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Smart Packaging: Demand for Present Era

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ABSTRACT

In order to reduce food wastage of perishable and minimally processed foods, intelligent packaging is crucial. This developing technology provides customers with food-related information without tampering with food packaging. Intelligent packaging technology operates based on chemical changes, enzymatic reactions, and microbiological activity of packaged food. Different indicators, sensors, and RFID tags are used to assess the quality of food depending on the kind of food. Intelligent packaging technology can translate alterations in food quality into readable form. With varied applications of indicators, sensors, or RFID tags, intelligent packaging technology can effectively monitor the quality of various food varieties. Intelligent packaging is more expensive than ordinary packaging since it is a new and evolving technology. Future advancements in this area will lead to greater usage of intelligent packaging.

Keywords: *Intelligent packaging, RFID, Sensors, Indicators and packaging.*

INTRODUCTION

Food packaging plays a very important role in the food supply chain and can be used as a protective layer to prevent contamination of food and maintain food quality. However, traditional packaging system only isolates food from the external environment and cannot provide food freshness information for producers, sellers and consumers (Wilbey, 2013). Food packaging has a crucial function in the modern food industry since it contributes to preserving food products' quality and guaranteeing food safety during its shelf-life (Ghaani et al., 2016). Packaging serves the four essential purposes of protection, communication, convenience, and confinement while insulating the goods from the outside environment.

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With useful characteristics like reclose- or microwave-ability, it facilitates handling of the enclosed items and interacts with the customer via written texts or images. Additionally, it provides containers in various shapes and sizes and adjusts to the customer's needs (Yam et al., 2012). Packaging not only enhances marketing and distribution but also delays the deterioration of quality. They, therefore greatly aid in the safe transportation and storage of packaged foods (Dobrucka et al., 2013). It is impossible to completely stop the quality degradation, though. Highly perishable foods' intrinsic qualities alter after processing. This may result in an improvement in quality (such as fruits ripening to a specific level) or a decrease in quality: Depending on the package's contents, biological, chemical, or physical processes take place that eventually cause the goods to deteriorate (Heising et al., 2014, & Fung et al., 2018). The majority of the time, customers find it challenging to evaluate these adjustments. Many people dispose of goods that would have still been safe for ingestion out of worry that their groceries may deteriorate. Most frequently, a minor variation in colour, consistency, or even the passing of the best-before date results in items being thrown away (Stubenrauch et al., 2005; & Bofrost, 2018). An intelligent packaging technique combines intelligent features with traditional packaging technologies. Intelligent packaging may feel, detect, and record product changes on the inside or outside, providing information on food quality and safety and extending the informational role of packaging.

ACTIVE AND INTELLIGENT PACKAGING

In order to preserve and prolong product shelf life, active packaging refers to the inclusion of certain additives into packaging film or within packing containers (Day, 1989). However, active packaging enables packages to communicate with the environment and the food while also playing a dynamic role in food preservation (Brody et al., 2001; & Lopez- -Rubio et al., 2004). It's vital to define each term in order to fully appreciate what active and intelligent packaging has to offer the world of packaging. In order to improve the performance of the package system, active packaging is precisely described as "packaging in which subsidiary constituents have been intentionally inserted in or on either the packing material or the package headspace." (Robertson, 2006). This expression highlights the significance of incorporating an ingredient on purpose with the goal of enriching the food product. Active packaging, which frequently shields against oxygen and moisture, is an extension of the protection function of a package. "Packaging that has an external or internal indication to convey information about aspects of the history of the package and/or the quality of the food" is what is referred to as intelligent packaging (Robertson, 2006). The capacity of intelligent packaging to sense, detect, or record changes in the surroundings of the product allows it to send information to the customer as an extension of traditional packaging's communication role.

Traditional packaging to new concepts

Due to its beneficial qualities, the food sector has extensively employed plastic packaging for over 50 years. Since they can be stiff (bottles, jars, cartons, and cases), thermoformed (food trays), or flexible (flexible food trays), they are affordable, practical, light, and extremely adaptable (woven mesh, multi-layer, films). Although they recently represented 37% of food packaging materials, they have displaced other conventional materials, including glass, metals (aluminium, laminated, tinplate and steel), paper, and cardboard (Food Packaging Forum, 2015). Because most of these materials come from petroleum, they are not biodegradable, and they contaminate the environment during production and disposal, their widespread usage has led to major environmental issues around the world. The market is evolving as a result of the creation of new eco-friendly packaging and creative packaging ideas. A fantastic option to preserve the environment and provide a market for unused goods or industrial waste is the use of biodegradable and renewable materials (Cazón et al., 2017). Bioplastics are starting to become more well-known in this regard. They are described as plastic materials that are either biobased (partially or wholly) or biodegradable or have both qualities, by the European Bioplastics Organization. According to Goswami and O'Haire (2016), the terms "biobased" and "biodegradable" refer to the ability of a material or product to be biologically decomposed down to base materials, including water, carbon dioxide, methane, basic elements, and biomass by living creatures that are present in the environment. Consequently, bioplastics may be divided into three basic categories:

- Biobased plastics that are not biodegradable, such as biopolyethylene (Bio-PE), biopolyamide (Bio-PA), biopolyethylene terephthalate (Bio-PET), biopolytrimethylene terephthalate (Bio-PTT), and biopolypropylene (Bio-PP)
- Biodegradable plastics made from fossil fuels, such as poly (butylene adipate-co-terephthalate), poly (butylene succinate-co-butylene adipate), polyvinyl alcohol, polyglycolic acid, and polycaprolactone (PCL).
- Plastics that are biodegradable and biobased. Polymers directly extracted from biomass, such as polysaccharides (such as starch, cellulose, chitin, etc.) and proteins (such as collagen, gelatin, casein, whey, soy protein, zein, wheat gluten, etc.), are included in the last group. These polymers can be further modified to yield additional valuable biobased materials, such as cellulose acetate, cellulose acetate butyrate, cellulose acetate propionate, and cellulose.

A biopolyester made from lactic acid produced during the fermentation of carbohydrates is called polylactic acid (PLA). Microorganisms or genetically modified bacteria also produce polyhydroxyalkanoates (PHA), such as polyhydroxy butyrate (PHB), polyhydroxy valerate (PHV), and bacterial cellulose (Petersen et al., 1999). The circular economy and sustainability are the goals of biobased and biodegradable polymers (Bio-based News—www.news.bio-based.eu) demonstrates the three different forms of bioplastics' life cycle assessments (LCA). Biodegradable plastics are meant for organic recycling, whereas biobased plastics, which are often drop-in replacements for their petroleum-based equivalents, are suitable for material recycling and/or energy recovery. These last ones are particularly encouraging since material recycling would be prohibitively costly when plastic items include food. When bio-waste is handled, separated, and collected properly, more useful compost may be produced and utilised later as fertiliser for crops that are just starting their life cycle. Bioplastics lessen the impact on the environment in this way (European Bioplastics Organization).

FOOD QUALITY INDICATORS

Specific indications must be used to describe the condition of the food product, either quantitatively or qualitatively, in order to construct sensors that can be included in food packaging. Food rotting indicators are often connected to physical or chemical changes in the individual food's qualities. Early detection of these markers can stop the consumption of contaminated food, lowering the risk of contracting food-borne diseases and preventing possible outbreaks (Halasz et al., 1994).

Temperature

Temperature is another factor that should be looked at in regards to food rotting. Temperature extremes and swings significantly impact the shelf life of foods kept in refrigerators. Any stage of the distribution chain, including loading, unloading, temperature cycling in walk-in coolers, storage displays, and home delivery, is susceptible to temperature changes (Fu et al., 1992). It is essential to monitor and regulate the storage temperature of food goods, including fish, as temperature heavily influences the rate of microbial activity. (Taoukis et al., 1999) Since the crucial temperature range is between 4 and 12 °C, which is the perfect range for growing certain psychotropic bacteria and thermotolerant fungi, a specific concern in key food product categories is also present during refrigeration (Russell et al., 2002).

Humidity

As it encourages a longer shelf life, maintaining stable humidity levels inside the food packaging is crucial to maintaining the condition and texture of food items (McDaniel et al., 1977; & Maddanimath et al., 2002). The impact of humidity level is crucial in several facets of the food sector, including dairy, meat, and dry foods (Nohria et al., 2006). It is possible to change the humidity inside the package in a number of ways. One issue that frequently occurs is the food's sealed package being broken by careless handling (Wani et al., 2013). Prolonged exposure to sharp temperature changes is another factor that may cause humidity levels in the packaging's inner compartments to change. Condensation may result from this, endangering the packing system's integrity. Humidity is an important factor to consider when evaluating the quality of food since high moisture levels encourage the growth of germs and fungus, which poses a risk to consumer safety. Humidity shortens shelf life in addition to encouraging microbial development because it deteriorates dry goods, softening and dampening them (Ayala et al., 2008).

pH Change

The environment around food may be affected by a variety of microbial metabolites; thus, keeping an eye on any changes in pH could be a useful way to detect food deterioration (Yoshida et al., 2014). Certain aerobic and anaerobic microbes can grow within food packaging while the food products are being stored. The main products of glucose fermentation are organic acids, such as lactic acid and acetic acid (Nopwinyuwong et al., 2010). These metabolites may lower the pH of the meal samples. Additionally, another byproduct of the metabolism of lactic acid is ethanol. However, because ethanol is just marginally more basic than water, the pH shift brought on by ethanol is minor. Microbial development generates carbon dioxide (CO2) gas, which can dissolve in food samples and produce carbonic acid (Puligundla et al., 2012). The carbonic acid's hydrogen ions may then split apart to generate bicarbonate and hydrogen ions. A water molecule and a proton from a hydrogen ion combine to create a hydronium ion, which lowers the pH of the sample (Smolander et al., 2003).

Specific Chemicals

Animal products, which include dairy, meat, fish, and chicken, are a class of foods that include a variety of microorganisms. This particular class of items is also vulnerable to the unintended development of harmful microbes, which produce certain compounds as they develop. Monitoring the presence and concentration of these compounds makes it possible to study the development of this group of bacteria (Morsy et al., 2016). One of the most perishable aquatic items is fish, which is vulnerable to certain spoilage organisms (SSO), which spread into various tissues after death (Cheng et al., 2015).

SMART PACKAGE DEVICES

Many forms and ideas for intelligent packaging. For intelligent packaging systems, the three primary technologies are as follows (Ghaani, 2016):

a) Data carriers
b) Indicators
c) Sensors

A subdivision according to the following types is also possible:

i. Environmental factors: This species keeps an eye on factors that could affect how well food is produced. Time-temperature indicators, gas leakage indicators, and relative humidity sensors are a few examples of these sorts. Depending on the monitoring aspect, these systems can be installed either inside or outside the package.
ii. Quality attributes, also known as quality indicator chemicals, are employed to directly monitor the food's quality attributes. Biosensors and freshness sensors/indicators are two examples. Typically, these gadgets are found within the box.
iii. While indicators and sensors are used to monitor the outside environment and show

the information afterwards, these systems are simply used to store and send data. (Heising et al., 2014; & Han et al., 2005).

Barcode

Barcodes are frequently utilised to simplify inventory control, stock tracking, and checkout since they are affordable and simple to use (Manthou et al., 2001). In general, one-dimensional and two-dimensional barcodes may be distinguished. They come in many types with various storage capacity (Ghaani, 2016). An arrangement of parallel gaps and bars makes up a one-dimensional barcode. Data is coded according to how the bars and gaps are arranged differently. The encoded data can be translated using a barcode scanner and its companion system (Ghaani, 2016).

Figure 1: An example of barcode

QR code

The Japanese company Denso Wave created the QR code, a sort of matrix barcode (or two-dimensional barcode) in 1994. A barcode is a label that can be read by a computer and can hold any type of information. Due to the combination of dots and spaces placed in an array or matrix, two-dimensional barcodes provide higher memory capacity (for packaging date, batch number, package weight, nutritional information, or preparation instructions) compared to one-directional bar code. This offers strong arguments for both customers and retailers.

Figure 2: An example of a QR Code

RADIO FREQUENCY IDENTIFICATION (RFID) TECHNOLOGY

With a data storage capacity of up to 1 MB and the ability to capture real-time data without touching or requiring a direct line of sight, RFID tags are sophisticated data carriers. These gather, store, and send real-time data to an information system used by the user. RFID tags are more costly than barcodes and require a more robust electronic information network. On the other hand, the data may be electronically put onto these tags and modified once more (Brockgreitens et al., 2016). Additionally, RFID has additional benefits for the whole food supply chain. Traceability, inventory control, and the promotion of quality and safety are a few of them (Kumar et al., 2009). A RFID system is made up of three components: a reader that transmits radio signals and receives responses from the tag in return, a tag made of a microchip attached to a small antenna, and middleware that connects corporate applications to RFID hardware.

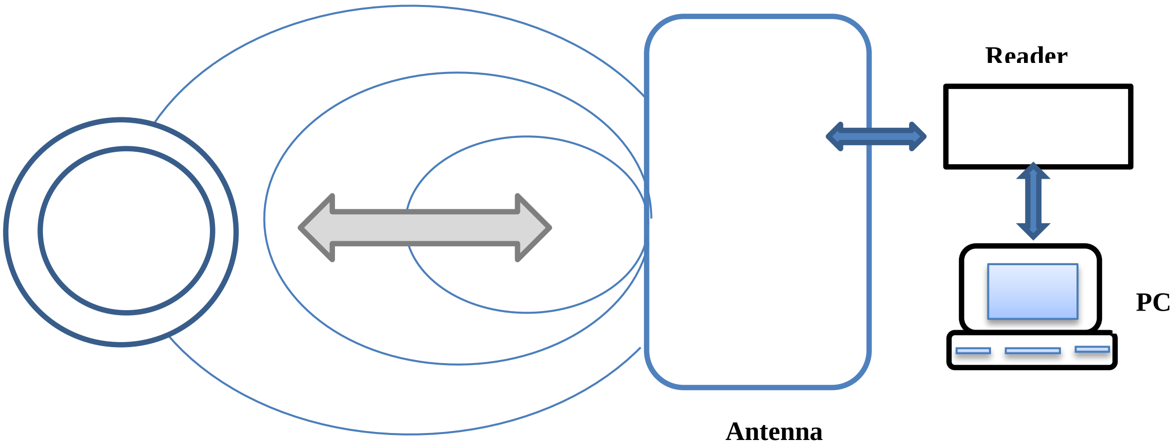

Figure 3: The working principle of radio frequency identification (RFID) tag (Ahmed et al., 2018)

Sensors

The sensor is a piece of equipment that uses a sensitive element to detect data from a measured item and a conversion element to transform that data into a signal that can be used, such as an electrical signal. The uses of conventional sensors in food packaging systems are severely constrained due to their drawbacks of big size, high production costs, and low detection limits for particular specific components (such as gas molecules). The use of flexible printing and nanotechnology might help to overcome these issues (Wyser et al., 2016; Chen & Gao et al., 2016). Food freshness changes are frequently detected using chemical and biological sensors that measure pH, temperature, and biological components (Mahalik & Nambiar, 2010). A polyaniline nanofiber-based taste sensor was created to assess the calibre of freshly squeezed orange juice. As determined by capacitance measurement, the sensor's detection threshold for citric acid in the juice was 2.0 ppm. As a result, several fruit juice types could be distinguished, and the ageing of fruit juices stored under various circumstances was also monitored (Medeiros, Greg'orio, Martinez, & Mattoso, 2009). To assess the respiration rate of fresh goods in real-time, a sensor system was also created. Utilizing nondestructive optical oxygen and dioxide sensors, the gas concentration in the package was detected to estimate the breathing rate (Borcherta et al., 2014). During storage, the sensor system has been utilised to evaluate the quality of mushrooms. Scheelite Technologies has created a commercially viable flexible biosensor for the detection of E. coli and salmonella in packaged goods in the food supply chain. The key innovations were the deposition of antitoxins on plastic packaging materials and real-time wireless network monitoring of the biosensor (Scheelite Technologies, 2011). In order to determine the freshness of fish, the biosensor based on nano metal ion polymer and xanthine oxidase was also utilised to determine the amount of xanthine in flesh (Devi, Yadav, & Nehra et al., 2013).

Biosensors for Pathogen or Toxin Identification

The food business is quite concerned about foodborne infections, and many customers are becoming more and more aware of this issue. To keep the customer safe, it is crucial to quickly and effectively identify even minute levels of pathogens or poisons in food. A biosensor is a scientific tool that analyses substances, in this case pathogens, and transmits the information as a measurable signal. To identify diseases or poisons, an intelligent technology is being developed that will bind antibodies to the surface of plastic packaging (Yam et al., 2005). The packing material would offer a visual indication to inform the customer if the antibodies come into contact with the target pathogen. Only when foods were tainted with extremely high amounts of infection or toxin would this intelligent system be beneficial? In truth, a customer might become unwell from just very minute amounts of a disease or toxin, and this clever system could deceive the consumer into believing they are safe. Additionally, this technology would only be able to identify infections or toxins on the surface of food products; it would not warn customers of potentially harmful ingredients that could be present throughout the whole product. Before this technology is made accessible on the market, more work must be done.

Advantages of intelligent packaging

Due to the increasing use of active components in food packaging, which necessitates a method of tracking both the operation of the active device and the general conditions of the packaging, intelligent packaging systems have grown in popularity. Intelligent packaging systems can aid in managing the food supply chain, improving customer convenience, and minimising food waste. The need for this type of packaging is growing as a result of shifting lifestyles, changing demographics, the demand for processed foods, the requirement for extended product shelf lives, and, most importantly, rising concerns about food safety and public health. Intelligent packaging has significant potential as a marketing tool and the construction of brand uniqueness aside from factors like quality, safety, and distribution. To inform the parties involved in the food supply chains of the product's state, intelligent packaging comprises a switching mechanism on the package that responds to shifting external/internal stimuli. An intelligent packaging system may display the food's temperature, its temperature history, whether the food is fresh or past its expiration date, and it can be used to verify the efficiency or integrity of active packaging systems. The manufacturers and merchants that seek information on the food goods during storage and delivery are one of the innovative drivers for intelligent packaging.

Additionally, consumers have paid close attention to these kinds of apps to check on the product's quality and learn more about the food product (e.g. country of origin, month of harvest). According to some predictions, the intelligent packaging market will experience the fastest growth. This is largely due to the increased use of indicators, particularly time-temperature indicators, and intelligent systems that offer product differentiation, traceability, and other interactive features at more reasonable prices.

CONCLUSION

Intelligent packaging is particularly intriguing and offers practical solutions for reducing food waste. There are several ways to use intelligent packaging for food to keep track of its shelf life. The key benefit of this technology over other packaging technologies is that it allows for the monitoring of the food product without interfering with the packaging. Depending on the type of food being packaged and the packaging methods, intelligent packaging has several uses. Indicators, sensors, and tags may all be used to monitor perishable food goods, for the most part. The majority of indicators base their operation on various alterations in the headspace of packaged food. Even still, the food packaging businesses do not readily accept it. New packaging technologies have been developed as a result of shifting consumer demands. In relation to the search for environmentally friendly packaging solutions, research and development in the field of active and intelligent packaging materials is particularly lively. Food goods are using active and intelligent packaging more and more frequently. Implementing this kind of solution helps to raise the standard of living for consumers.

Additionally, innovative systems will raise the quality of the product, increase food safety and security, and thereby lower the volume of complaints from retailers and customers. There are several causes for this issue. It has been shown that intelligent packaging is essential for maintaining food quality and safety, but market acceptance still has to be fully achieved. Since this technology is still in its infancy, not all types of foods can use it. In comparison to other packaging technologies, it is also a costly technique. It can therefore be utilised for pricey and very perishable food goods. Future food goods will employ active and intelligent packaging more and more frequently.

FUTURE DEVELOPMENT

Using nanotechnology, printed electronics, and photonics to improve already used systems will result in low-cost materials with superior ability to detect and monitor changes in food goods. Intelligent packaging will be utilised to activate the intended function of the active packaging, release the active ingredient only when necessary, and control the efficacy of active packaging systems. Integration of many features into a single device and the creation of new features, such as systems that can transmit the presence of probable allergens, diet management warnings, and alerts for error prevention. A cutting-edge food safety management system (like HACCP) will be able to monitor food loss and food waste, identify potential hazards, conduct biohazard analysis, and recommend controls, critical limits, and the appropriate corrective actions as a result of the Internet of Everything (IoE), a new concept that aims to create a global network of interconnected objects with sensors and RFID tags.

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