific, sensitive, reliable, portable, and simple. They are placed either inside the food package or into the packaging material (Yam *et al.*, 2005, p. 6). Biosensors consist of a receptor and a transducer. Receptors are either organic or biological materials, such as enzymes, antigens, hormones, and microbes. Depending on the system, transducers can be either electrochemical or calorimetric or optical (Fang *et al.*, 2017, p. 68). The receptor transforms physical and chemical information into one form of energy and the transducer converts that energy into a signal (Sohail *et al.*, 2018, p. 2652).

For instance, Toxin Guard (Toxin Alert Inc., United States of America) is a biosensor placed within the package and can detect pathogens and other micro-organisms that contaminate food, such as Escherichia coli O157, Listeria species, and Salmonella species (Ghaani *et al.*, 2016, p. 7). When a pathogen is detected, a visual sign from the packaging material is displayed and warns retailers and consumers about the pathogen (Yam *et al.*, 2005, p. 6).

2.2.3.2 Gas sensors

Gas sensors detect the presence of gaseous and volatile compounds, such as oxygen and carbon dioxide (Kalpana *et al.*, 2019, p. 153). Spoilage can be determined by the concentration of gases, like hydrogen sulfide and carbon dioxide. In the presence of a gas, Gas sensors respond immediately by changing their physical parameters. Specifically, Carbon dioxide sensors are chemical sensors or Non-Dispersive Infrared (NDIR) sensors that are capable to measure carbon dioxide content by absorbing a certain amount of gas (Müller and Schmid, 2019, p. 7).

Oxygen gas sensors indicate the existence of oxygen and quantify it in a gaseous phase and dissolved state. The concentration of oxygen in packaged food products is an important factor and is considered to be a necessary substance that indicates the quality of food products. But high oxygen concentration within the package affects the quality and shelf life of products which may deteriorate under high oxygen concentration levels (Meng *et al.*, 2014, p. 727).

2.3 The Diffusion of Innovation Theory

The Diffusion of Innovation Theory (DIT) *'is a general process, not bound by the type of innovation studies, by who the adopters are, or by place or culture such that the process through which an innovation becomes diffused has universal applications to all fields that develop innovations'* (Murray, 2009, p. 110). It *'is a valuable change model for guiding technological innovation where the innovation itself is modified and presented in ways that meet the needs across all levels of adopters'* (Kaminski, 2011, p. 1). *Diffusion* is the process that communicates innovation to the members of a social system through certain channels over a period of time. *Innovation* is the idea, practice, or object that is perceived to be new by individuals and organizations (Murray, 2009, p. 110).

It is a process that occurs when people adopt an idea, a product, or a practice. In most cases, only an initial few are eager to adopt the new idea. Subsequently, more and more innovators adopt it which leads to the development of a critical mass. The innovative idea becomes diffused across the population until a saturation point is reached (Kaminski, 2011, p. 1). Diffusion of Innovation is a linear process that is developed in a sequential manner. DIT establishes new routines and practices in order to match the potential innovation with individuals or organizations (Crespin-Mazet *et al.*, 2021, p. 1693). Diffusion ends up with adoption, implementation, and institutionalization. Individuals and organizations adopt an innovation and implement it after practicing and testing it. The innovation is institutionalized by incorporating it into typical routines (Murray, 2009, p. 110).

2.3.1 Adopter characteristics

As illustrated in *Figure 3*, there are five categories of adopters: Innovators, Early Adopters, Early Majority, Late Majority, and Laggards. The percentage of each category is very similar to the percentages found in a normal bell curve (Kaminski, 2011, p. 3).

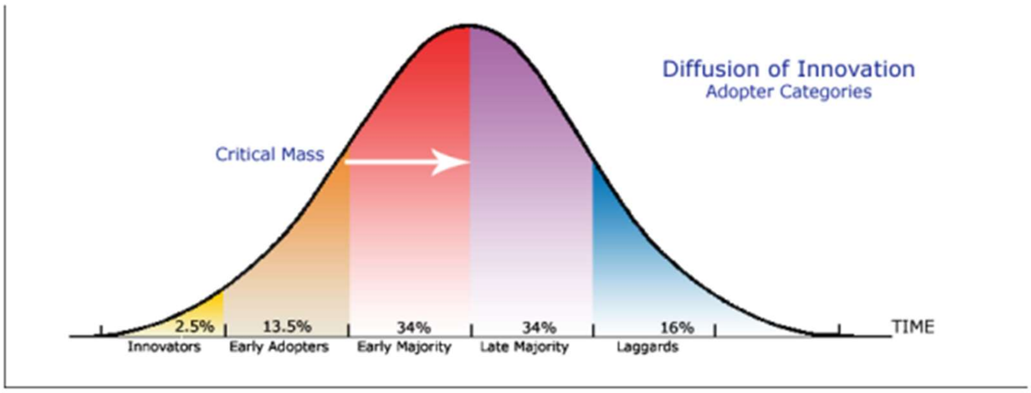

Figure 2. 3: The Diffusion of Innovation according to Rogers (Kaminski, 2011).

Innovators account only for 2.5% and are known as technology enthusiasts. They undertake risks and apply complex technical knowledge to deal with uncertainty. They are the gatekeepers for the next category of adopters. *Early Adopters* (13.5%) are visionaries. They are opinion leaders and serve role models across the social system. They seek adventure by undertaking high-risk projects with great rewards. They are not cost-sensitive, and they test the trial innovation (Kaminski, 2011, p. 3).

The *Early Majority* (34.0%) are pragmatists. They serve as opinion leaders during the diffusion process. They are only comfortable with revolutionary innovations, which increase their productivity. They do not seek complexity. Instead, they only seek proven and reliable applications, avoiding any kind of risk. They are cost sensitive and buy only with a reference from their trusted colleagues. *Late Majority* (34.0%) are conservatives. They are suspicious, cautious, and sceptical. They are cost-sensitive and technologically shy. They only trust proven trends and are influenced by Laggards. *Laggards* (16.0%) are sceptic and suspicious of innovations. They maintain a status quo and think of technology is a barrier to operations. They invest in technology only if the alternative solutions are worse (Kaminski, 2011, p. 3).

2.3.2 The Diffusion of Innovation attributes

Understanding the factors that influence the adoption of intelligent packaging based on the DIT has not been examined yet (Young *et al.*, 2020, p. 19). This study will attempt to close the existing gap in the literature by employing the DIT to interpret the factors that influence the adoption of intelligent packaging innovation.

The attributes of an innovation that influence the adoption behaviour are several. More specifically, these are Relative Advantage, Complexity, Compatibility, Trialability, and Observability (Al-Jabri and Sohail, 2012, p. 381).

The *Relative Advantage* is the degree to which an innovation provides more benefits than its predecessor. It increases efficiency, provides economic benefits, and enhances status. Relative advantage is positively related to the rate of adoption. When the users understand the relative advantage of new technology compared to an old one, they adopt it (Al Jabri and Sohail, 2012, p. 381). It is the willingness of individuals to adopt an innovation based on its advantages over an idea that already exists (Quader *et al.*, 2022, p. 5). In terms of intelligent packaging, important benefits have been reported including microbial safety, maintenance of the quality of the packed food, and extension of product shelf life (Fang *et al.*, 2017, p. 61). Therefore, when customers perceive the advantages that are offered by intelligent packaging, they are more likely to adopt the technology.

Hypothesis 1: Relative advantage will have a positive effect on the adoption of intelligent packaging.

Complexity is the degree to which an innovation is considered relatively difficult both to be understood and used. It is the opposite of ease of use, which is the extent to which intelligent packaging is perceived as easy to be understood and used by individuals (Al-Jabri and Sohail, 2012, p. 381). Research suggests that understanding how intelligent packaging works is quite challenging. Customers have poor knowledge and little understanding of the technologies that are used for the production of intelligent packaging, like the RFID tags and indicators. Moreover, they are not aware of the benefits and the opportunities of intelligent packaging (Kocetkovs *et al.*, 2019, pp. 223, 226). Therefore, it is hypothesized that complexity inhibits the adoption of intelligent packaging.

Hypothesis 2: Complexity will have a negative effect on the adoption of intelligent packaging.

Compatibility is the degree to which a service is perceived to be in accordance with an individual's beliefs, habits, existing values, and previous experience. It is an inextricable feature of innovation because when the innovation corresponds to the lifestyle of the users, they enable them to adopt it (Al-Jabri and Sohail, 2012, p. 381). Generally, consumers demand convenient, fresh, and high-quality food products with fewer preparation steps (Sohail *et al.*, 2018, p. 2657). They have high standards for fruits and vegetables, and they refuse edible products and bad package appearance (Caprita, 2016, p. 191).

Research has shown that intelligent packaging is capable to satisfy customers' needs who seek freshness, convenience, and natural and healthy products with longer shelf life. It helps consumers spend less time cooking and shopping for fresh foods (Aday and Yener, 2015, p. 157). Moreover, customers expect important quality attributes to be satisfied, such as food protection and packaging integrity. Since customers are not able to monitor food quality attributes inside the package, intelligent packaging can assist in assuring product quality significantly (Heising *et al.*, 2014, p. 646). Therefore, it is likely that the relation between compatibility will help the adoption of intelligent packaging.

Hypothesis 3: Compatibility will have a positive effect on the adoption of intelligent packaging.

'Observability is the degree to which an innovation is visible to the members of a social system, and the benefits can be easily observed and communicated' (Al-Jabri and Sohail, 2014, p. 381). It is a way to see how innovation works and acknowledge its safety and its opportunities. When there is evidence of improved experience and increased functionality, it is more likely that users will adopt the innovation (Cain and Mittman, 2002, p.10). In the context of intelligent packaging, observability could be seen as the ability of intelligent packaging technologies to monitor changes both in the internal and external environment of a food package and to communicate its conditions to customers so that they can make decisions timely (Yam *et al.*, 2005, p. 3). It communicates product information with customers, such as product ingredients and conditions during transport (Schaefer and Cheung, 2018, p. 1025). For instance, what most Turkish consumers expect from intelligent packaging is the ability to observe the history and the freshness of foods inside the package (Kocetkovs *et al.* 2019, p. 225).

Hypothesis 4: Observability will have a positive effect on the adoption of intelligent packaging.

Trialability is the experiment with new technology before it is adopted. Individuals are more likely to adopt a new technology when they are allowed to experiment with it first (Al-Jabri and Sohail, 2012, p. 382). The feelings of fear and uncertainty about the risks and benefits of an innovation are significantly minimized when customers are given the chance to try the innovation (Cain and Mittman, 2002, p. 9). Therefore, it is hypothesized that trialability will encourage the adoption of intelligent packaging.

Hypothesis 5: Trialability will have a positive effect on the adoption of intelligent packaging.

The *Perceived value pricing* is the price that customers are willing to pay for a product that is offered. Price as a reflection of value is what customers are willing to pay (Kortge and Okonkwo, 1993, pp. 133-134). Consumers are value-conscious and focus especially on the price of products which is one of the most important attributes of all purchasing decisions (Anuwichanont, 2011, p. 37). In the context of intelligent packaging, the price could hinder the adoption of this technology as the development and production costs are very high (Müller and Schmid, 2019, p. 8). It is estimated that the cost of food products that use intelligent packaging is almost double the cost of traditional food packaging (Sohail *et al.*, 2018, p. 2659). Customers seek economical packaging with a reasonable quality of resources to gain most of the value of intelligent packaging (Young *et al.*, 2020, p. 13).

Hypothesis 6: High prices will have a negative effect on the adoption of intelligent packaging.

Hypothesis 7: Customers are not willing to pay double the price of conventional packaging for intelligent packaging.

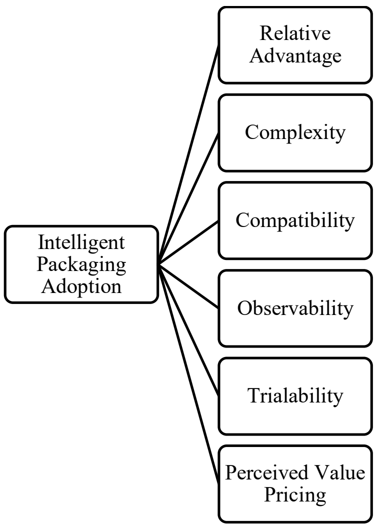

Figure 2. 4: The Research Model (Adapted from Al-Jabri and Sohail, 2012).

3. Research Methodology

The theory of positivism was developed by Auguste Comte in the 19th century aiming for social reconstruction. He aimed to create a social science methodology that would strongly be supported by evidence (Nnaji, 2019, p. 90). In the introduction of his original work on positivism, *'A General View of Positivism'*, Auguste Comte introduces his object which is *'to generalize our scientific conceptions, and to systematize the art of social life'* (Comte, 2015, p. 3). The world is reduced to empirical facts that are quantified and form statements. Things that cannot be observed are not considered to be real (Nnaji, 2019, p. 91). An online survey was conducted for the data collection. Surveys are data collection tools that facilitate research. They are the mean by which information relating to characteristics, actions, and opinions of a group of people are gathered. They evaluate demand and examine the impact (Glasow, 2005, p. 1).

3.1 Epistemological position

Positivism is the philosophical stance of the natural scientist that observes social reality and produces law-like generalizations. It is clear in meaning, it promises accurate knowledge, and its origins can be found back in the works of Auguste Comte and Francis Bacon as well as the philosophers and scientists of the early 20th century that are known as *the Vienna Circle* (Saunders, 2016, pp. 135-136). Positivism believes that the world is external and there is a single objective reality to any research phenomenon regardless of the beliefs of the researcher. *'Positivism takes a realist position and assumes that a single, objective reality exists independently of what individuals perceive'*. The social world exists as a real and concrete structure and does not depend on individual perceptions. *'Reality exists as a structure composed of relationships among its parts'*. Therefore, it offers precise and accurate measurements and observations that are able to monitor confounding variables (Hudson and Ozanne, 1988, p. 509). It is an empirical method that is designed to gather data that are not influenced by human interpretation and bias. In positivism, hypotheses are developed according to the existing theory, and they are either confirmed or refuted (Saunders, 2016, pp. 136-137).

For the hypotheses (derived from the literature review) to be tested, a survey-based quantitative study was conducted. Surveys are capable of explaining the attitudes and opinions of a population either by studying a certain group of people or by applying questionnaires or structured interviews for data collection (Nnaji, 2019, p. 73). The theory was developed in accordance with the deductive approach. In the deductive approach, research starts with theory and develops from the use of the academic literature and the design of a research strategy, which tests the theory (Saunders, 2016, p. 145).

The quantitative research method employs empirical methods and statements. *'Quantitative research is a type of research that explains phenomena by collecting numerical data that are analysed using mathematically based methods'* (Sukamolson, 2007, p. 2). Quantitative research starts with theory development and ends up with specific hypotheses that are measured quantitatively and analysed precisely (Holton and Burnett, 2005, p. 30). It identifies and quantifies variables so that results can be collected. It involves the analysis of numerical data using statistical techniques to answer questions like who, where, how, and when (Apuke, 2017, p. 41). Quantitative research provides a synopsis of the examined case. It explains the attitudes and actions of a large number of people and collects the data quicker from a large number of people correspondingly (Nnaji, 2019, p. 73).

3.2 Data collection

A survey is used *'to answer questions that have been raised, to solve problems that have been posed or observed, to assess needs and set goals, to determine whether or not specific objectives have been met, to establish baselines against which future comparisons can be made, to analyse trends across time, and generally, to describe what exists, in what amount, and in what context'* (Isaac and Michael, 1997, p. 136). Surveys include three important characteristics. Firstly, they are used to quantify and examine variables of a given population. Secondly, the data are subjective because they are collected from people, and thirdly, surveys use a selected percentage of a population from which the findings are later generalized and presented back to the population (Pinsonneault and Kraemer, 1993, pp. 6-7).

On the one hand, surveys obtain information from a large sample population. They are designed in a way to gather demographic data that are capable of describing the characteristics of the sample population. They facilitate information gathering relating to attitudes and behaviours that would otherwise be difficult to be measured by applying observational techniques. However, it should be highlighted that surveys provide estimates for the true population and not actual measurements (Glasow, 2005, p. 1).

3.3 Survey development

The survey design process consisted of seven steps. *Firstly*, the literature was reviewed. Literature review helped intelligent packaging to be clearly defined and determined if other measures of intelligent packaging already existed. Definitions are important because they align the construct with the existing literature and determine the correlation level to other constructs. The literature review ensured the alignment of intelligent packaging with the theory and identified the items used in the questionnaire. *Secondly*, the target group was identified. Through the literature, it was examined what respondents think about the concept of intelligent packaging and the language they used to describe the term. Respondents were asked focused questions to evaluate the level of agreement with the concept of intelligent packaging as described in the literature. *Thirdly*, the literature review and target group were synthesized. At this step, the definition of intelligent packaging was shaped by the questionnaire, the literature, and the focus group (Artino *et al.*, 2014, pp. 464-466).

In the next step measuring attributes were developed. The survey attributes were written in a language that respondents could easily understand. Although the decision about the number of items might be challenging (e.g., because of the complexity of the construct), the attributes of this survey were developed in accordance with the DIT. Unambiguous terms, negative words, and biased language were avoided. Instead, response anchors that measure the construct were applied. Furthermore, the response options for each attribute were selected. Respondents were asked to answer on a Likert-type response scale with the level of agreement or disagreement with each statement (Artino *et al.*, 2014, pp. 466-467).

Subsequently, validation was conducted. Based on the content of the survey evidence was collected to examine the survey validity. Data were collected from the literature and ensured the relevance of the survey to the research aim of improving the overall quality, therefore. In the following step, a cognitive pre-testing was conducted to determine the content validity of the survey and identify mistakes. It examined how potential respondents would interpret the statements and if their interpretation is related to the research aim. In the final step, pilot testing was conducted (Artino *et al.*, 2014, pp. 467, 470-471). A pilot survey was conducted on 15 randomly selected people from various backgrounds so that individuals' understanding of the questions could be examined. When the pilot survey was completed, some questions were lacking clarity and thus were modified to ensure the validity of the survey. The measurement items and their corresponding references can be found in the *Appendix* of this Thesis.

3.4 Survey execution

The survey was developed in accordance with the literature review and consisted of a two-part questionnaire. In the first part of the questionnaire, basic information about the respondents was collected relating to their gender, age, educational status, and the frequency of their supermarket visits. The second part of the questionnaire was designed to capture information relating to the attributes that affect the adoption of intelligent packaging. The attributes were identified from the literature review. These attributes were the relative advantage, complexity, compatibility, observability, trialability, and perceived value pricing. Previous studies have used these measuring items to examine the adoption of innovations, such as the adoption of mobile banking or the adoption of halal meat in the supply chain (Al-Jabri and Sohail, 2012, pp. 379-380; Quader *et al.*, 2022, pp. 2-3). In order for this survey to be carried out, these attributes were adjusted accordingly, and they were all measured according to a five-point Likert scale, ranging from 1 (strongly agree) to 5 (strongly disagree). The research lasted approximately one month, and the findings were used to design the survey.

The questionnaire was distributed through social media platforms, and everyone was requested to participate. Participation was encouraged and individuals' responses were protected. Participants were informed about the purpose of the questionnaire, and they were asked to consent to the conditions of the survey. Reminders were sent occasionally in order for a huge number of responses to be collected. Finally, a total of 114 questionnaires were returned and a total of 106 usable questionnaires were included in the analysis. The response rate was 93% and the average response time was fewer than four minutes. All the questionnaires were checked for concurrence, completeness, and validity. To increase the accuracy of the survey, arbitrary and ambiguous responses were not taken into consideration.

The questionnaire was designed on the *Qualtrics eXperience management (XM)* software which is designed to improve research and is provided by the Newcastle University Business School. Qualtrics provides ready-to-use and expert-designed workflow and automation (Get you customer eXperience program up and running faster, 2022). All the questions were created, edited, and stored inside blocks. Once a huge sampling size was collected, data were coded, and the results were analysed and graphically displayed accordingly.

4. Results

Table 4.1 shows the characteristics of the 106 respondents who participated in the survey. Overall, almost 55% of the participants were women and more than two-thirds of the respondents were between 18 and 25 years old (75.47%). 12.26% of the respondents were between the ages of 26 and 30, 7.55% between 31 and 40, and 4.72% were more than 41 years old. In response to their education, the majority held a bachelor's and master's degree, accounting for 33.96% and 22.64% correspondingly. 64.15% of the participants visit the supermarket at least one to five times per month, while 22.64% six to ten times and 13.21% more than ten times monthly.

Table 4. 1: Characteristics of the respondents.

Gender	*%*	*Count*
Male	43.40	46
Female	54.72	58
Non-binary / third gender	0.94	1
Prefer not to say	0.94	1
Age	*%*	*Count*
18-25	75.47	80
26-30	12.26	13
31-40	7.55	8
41+	4.72	5
Education	*%*	*Count*
High School	19.81	21
Diploma holder	17.92	19
Bachelor's Degree	33.96	36
Master's Degree	22.64	24
Ph.D.	1.89	2
Others	3.77	4
Number of Supermarket visits per month	*%*	*Count*
1 to 5 times	64.15	68
6 to 10 times	22.64	24
Over 10 times	13.21	14

Based on the literature review different measurement items were grouped together to measure the attributes of DIT in intelligent packaging. Six items were used to measure relative advantage, four items were used to measure complexity and compatibility, three items measured observability and perceived value pricing, and two measuring items were used to examine trialability.

4.1 Relative advantage

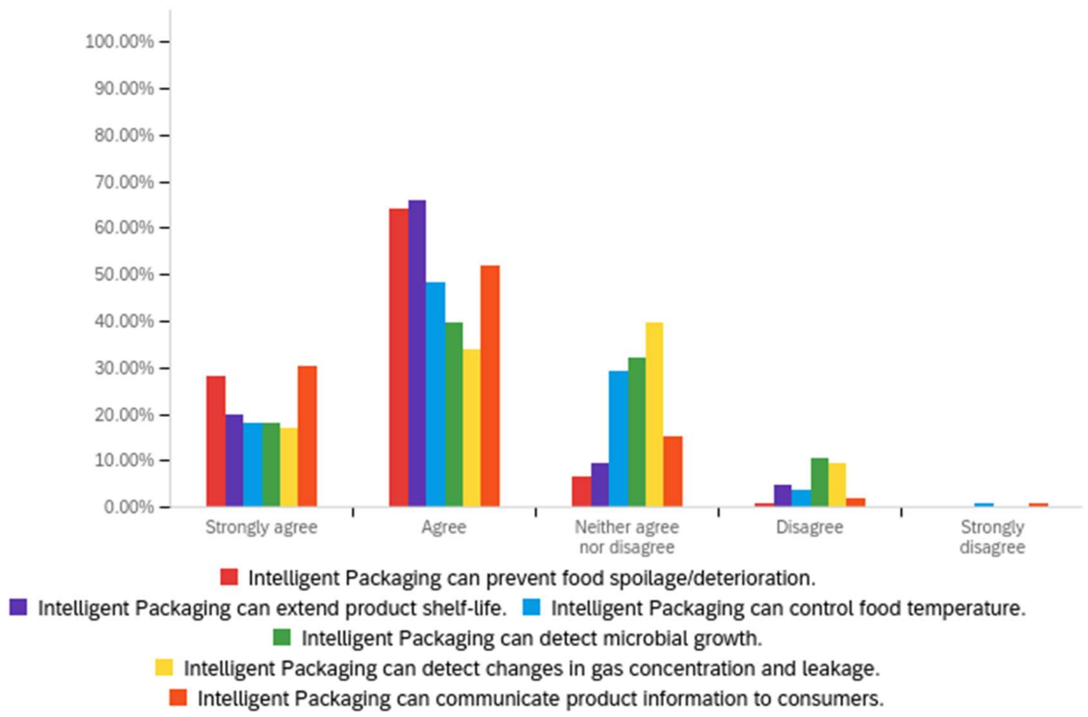

Figure 4. 1: Relative Advantage of intelligent packaging.

Overall, consumers agreed on the advantages of intelligent packaging technologies. As shown in *Figure 4.1*, 92.45% recognised the ability of intelligent packaging to prevent food spoilage and deterioration, which accounts for the highest proportion. Moreover, 85.85% of the respondents agreed that intelligent packaging can extend product shelf-life. 82.08% of the questionnaire participants agreed that intelligent packaging can communicate product information to consumers, 66.03% that can monitor food temperature, 57.54% that can detect the presence of microbes, and 50.94% that is capable to detect changes in gas concentration or leakage. On the contrary, 39.62% hesitated to realise the ability of intelligent packaging to detect changes in gas concentration and 32.08% that it can detect microbial growth. Likewise, 29.25% did not support a particular opinion regarding the ability of intelligent packaging to control food temperature.

Table 4. 2: Relative Advantage in figures.

Question	1		2		3		4		5		Total
Intelligent Packaging can prevent food spoilage/deterioration.	28.30%	30	64.15%	68	6.60%	7	0.94%	1	0.00%	0	106
Intelligent Packaging can extend product shelf-life.	19.81%	21	66.04%	70	9.43%	10	4.72%	5	0.00%	0	106
Intelligent Packaging can detect microbial growth.	17.92%	19	39.62%	42	32.08%	34	10.38%	11	0.00%	0	106
Intelligent Packaging can detect changes in gas concentration and leakage.	16.98%	18	33.96%	36	39.62%	42	9.43%	10	0.00%	0	106
Intelligent Packaging can control food temperature.	17.92%	19	48.11%	51	29.25%	31	3.77%	4	0.94%	1	106
Intelligent Packaging can communicate product information to consumers.	30.19%	32	51.89%	55	15.09%	16	1.89%	2	0.94%	1	106

4.2 Complexity

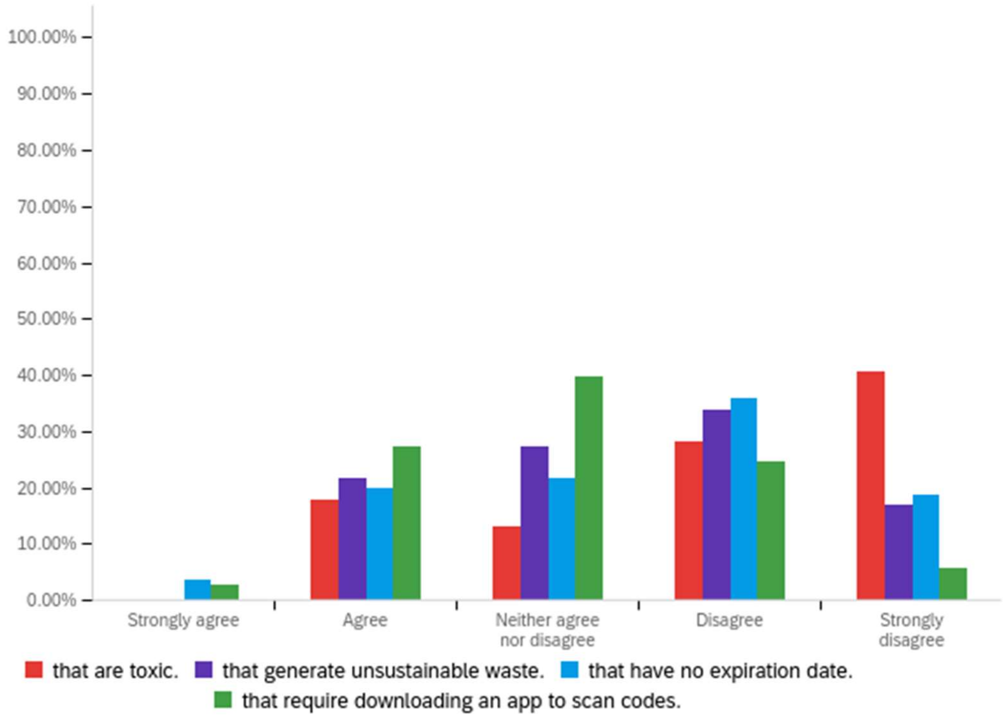

Figure 4. 2: Complexity of intelligent packaging.

Overall, consumers found intelligent packaging technologies relatively complex. More specifically, almost 68.9% were against purchasing products enhanced with technologies that could be toxic. 54.72% would prefer packages to include food expiration dates and approximately half of the questionnaire participants (51%) would not buy products in packages that would not be recyclable. However, consumers' opinion regarding the use of an app was divided with 30.19% being in favour, 30.19% being against, and 39.62% remaining neutral.

Table 4. 3: Complexity in figures.

Question	1		2		3		4		5		Total
that are toxic.	0.00%	0	17.92%	19	13.21%	14	28.30%	30	40.57%	43	106
that generate unsustainable waste.	0.00%	0	21.70%	23	27.36%	29	33.96%	36	16.98%	18	106
that have no expiration date.	3.77%	4	19.81%	21	21.70%	23	35.85%	38	18.87%	20	106
that require downloading an app to scan codes.	2.83%	3	27.36%	29	39.62%	42	24.53%	26	5.66%	6	106

4.3 Compatibility

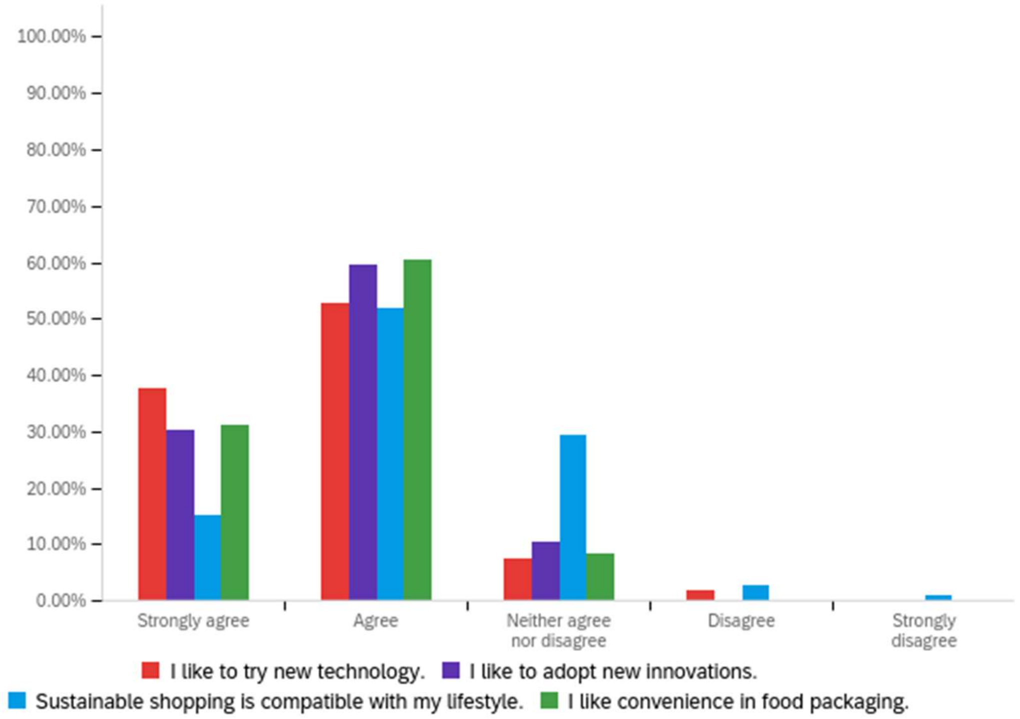

Figure 4. 3: Compatibility of intelligent packaging.

Overall, intelligent packaging seems to strongly fit with consumers' beliefs and lifestyles. According to *Figure 4.3*, nearly 91.5% of the respondents would prefer convenience in their food packaging. 90.6% would try new technology and almost 89.6% would adopt an innovation. Approximately 67% responded that intelligent packaging is compatible with their shopping behaviour, while 29.3% sat somewhere in the middle and only 3.8% disagreed with that.

Table 4. 4: Compatibility in figures.

Question	1		2		3		4		5		Total
I like to try new technology.	37.74%	40	52.83%	56	7.55%	8	1.89%	2	0.00%	0	106
I like to adopt new innovations.	30.19%	32	59.43%	63	10.38%	11	0.00%	0	0.00%	0	106
Sustainable shopping is compatible with my lifestyle.	15.09%	16	51.89%	55	29.25%	31	2.83%	3	0.94%	1	106
I like convenience in food packaging.	31.13%	33	60.38%	64	8.49%	9	0.00%	0	0.00%	0	106

4.4 Observability

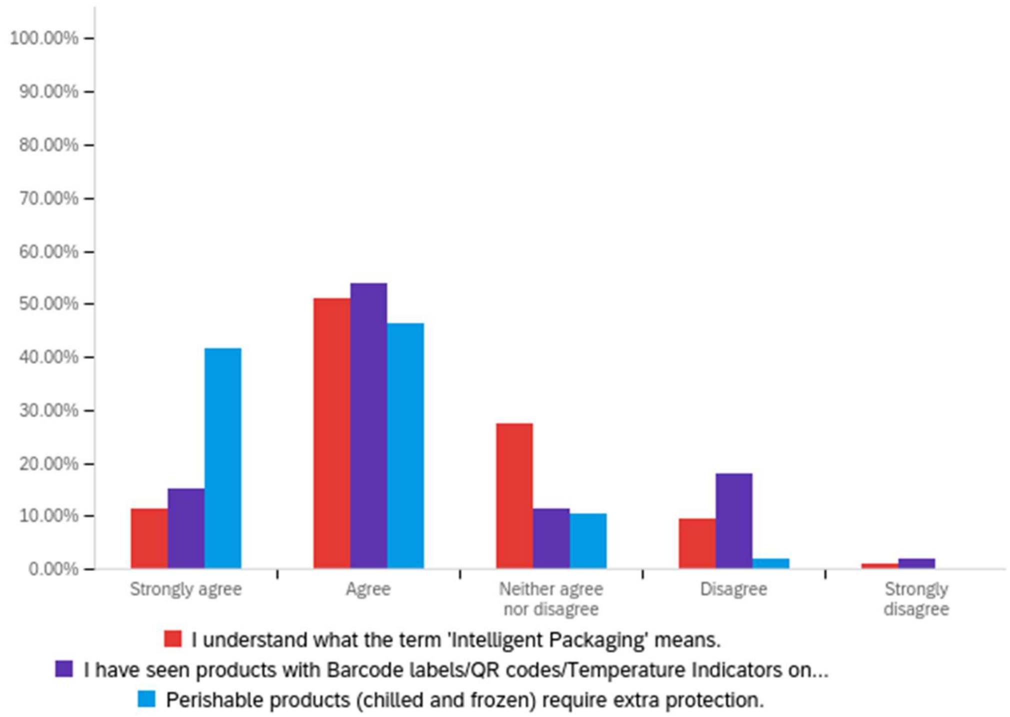

Figure 4. 4: Observability of intelligent packaging.

In general, intelligent packaging technologies are visible to customers. As shown in *Figure 4.4*, the majority of the respondents (87.74%) agreed that perishable food products require extra protection. 68.86% have seen products on supermarket shelves including intelligent packaging technologies, such as Barcode labels and QR codes. In spite of that, nearly 62.2% of the participants were aware of intelligent packaging, with almost 27.3% remaining neutral and a few (10.3%) having poor knowledge of the term.

Table 4. 5: Observability in figures.

Question	1		2		3		4		5		Total
I understand what the term 'Intelligent Packaging' means.	11.32%	12	50.94%	54	27.36%	29	9.43%	10	0.94%	1	106
I have seen products with Barcode labels/QR codes/Temperature Indicators on supermarket shelves.	15.09%	16	53.77%	57	11.32%	12	17.92%	19	1.89%	2	106
Perishable products (chilled and frozen) require extra protection.	41.51%	44	46.23%	49	10.38%	11	1.89%	2	0.00%	0	106

4.5 Trialability

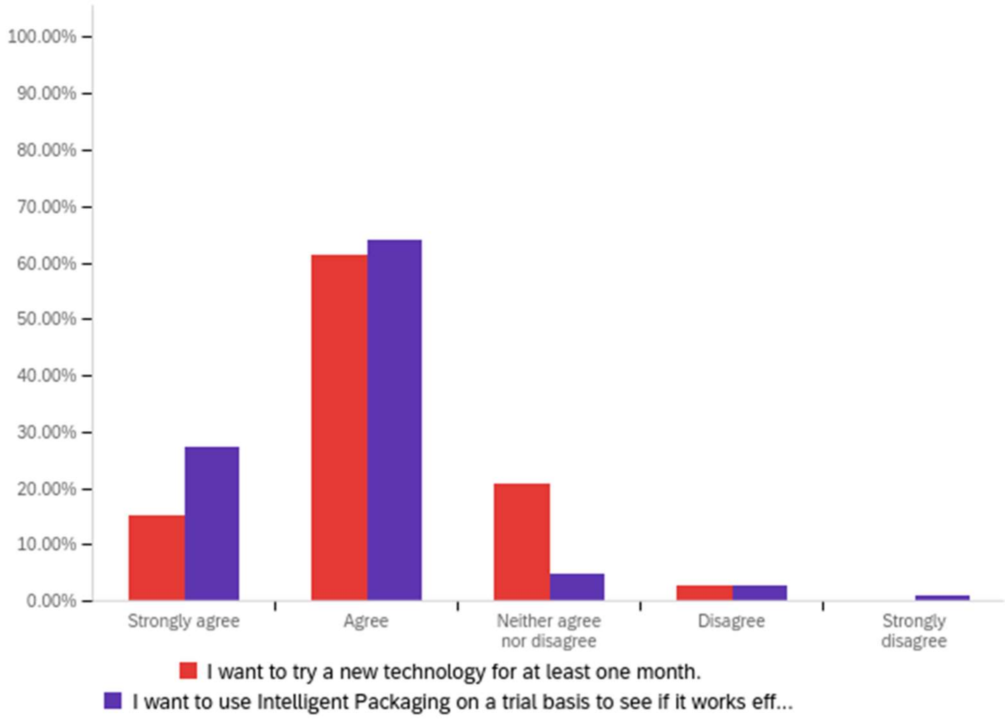

Figure 4. 5: Trialability of intelligent packaging.

Overall, customers would like to experiment with intelligent packaging technologies. According to *Figure 4.5*, nearly 76.4% of the respondents would prefer to try a new technology for at least one month, with 20.75% being somewhere in the middle. In terms of intelligent packaging technologies, almost 91.5% of the questionnaire participants would like to experiment with intelligent packaging on a trial basis in order to see if it works successfully.

Table 4. 6: Trialability in figures.

Question	1		2		3		4		5		Total
I want to try a new technology for at least one month.	15.09%	16	61.32%	65	20.75%	22	2.83%	3	0.00%	0	106
I want to use Intelligent Packaging on a trial basis to see if it works effectively.	27.36%	29	64.15%	68	4.72%	5	2.83%	3	0.94%	1	106

4.6 Perceived value pricing

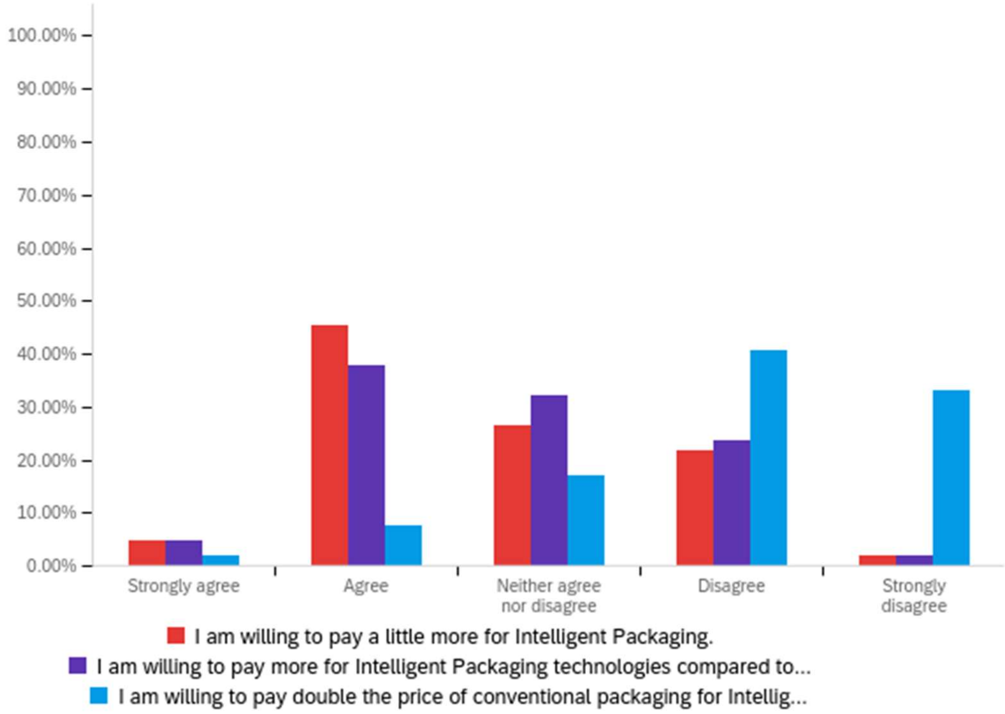

Figure 4. 6: Consumers' readiness to pay more for intelligent packaging.

In general, customers would only be willing to pay a bit more for intelligent packaging. 50% would be ready to pay a little more for intelligent packaging. 26.42% remained neutral and almost 23.6% disagreed on that. Similarly, and compared to conventional packaging, 42.46% would pay more for intelligent packaging. 32.1% did not support a particular opinion and 25.4% disagreed with that respectively. On the contrary, almost 33% of consumers would strongly disagree to pay double the price of conventional packaging for intelligent packaging. Only 9.44% would be willing to do that with almost 17% supporting no particular side of the argument.

Table 4. 7: Perceived value pricing in figures.

Question	1		2		3		4		5		Total
I am willing to pay a little more for Intelligent Packaging.	4.72%	5	45.28%	48	26.42%	28	21.70%	23	1.89%	2	106
I am willing to pay more for Intelligent Packaging technologies compared to conventional packaging.	4.72%	5	37.74%	40	32.08%	34	23.58%	25	1.89%	2	106
I am willing to pay double the price of conventional packaging for Intelligent Packaging.	1.89%	2	7.55%	8	16.98%	18	40.57%	43	33.02%	35	106

5. Discussion

Relative advantage is a significant determinant in the adoption of intelligent packaging. This result is consistent and supported by prior research (Al-Jabri and Sohail, 2012, p. 387; Quader *et al.*, 2022, p. 10). Customers seem to understand the advantages of intelligent packaging. More than two-thirds of the respondents agreed on the advantages of intelligent packaging. More specifically, 92.45% agreed that intelligent packaging can prevent food spoilage and deterioration, 85.85% that it can extend product shelf-life, and 82.08% that it can communicate product information to consumers.

Hypothesis 2, that complexity will have a negative effect on the adoption of intelligent packaging is confirmed. Customers are not well aware of intelligent packaging and have little understanding of the technologies that it applies. Particularly, 28.3% of the respondents disagreed to buy products enhanced with technologies that are toxic and 40.57% strongly disagreed. 54.72% would like their food packages to include expiration dates, while 39.62% were neutral to download apps to buy such products. Furthermore, it is proved that intelligent packaging can generate unsustainable waste (Schaefer and Cheung, 2018, p. 1025). In this case, almost half of the questionnaire participants (51%) disagreed to support unrecyclable technologies.

According to the survey, compatibility is the most important determinant for the adoption of intelligent packaging. Previous studies have similar findings (Al-Jabri and Sohail, 2012, p. 387; Quader *et al.*, 2022, p. 10). They have shown that the perceived compatibility impacts positively the adoption of an innovation (Al-Jabri and Sohail, 2012, p. 387). This means that intelligent packaging fits well with customers’ lifestyle, beliefs, and existing values. Therefore, customers like to adopt new innovations and try new technologies and as result compatibility helps the adoption of intelligent packaging.

Observability has a significant effect on the adoption of intelligent packaging, supporting Hypothesis 4. It is the ability to examine the functions of intelligent packaging and recognize its benefits. The majority of the customers (68.86%) have identified technologies used in intelligent packaging, such as QR codes, Barcode labels, or TTIs. And moreover, 87.74% of the respondents agreed that intelligent packaging is necessary for perishable food products, like chilled and frozen food because they lack the appropriate protection.

Trialability has also a significant effect on the adoption of intelligent packaging. Customers seem to prefer a trial period of intelligent packaging to fully support the innovation. More specifically, nearly 76.4% of the respondents would prefer to try a new technology for at least one month and almost 91.5% agreed that they would be eager to try intelligent packaging on a trial basis before adopting the innovation. These high percentages can be justified by the fact that customers tend to avoid risks and are usually sceptic and suspicious when adopting new technology. Because intelligent packaging is an innovation that is currently growing, building trust is one of the most important steps. Therefore, it is very likely that during the trial period customers would be convinced of the benefits of intelligent packaging.

Perceived value pricing has a relatively insignificant effect on the adoption of intelligent packaging, not fully supporting Hypothesis 6. The result was not expected, but prior studies had similar findings (Al-Jabri and Sohail, 2012, p. 387). 50% of the respondents would be willing to pay more for intelligent packaging, whereas 26.42% were neutral. Likewise, 42.46% of the participants would pay more for intelligent packaging compared to conventional packaging, with 32.1% not supporting a particular opinion. This might be because the majority of the questionnaire participants (75.47%) were young aged between 18 and 25 years old. Youth are more experienced with new technologies and innovations. They have the tendency to learn easier or they may be experienced with similar technologies. Hence, they might have good knowledge of the significance and the necessity of intelligent packaging innovation.

Finally, Hypothesis 7 is strongly confirmed. According to the survey results, customers would not be willing to pay double the price of conventional packaging for intelligent packaging. Almost 73.6% of the respondents were against this statement out of which 33% strongly disagreed.

6. Conclusion

The findings of this research suggest that the adoption of intelligent packaging is positively affected by compatibility, relative advantage, observability, and trialability. Intelligent packaging is compatible with consumers' lifestyles and complies with their existing values and beliefs. Customers are able to understand the advantages of intelligent packaging and identify products with intelligent packaging technologies, like QR codes or TTIs. Building trust with innovation is one of the most important steps for its adoption and this can only happen by confronting any fear and scepticism consumers might have. On the contrary, the complexity of intelligent packaging technologies negatively affects the adoption of this innovation. Although consumers are familiar with the concept of intelligent packaging, a large percentage were not able to understand how intelligent packaging works and what consequences might lurk. In addition, the high cost of intelligent packaging strongly affects its adoption. Even though many customers would be willing to pay a little more for such technologies, only a small percentage would be willing to pay double the price of conventional packaging for intelligent packaging.

Intelligent packaging is relatively new and therefore further research is required so that additional factors that facilitate or inhibit the adoption of the innovation can be identified. Additional variables will improve the ability to understand the concept of intelligent packaging, while variables such as the age and education of the respondents might contribute significantly to future findings.

7. References

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Appendix

Measurement items:

Relative Advantage

Intelligent Packaging can prevent food spoilage/deterioration (De Jong *et al.*, 2005, p. 978).

Intelligent Packaging can extend product shelf-life (Prasad and Kochhar, 2014, p. 1).

Intelligent Packaging can control food temperature (De Jong *et al.*, 2005, p. 977).

Intelligent Packaging can detect microbial growth (Shao *et al.*, 2021, p. 286).

Intelligent Packaging can detect changes in gas concentration and leakage (Sohail *et al.*, 2018, p. 2654).

Intelligent Packaging can communicate product information to consumers (Yam *et al.*, 2005, p. 3).

Complexity

Intelligent Packaging can be toxic (Young *et al.*, 2020, p. 13).

Intelligent Packaging can generate unsustainable waste (Schaefer and Cheung, 2018, p. 1025).

Intelligent Packaging can include no expiration date (Young *et al.*, 2020, p. 12).

Intelligent Packaging can require the download of an app to scan codes (Young *et al.*, 2020, p. 12).

Compatibility

I like to try new technology (Al-Jabri and Sohail, 2012, p. 391).

I like to adopt new innovations (Al-Jabri and Sohail, 2012, p. 391).

Sustainable shopping is compatible with my lifestyle (Al-Jabri and Sohail, 2012, p. 391).

I like convenience in food packaging (Young *et al.*, 2020, p. 2).

Observability

I understand what the term ‘Intelligent Packaging’ means (Kocetkovs *et al.*, 2019, p. 223).

I have seen products with Barcode labels/ QR codes/ Temperature indicators on supermarket shelves (Kocetkovs *et al.*, 2019, p. 224).

Perishable products (e.g., chilled, and frozen) require extra protection (Young *et al.*, 2020, p. 11).

Trialability

I want to try a new technology for at least one month (Al-Jabri and Sohail, 2012, p. 391).

I want to use Intelligent Packaging on a trial basis to see if it works effectively (Al-Jabri and Sohail, 2012, p. 391).

Perceived value pricing

I am willing to pay a little more for Intelligent Packaging (Al-Jabri and Sohail, 2012, p. 391).

I am willing to pay more for Intelligent Packaging technologies compared to conventional packaging (Al-Jabri and Sohail, 2012, p. 391).

I am willing to pay double the price of conventional packaging for Intelligent Packaging (Sohail *et al.*, 2918, p. 2659).