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Opinion

Using Smart Packaging as Healthy and Safe Alternatives to Traditional Packaging Materials

Hosam El din Aboul Anean*

Food Engineering and Packaging Department-Food Technology Research Institute (FTRI), Agriculture Research Center (ARC), Egypt

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***Corresponding authors:** Hosam El din Aboul Anean, Food Engineering and Packaging Department-Food Technology Research Institute (FTRI), Agriculture Research Center (ARC), Giza, Egypt

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Opinion

The modern world has turned to expanding the production of these smart and active biodegradable packaging, as it has received increasing attention in recent years to develop and improve packaging and control biologically active compounds by producing and developing active packaging with the aim of improving strategies for maintaining the integrity of the film called smart packaging, which has become an important role in preserving food products and has become more common in global markets and increasingly popular around the world as a new type of packaging capable of responding to changes in the packaged product during storage because it contains more attractive and easy-to-use sensors that can give confidence to the consumer at a reasonable price. It is also smarter and capable of ensuring safer food with improved shelf life and real-time food monitoring. These functions can also be improved by combining the use of nanomaterials and the ability to deliver these nanocomposites by notifying the consumer of the safety and consumption of packaged food, as these smart packaging works with an external or internal system called a sensor or indicator to provide information about the storage history and the quality of the packaged product.

Smart packaging is defined as a package containing two indicators

The first is internal, and the second is external. This is to provide information about the storage history of the package and the quality of the product. Smart packaging is characterized by the presence of sensors that show actual information about the food product and show the development of food decomposition processes for packaged products, thus reliably preventing food poisoning. Smart packaging is applied to the surface of the package by printing techniques or as separate cards as chip indicators that indicate a change in color according to the age of the product, taking into account the storage temperature inside the package. At present, it has been widely used in detecting food-borne pathogens, chemicals, toxins, and pesticides present in food products compared to traditional sensors, as nanosensors are more prominent and efficient due to their high sensitivity and purity.

Food packaging is broadly classified into two groups

Smart food packaging, active food packaging, and nano sensors and composites Smart packaging: nanoparticle sensors that respond to environmental stimuli and alert consumers to product contamination or the presence of pathogens Active packaging: nanoparticles with antimicrobial, antioxidant, and moisture-regulating activities such as oxygen scavengers, carbon dioxide scavengers, emitters, and antimicrobials scavenging oxygen. Smart packaging is applied to the surface of the package by printing techniques or as separate cards as chip indicators that indicate color change according to the age of the product, taking into account the storage temperature inside the package.

a. Smart packaging is characterized by the presence of sensors that show actual information about the food product, as it indicates the development of food decomposition processes for packaged products, thus reliably preventing food poisoning.

b. Nanophotonic smart packaging is characterized by containing printing colors that have the ability to provide information such as light luminescence as a result of changes (color, density) and shows the appearance of deterioration processes in the packaged product as a result of biological reactions that occur in food products, which leads to spoilage of food products.

c. There are many optical biosensors. They work as indicators of the presence of microorganisms and gases and appear on the surface of the packages as a visual indicator that informs the customer of product spoilage.

d. Active smart packaging includes a cover film and sheets for product traceability. The figure illustrates smart packaging technologies, classification and contributions to improving food quality and safety. This figure focuses on providing the latest developments in smart packaging in active form (gas emitting scavengers/active absorbents) that contribute to sustainable monitoring of food safety and quality for future applications.

Smart packaging systems

It mainly consists of nanosensors to detect food contaminants, and nanoparticles are mostly used to develop them. Nanosensors containing nanoparticles also have great potential in tracking chemical, physical, and biological modifications during food processing and preservation. The use of these sensors in smart packaging helps in detecting chemicals, toxins, and food pathogens. Smart packaging equipped with nanosensors and indicators also helps in tracking information related to the quality of packaged food products easily during transportation and storage. It has been observed that smart packaging helps in maintaining the quality of food during distribution, as the sensors attached to the package record all the responses related to changes associated with internal or external environmental stimuli. Some indicators are commonly attached in food packaging applications in order to measure the integrity and quality of the package. Monitoring changes in the food product during production and supply chain using indicators helps maintain quality and increases the shelf life of the product. In addition, nanoparticle-based barcodes can be used as identity tags for smart packaging.

Active packaging systems

The term “active food packaging” was initially applied to include various additives and ingredients in packaging film or packaging units to preserve the product and extend the shelf life of the product. Furthermore, active packaging can be defined as a technology that reduces the rate of respiration, reduces microbial and moisture migration, and oxidation with the main goal of enhancing the safety, quality, shelf life, and freshness of food. Active packaging focuses on the properties of polymers used in the package itself or on the surface of the multi-layer package or on the incorporation of certain compounds within the polymeric material in order to avoid microbiological contamination, limit the change in biochemical reactions, and maintain the visual and sensory properties of food and materials capable of thermal co-extrusion or polymer mixing and integration or micro-perforated packages to regulate selectivity in order to change the concentration of gases at ambient levels inside the package. Co-extrusion, polymer mixing, or micro perforation Active packaging systems generally work to increase the shelf life and improve the quality of packaged foods. The development of active packaging systems is mainly based on food storage, as these active systems are designed by incorporating components with Polymer in the package and therefore these materials are widely used in various applications for active packaging that work to: - 1- Absorb oxygen or release antimicrobials or antioxidants in or from packaged foods, making them more resistant and effective in increasing the shelf life of packaged foods and maintaining their quality 2- Integrating active compounds with nanoparticles and antimicrobials to absorb oxygen and water vapor. Nanoparticles work either in direct contact or can migrate slowly and interact with organic materials present in food (metals and nanoparticles of metal oxides, zinc, gold, silver, zinc oxide, titanium dioxide, and silicon oxide) 3- Silver is one of the most widely used nanoparticles because it is known for its established capabilities as antimicrobials and pathogenic strains and prevents the presence of many viruses and fungi. It also prevents respiratory chain enzymes and stimulates the production of reactive oxygen species 4- Integrating the packaging film with fine silver particles and nanoparticles that can prevent the growth of *Escherichia coli* and Staphylococcus aureus and bacteria or incorporation of silver nanoparticles into sodium alginate films and food packaging where it has a remarkable antibacterial effect against *Escherichia coli*.

Nanosensors or nanosensors, also called bioanalytical devices, are an integrated system consisting of various nanomaterials and biological receptors. In recent years, nanosensors have been used in the food processing and packaging industries and have gained a lot of attention due to their safety, rapid detection ability, and low cost. Nanosensors also integrate easily with analytical materials due to their specificity and high sensitivity. Types of nanosensors: They are different nanomaterials such as nanoparticles (metallic, non-metallic, and metal oxide), nanorods, nanowires, carbon nanotubes, and nanofibers. These materials are used in the development of nanosensors as they enhance surface-to-volume ratios, optical and electrical properties, and sensors that have the ability to detect color changes and gases resulting from microbial contamination of food. It has also been noted that nanosensors are very sensitive to various gases such as ammonia, hydrogen, and Sulfide, sulfur dioxide, and nitrogen oxides are usually composed of:

i. Nanosensors are electronic devices (data processing devices) that are sensors that enable them to detect changes in temperature, light, gases, chemicals, and microbial contamination by converting them into electrical signals.

ii. Gas sensors are mostly composed of metal nanoparticles such as silver, gold, copper, platinum, and zinc, which are commonly used to form sensors to observe and detect the presence of aflatoxin and harmful microbes, which are a group of organisms that secrete toxins (toxic carcinogenic compounds) that are commonly found in many foods.

iii. Electrochemical or biological sensors containing metal nanoparticles, supermagnetism, and newly developed nanomaterials (carbon nanotubes), which are used to detect toxins resulting from various harmful microbes found in food products.

iv. Electronic tongue sensors, where the color changes when it comes into contact with any change or the appearance of a sign to show symptoms of food spoilage, indicating that the food is spoiled and unfit for human consumption.

v. Biosensors where protein membranes are used to detect toxins, mycotoxins, microbial toxins, and other toxic compounds, etc. in various sectors of the food industry.

vi. Reflective interferometry sensors and nano-barcodes that are effective in detecting *E. coli* contamination in packaged foods, as this special sensor works on the principle of light scattering by mitochondria and light scattering is detected through digital image analysis with reflective interferometry where *E. coli* protein is placed on silicon chips that bind the similar protein in the event of contamination and is successfully used in determining food quality.

vii. Nanophotonic smart packaging: It is characterized by containing printing colors that have the ability to provide information such as photoluminescence as a result of changes (color, density) and shows the appearance of deterioration processes in the packaged product as a result of biological reactions that occur in food products, which leads to spoilage of food products. There are many optical biosensors that work as indicators of the presence of microorganisms and gases and appear on the surface of the packages as a visual indicator that informs the customer of product spoilage. Nano composites Nano composites are composed mainly of polymers with nanoparticles and are biodegradable nanocomposites as their presence increases the overall properties of the polymer and these nanocomposites help in maintaining the freshness of food and delaying microbial spoilage for a longer period of time by providing versatile chemical functions as a result they are mainly used to produce materials that have high barrier properties as nanocomposites act as a gas barrier to prevent carbon dioxide leakage from soft drink bottles and cans and the nanocomposite layer can be used on cans or bottles of drinks to reduce leakage instead of using heavy glass bottles as a gas barrier and these nano sheets are very popular due to their transparency, low density, surface properties, biodegradable nature and superior flow properties and they have also been used to provide rigidity to fruit juice containers made of cardboard as they are made of polyamide Nano Aegis is mainly used in the production of soft drinks and acts as an oxygen scavenger and retains carbon dioxide by providing enhanced barrier properties Nylon also acts as an oxygen scavenger with nanocomposites that help in preserving fresh produce, packaging, enhancing the shelf life of the product in the market and accelerating the ripening process of fruits and vegetables. Another example of nanoencapsulation is generally used for coating fruits, vegetables, meats and baked goods.

Microchip smart packaging systems and functions capable of executing tasks

Detecting, Sensing, Recording, Tracing, Communication, Convenience, Containment, Protection, Applying Scientific Logic (Figure 1).

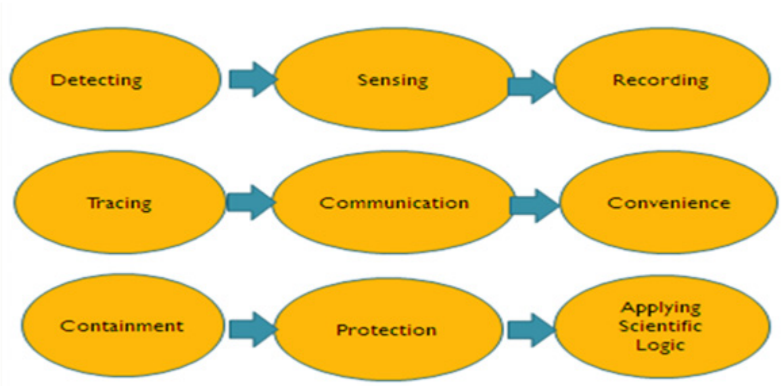

Figure 1

Summary

a) Producing smart packaging as a new type of packaging capable of responding to changes in the packaged product during storage while notifying the consumer of the safety of consuming packaged food

b) Applying smart packaging on the surface of the package through printing techniques or as separate cards as chip indicators that indicate color change according to the age of the product

c) Smart packaging systems and functions with microchips capable of performing the following tasks (detection - sensing - recording - tracking - communication - suitability - containment - protection - scientific logical application)

d) Using smart packaging technologies and classifying them into smart and active packaging containing sensors in the form of nanoparticles with antimicrobial and antioxidant activities that show actual information about the food product and improve food quality and safety and provide the latest developments in smart packaging in an active form that contributes to sustainable monitoring of food safety and quality for its future applications

e) Packaging materials containing sensors have become more attractive, easy to use, and can give confidence to the consumer at a reasonable price. They are also smarter and capable To ensure safer food with improved shelf life and real-time food monitoring. These functions are also improved by combining the use of nanomaterials and the ability to deliver these nanocomposites.

f) Using nanotechnology in developing modern packaging materials to keep pace with the latest developments in this field and focusing on increasing the new food films by converting them into an active nano image to extend the life and freshness of the food preserved in them.