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A Review

The Traits of Smart Packaging

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Abstract

Smart packaging systems are those that monitor the condition of packaged products, to provide information on the quality of food during transport and storage. The determination of surface gases, using gas sensors, fluorescence-based oxygen sensors and/or biosensors, provides a means by which the quality of a product can be determined quickly and cheaply. Other sensors, such as visual diagnostic systems, incorporate antibodies into a polyethylene-based plastic package that are able to detect pathogens. Smart digital packaging is becoming more and more necessary, as determined by the equally necessary connection to the world, to the global economy, and in line with the online world. As a result, companies have many options for interconnecting the packaging, so the product: QR codes and other graphic markers, NFC communication, radio frequency identification (RFID), bluetooth, augmented reality (AR), etc. Interconnected packaging creates marketing opportunities, facilitating the interaction in the online world between product, brand and buyer, which creates a potential to influence the purchase. Brought home, packaging, through its connections, can increase the interaction between the consumer and the brand, adding a new consumer experience. At European level, drastic decisions have recently been taken with regard to packaging and especially plastic packaging. The EU wants all plastic packaging to be recyclable.

Keywords: smart packaging, classification, evolution

1. Introduction

Packaging is defined as a means (or set of means) intended to encompass or wrap a product or a set of products, in order to ensure their temporary protection from a physical, chemical, mechanical, biological point of view, in order to maintain quality and integrity. in the form of delivery, during handling, transport, storage and sale to the consumer or until the expiry of the warranty period [29].

The packaging of goods according to Segal et al., 1989, [30] can be viewed and analyzed from two points of view: technical and economic

- From a technical point of view, the packaging of goods is a set of materials designed to protect the quality and integrity of the product, designed to facilitate all operations that follow in the economic circuit after packaging the products.

- From an economic point of view, the packaging is seen as a finished product because material and human expenses have been invested in obtaining it.

In today's trade, it is practically impossible to conceive of goods without their packaging. In recent decades, packaging has diversified a lot, both in terms of the materials from which they are made, and in terms of functionality. Packaging is classified

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according to several criteria, which are frequently used in practice [1]:

- according to the material used in the packaging
- according to the manufacturing system: fixed packaging; removable packaging; foldable packaging.
- by type: envelopes, bags, nets, crates, boxes, bottles, jars, etc.
- by field of use
- according to the specifics of the packaged product
- by degree of rigidity
- according to the mode of movement of the packaging
- by traffic system
- by manufacturing system
- by transport routes
- by destination.

Packaging has become indispensable in the technical circulation of goods. It is currently estimated that approx. 99% of the goods are packed in one way or another.

The main functions that packaging must perform are according to Sarca G., 2010:

1. The function of preservation and protection of products - is the basic function of packaging and consists in the ability of the packaging to protect the contents from the influences of the external environment.

2. The function of transport - handling - storage - is manifested in the economic circuit that follows the production of goods, on its way to the beneficiary or consumer. On this circuit there are a number of problems related to maintaining the quality of the product.

3. The function of product promotion and information - is the newest function of packaging. The creation of packaging is one of the strategic elements of companies in the product marketing policy.

2. The concept of smart packaging

EFSA defines smart packaging materials as "materials and articles that monitor the condition of packaged foods or the environment around them" [7]. They have the ability to communicate the conditions of the packaged product, but do not interact with the product [2]. Their purpose is to monitor the product and pass the information on to consumers. This can be information about the condition of a package and its contents, manufacturing time or storage conditions [14]. Depending on the simple or reactive smart packaging, they can be placed on the primary (outer or inner), secondary or tertiary packaging [11].

The trend towards sustainability, improved product safety and high quality standards are important in all areas of life sciences. To meet these requirements, smart packaging is used in the food sector. These systems can constantly monitor the quality of a product and share information with the customer. In this way, food waste can be reduced and customer satisfaction can be optimized. Depending on the product, different types of smart packaging technologies are used and discussed in this review. The three main groups are: data carriers, indicators and sensors. At the moment, they are not so widespread, but their potential is already known [25].

At present, the general requirements are dealt with in EC Regulation no. 1935/2004 on materials and articles intended to come into contact with food. EU Regulation no. 10/2011 refers in particular to plastic materials and articles. Article 3 of EC no. 1935/2004 provides that smart packaging does not transfer their constitutions in quantities to food. This could endanger human health, lead to an unacceptable change in the composition of food or lead to a deterioration of their organoleptic characteristics. Article 4 regulates on the one hand the labeling, which must indicate that the parts are not edible and that the packaging is intelligent. On the other hand, it is required that information transmitted through intelligent packaging does not mislead the consumer [27].

3. Classification of smart packaging

Technologies for the production of intelligent packaging use methods related to the physics and mechanics of the materials used, biology, chemistry or the interaction between packaging and product, but also to the interaction between packaging and the consumer. The most common smart packaging currently in use is those with oxygen annihilation / absorption / cleaning systems. The systems can be internal or activated from the outside, using a UV light source. In turn, smart packaging can comprise active systems inside the package, by placing micro-pads or active envelopes. Another way to make smart packaging is to incorporate the active ingredients into the material from which the package is made.

Generally speaking, there are three main technologies that are used for intelligent packaging systems: data carriers, indicators and sensors [10]. A subdivision according to the following types is also possible:

- Environmental conditions: This species monitors conditions that may lead to changes in food quality characteristics. Examples of these types are weather temperature indicators, gas leakage indicators and relative humidity sensors. Depending on the monitoring factor, these systems can be placed on the outside or inside of the package.

- Quality characteristics or compounds of quality indicators: This type is used for direct monitoring of the quality attributes of the food itself. Examples are bio sensors and freshness sensors / indicators. These devices are usually placed inside the package.
- Data carriers: These systems are used only for data storage and transfer, while indicators and sensors are used to monitor the external environment and to display information later [11, 12].Operatorii de date contribuie la eficientizarea fluxului de informații din cadrul lanțului de aprovizionare. Funcția purtătorilor de date nu este de a monitoriza calitatea produselor, ci de a garanta trasabilitatea, automatizarea sau protecția împotriva furtului[19].

To ensure this, data carriers store and transmit information about storage, distribution and other parameters. Therefore, they are often placed on tertiary packaging. The most commonly used data carriers are barcode tags and RFID (Radio Frequency Identification) tags [10].

4. The bar codes

Bar codes are inexpensive, easy to use and are widely used to facilitate inventory control, inventory recording and payment [18]. Generally speaking, barcodes can be divided into one-dimensional and two-dimensional. Depending on the type, they have different storage capacities [10]. A one-dimensional barcode is a model of parallel spaces and bars (Fig.1). The different arrangement of bars and gaps results in data encoding. A barcode scanner and an associated system can translate the encoded information [10].

Two-dimensional barcodes provide a greater memory capacity (for example, for the date of packaging, batch number, weight of the package, nutritional information or preparation instructions) due to the combination of points and spaces arranged in an array or array. This provides great convenience for retailers and consumers. An example of 2D barcodes are QR codes - quick response (Fig. 2) [8].

Figure 1. The unidimensional bar-code [33]

Figure 2. The bidimensional barcode [34]

5. Radio frequency identification technology (RFID)

RFID tags are advanced data support with a data storage of up to 1 MB, as well as the ability to collect real-time data without contact and without line of sight. They collect, store and transmit information in real time to a user's information system. Compared to barcodes, RFID tags are moreexpensive and require a stronger electronic information network [8].

On the other hand, the information can be uploaded electronically on these labels and can be exchanged again [4].

In addition, RFID offers additional benefits for the entire food supply chain. These include traceability, inventory management and the promotion of quality and safety [15].

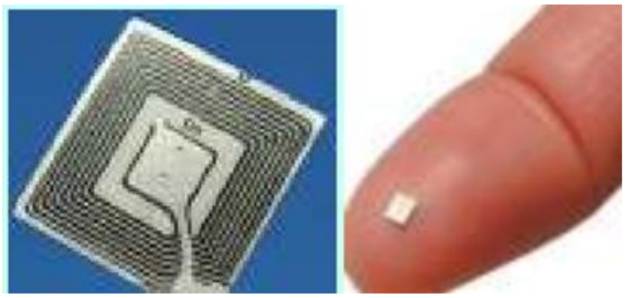

Figure 3. Indicators with radio frequency – RFID [35]

6. Temperature/time indicator (TTI) Integrated barcodes and RFID tags

Barcodes and QR codes are the first so-called smart packaging technologies. In the meantime, they have been further developed and integrated into the TTI. The principle is based on the fact that a label is scanned and provides information about the product, as well as about the progression of temperature. Compared to traditional data carriers, these systems can be used not only to track the distribution chain, but can also help reduce food waste [22].

Time temperature indicators (TTI). Temperature is an important factor in determining the shelf life of a food product. Deviations in the temperature profile can lead to the growth or survival of microorganisms, which ultimately causes damage to the product.

In addition, improper freezing can distort meat proteins or other products. Regardless of whether the required cold chain or temperature is properly maintained during the food supply chain, time temperature indicators can be used [21].

The functional principle of TTI is based on the detection of mechanical, chemical, electrochemical, enzymatic or microbiological changes depending on the time and temperature of a food.

For example, chemical or physical responses are based on acid-base reactions or polymerization to time and temperature. Instead, biological responses are based on biological changes, such as microorganisms, spores, or enzymes, in relation to time and temperature [26].

The measured values are usually expressed as a visible response, such as color changes (Fig. 4) or mechanical deformations [6].

Figure 4. The principle of the temperate/time indicator

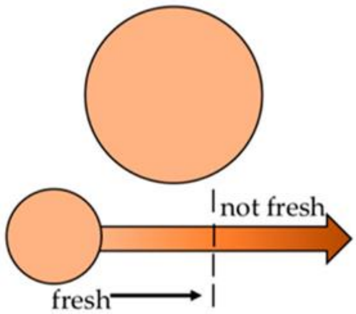

Figure 5. The principle of SensorQ™, Smart Sensor Label by FQSI

Freshness indicators. Freshness indicators monitor the quality of food during storage and transport. The reasons for the loss of freshness may be disadvantageous conditions or outdated durability. Therefore, they provide information on microbiological growth, the presence of microbiological metabolites or chemical changes in products [16].

Metabolites that indicate quality are, for example, glucose, organic acids, ethanol, volatile nitrogen compounds, biogenic amines, carbon dioxide, ATP degradation products and sulfur compounds [14,31]. In order to be able to come into contact with the compounds, the freshness indicators must be placed in the package. An example of a freshness indicator is a sensor label from FQSI (Food Quality Sensor International Inc., Lexington, MA, USA), which is capable of detecting biogenic amines. The SensorQ ™ sticker is applied on the inside of the package and indicates that a critical level of bacterial growth has been reached through a change of color - orange to brown (Fig. 5) [31].

Gas indicators. Gas indicators indicate the state of food quality depending on the indoor atmosphere. A sensor detects and reacts to changes in the atmosphere inside the package, while the actual indicator displays the status of the quality. Changes in the atmosphere are based on part of the food business, such as enzymatic or chemical reactions, and on the other hand, the nature of the packaging and environmental conditions, such as the generation of gases through the metabolism of micro-organisms or the transmission of gases through the packaging. Most monitor oxygen and carbon dioxide levels [20]. But water vapor, ethanol, hydrogen sulfide and other gases are also checked [14]. Concentrations of these gases are often closely correlated with the progress of damage [20]. The functionality of most devices is based on redox dyes, a reducing compound and an alkaline component [10].

In order to be able to monitor the gases, the indicators must be placed in the package. But many of these indicators have a loss of color due to the moisture in the packaging. However, companies are already researching UV-activated colorimeter indicators [28] that show less dye leaching due to encapsulation or coating technologies.

Senzors

A sensor is defined as a device used to detect, locate, or quantify energy or matter, providing a signal for detecting or measuring a physical or chemical property to which the device responds [17]. It can detect the presence, activity, composition or concentration of certain chemical or physical analyzes. Physical or chemical information is also converted by the receiver into a form of energy that can be measured by the second component, the transducer [28].

Moreover, the transducer is used to convert the measured signal into a useful analytical signal. This can be an electrical, chemical, optical or thermal signal. There are different types of sensors that investigate different parameters, for example gas sensors. The progress of the damage can be determined by the concentration of certain gases, such as CO_2 or H_2S. Gas sensors use these properties by monitoring them.

They respond quantitatively and reversibly to the presence of a gas by changing the physical parameters of the sensor. CO_2 sensors are mostly non-dispersive infrared (NDIR) sensors or chemical sensors. NDIR sensors are spectroscopic sensors that measure the CO_2 content by absorbing gases at a certain wavelength [23]. Chemical CO_2 sensors work with polymers or solid electrolytes. Infrared sensors as well as electrochemical, ultrasonic and laser technologies are used to detect O_2 [24]. Another type of sensors are biosensors. Compared to chemical sensors, they have a receptor made up of biological materials such as enzymes, antigens, hormones or nucleic acids. Depending on the measurement parameters, the transducer can be electrochemical, optical, acoustic, etc. For example, there is a biosensor (Toxin Guard by Toxin Alert) whose functional system is based on antibodies, which are integrated into plastic packaging and thus make it possible to detect pathogens such as Salmonella, E. coli, Listeria and Campylobacter . A positive result is indicated by a visual signal [3]. Another biosensor is able to detect xanthine, which is a degradation product of nucleotide adenine in animal tissue. To do this, xanthine oxide is immobilized on platinum, silver or graphite pencil electrodes [2].

Positive and negative aspects of using smart packaging

In general, smart packaging is easy to use and offers a number of benefits to consumers, food producers and the entire food industry. Depending on the system, they offer different features [9].

The current state of the quality of a product can be determined by the use of indicators and sensors. This results in an overall increase in product safety and a reduction in unnecessary food waste [32]. In addition, this consistent quality monitoring also reduces the time and material costs in the methods of analyzing packaged foods [31].

The advantages of additional costs also appear along the supply chain when smart packaging minimizes food waste. These aspects could be even more important in other life sciences, such as the pharmaceutical industry. Data operators allow a better traceability of the supply chain.

Due to their low price, ease of use and the benefits they offer, barcodes and QR codes are now widespread. Instead, indicators and sensors are barely on the market [16]. One reason for this is the price, as development and production costs are still very high. Packaging costs can amount to 50–100% of the total cost of the final product. In fact, there is a limit for packaging costs of 10% of the value of the products to be packaged [5].

In addition, the use of indicators and sensors could lead to a negative change in consumer buying behavior: customers would most likely put products with a faded freshness indicator on the shelf and choose a product with a colorless freshness indicator. If the customer often sees labels of a branded product with a divergent color, he might even lose confidence in that brand.

At the same time, this behavior could also lead to an increase in unsold food [5]. On the other hand, smart packaging can optimize the classic "first in - first out" principle. As the current actual state of food quality is known, the retailer can first sell the products with a shorter shelf life and thus reduce food waste.

It must be ensured that the systems are compatible with the food to be monitored. Not every smart package can be used for every type of food. Therefore, it must be clarified which indicator or sensor is suitable for the product. Smart packaging can only be advantageous if it matches the food. For example, an oxygen sensor would be useful for MAP (Modified Atmosphere Packaging) packaged foods, while for refrigerated and frozen products a TTI should be applied [2].

Another aspect that still needs to be clarified is the recycling of packaging. The additional waste generated by the installation and production of smart packaging is in fact contradictory in order to reduce the amount of food waste.

It should also be noted that it is not possible to rely 100% on intelligent packaging for optimal product quality, as misuse or failure of the systems cannot be ruled out. Several factors are often responsible for quality loss.

Monitoring a single parameter cannot provide a complete statement about the quality status of a product. In addition, external environmental influences, such as light, temperature or mechanical stress, can sometimes have a negative effect on technologies. To summarize, it can be said that the robustness of systems needs to be improved and that individual packaging technologies should be combined to exploit as many benefits as possible [31].

4. Conclusions

Also known as the 'silent seller', packaging is a system with complex functions designed to provide temporary protection for products, but due to its ability to influence consumers at the point of sale, packaging is also a key component of the packaging mix. marketing.

Choosing a quality packaging, produced in safe health conditions, is a form of respect both for the product sold by a manufacturer in the field and for the final consumer. Due to lifestyle changes, consumer requirements or marketing trends, packaging has a major role to play in preserving fast-moving consumer goods. Unfortunately, smart packaging systems are not yet widespread on the market. The reasons for this are the disadvantages mentioned above (additional costs, acceptance of dealers/brand owners, systems, etc.). But the advantages of these systems should not be ignored. Further research and improvement measures are needed to make use of its benefits and allow for wider use. The interest in methods to improve food quality and safety, as well as the management of the food supply chain is huge.

There is a growing demand for information on packaging and food. Consumers want to know what ingredients are in the products or how the product was and should be stored. If they are well informed about the benefits of the systems, customers may be more willing to spend more on food with smart packaging. In addition, consumer confidence in the safety of systems also needs to be strengthened. Therefore, further steps should be taken to promote technologies.

Last but not least, the manufacturer must realize that the use of smart packaging can give them a real advantage in the market. If all these aspects can be achieved, it would be possible to use smart packaging more widely.

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