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A REVIEW ON TRADITIONAL AND MODERN FOOD PACKAGING TECHNOLOGIES

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Abstract

In response to consumers current requests and market trends, the manufacturers need to give modern and safe packaging to maintain the quality and shelf life of food items with less effect on the environment. The materials that are commonly used in traditional food packaging are glass, metals, papers and plastics. Using these traditional packaging materials, several laminates and coatings with various physical, chemical, and barrier qualities were developed. These traditional packaging materials, are non-biodegradable, pollute the environment, reduce food safety, and have relatively short shelf lives. So, it is a difficult task for food packaging industry to develop better ideas, where certain developments in food packaging innovations like active and intelligent packaging systems has assisted the food industries in giving a safe and high-level packaging to fulfil consumer needs of utilizing fresh and good quality food items. In addition, smart food packaging technology acts as a bridge to communicate between the manufacturers and consumers by giving complete detail about the product supply chain, the condition of the package, product handling, manufacturing details, and storage details. This article reviews different types of food packaging systems like traditional food packaging (paper, glass, plastic and metal), and smart packaging technologies (active and intelligent packaging) in food industry along with the challenges and future research opportunities.

Key words: Food quality, Innovations in packaging, Shelf-life, Smart Packaging, Traditional Packaging

INTRODUCTION

Food contamination is a major problem that leads to the loss of colour, texture, and nutritional content and also leads to the proliferation of pathogenic bacteria that degrades the product's quality. Food contamination mainly occurs when the food product is exposed to the environment during the production and packaging (1) & (2). Packaging materials have traditionally been employed as passive, inactive, and inert barriers to prevent moisture, oxygen, and contaminants from reaching the food product, thereby maintaining the food's quality and safeguarding it from chemical and mechanical pressures (3). The major requirements that the food processing industry considers when choosing packaging material are heat sealability, process ability, printability, strength, barrier qualities (water, oil, and gas barrier), cost-effectiveness, and sustainability. Food packaging can be made out of a variety of materials, including paper, plastic, glass, aluminium, wood, or a combination of these materials (4). Furthermore, using these materials for food packaging has secondary negative environmental consequences, such as pollution from CO_2 and other toxicants released during incineration, reliance on non-renewable petroleum reserves, and the potential for harmful interactions between recycled/reused plastics and food. So, food packaging that does not contribute to pollution and made using sustainable technologies are becoming increasingly popular (5). Electrically driven packing machinery, metallic cans, aseptic packaging, flexible packaging, aluminium foils, and flexographic printing were among the first innovations in food packaging. Moreover, the development of diverse materials such as polyester, polypropylene, and ethylene vinyl alcohol polymers resulted in a significant shift away from metal, paperboard, and glass packaging, plastic and flexible packaging (6). Many advances in packaging technology emerged during the past few decades, including intelligent or smart packaging (IOSP; time-temperature indicators (TTIs), gas indicators, microwave doneness indicators, radiofrequency identification (RFID), and others), as well as active packaging (such as oxygen scavengers, moisture absorbers, and antimicrobials). These advancements enhanced food quality, safety, and shelf life (7). The major distinction is that intelligent packaging does not interact with food in any way other than monitoring its condition, but active packaging interacts with the environment around food to extend its shelf life. As a result, active packaging is the part that does something, whereas intelligent packaging is the part that perceives and exchanges data. Intelligent and active packaging can almost always operate together to generate what is referred to as "smart packaging" (8). Thus, modern packaging extends the shelf life of food products during longer transportation and storage period.

TRADITIONAL PACKAGING SYSTEM

Glass

Glass is a common packaging material which is used mostly for packaging processed foods especially where moisture and oxygen barrier is mostly required (9). The significant advantage of glass packaging is it does not impact odour to the product and it is resistant to moisture. It gives pleasant physical appearance that adds values in marketing prospects (10). The raw materials like soda ash, sand and limestone used for making glass containers are molten with temperatures more than 1500 °C and formed with compressed air.

The hot glass is heated by an annealing oven to about 600 °C and cooled down slowly to 60 °C to ensure an even cooling. The high energy impact and the carbon dioxide vapours out of the glass during the process can cause high Global warming impact (11).

Paper and cardboard

Wood, plants, recycled paper and cardboard waste are used to make paper and cardboard (11). Paper has an environmental label linked to it, making it the preferred material in the food industry based on its grade, smoothness and treatment given to pulp and paper (12). With good mechanical strength, flexibility, lightweight, recyclability, and low cost, paper and cardboard are popular green packaging materials. They are mostly made of cellulose, a biodegradable and compostable material. This polysaccharide is a biopolymer that is renewable, water-insoluble, and biodegradable (13).

Metal

Aluminium, tin plate, tin-free steel, stainless steel, and metal-based packaging products in rigid and semi-rigid forms, like cans, foil wraps, and retort pouches, are the most often used metals for food packaging applications (14). Tinplate and aluminium are the most popular metals used in food packaging. Although aluminium is one of the safest packing materials, it can be easily affected by acidity (11). These metals come into touch with a wide range of foods and beverages, so a greater understanding of their behaviour as packaging materials is required, especially in crucial applications (15). Coatings derived from oil (e.g., lipids, petroleum) are used by the metal packaging industries to protect metal containers. It may then be assumed that the manufacturing procedures of synthetic resins like epoxy based used in food coatings, produce significant CO_2 emissions (16).

Plastic

Plastics are most commonly used for a wide range of food packaging applications. Food packaging containers that were formerly made of conventional materials were increasingly manufactured using plastics, allowing for better food preservation (17). Plastic packaging is becoming more popular, owing to the desire to reduce food waste and rising demand as a result of population development and market expansion. However, there are growing concerns about the environmental and human health consequences. Littering and the accumulation of nondegradable plastics in the environment, the production of secondary microplastics and nano plastics, and the release of hazardous chemicals during manufacturing process and use, as well as, incineration, or improper disposal, all contribute to environmental pollution (18).

SMART PACKAGING METHODS

ACTIVE PACKAGING

Active packaging is described as packaging that has certain active functions that can improve food quality and safety, rather than just acting as a barrier to the outside world (19). The primary goal of active packaging is to keep food products fresh and extend their shelf life (20). There are five categories of active packaging applications for use in the food industry: (1) scavenging of oxygen, carbon dioxide, moisture, ethylene, UV light, flavours; (2) release of ethanol, antioxidants, preservatives, sulphur dioxide, antioxidants or flavours; (3) removal of food components such as lactose or cholesterol; (4) temperature control of insulating materials, temperature-sensitive packaging, and (5) microbial and quality control that includes ultraviolet light (21) & (22). The smart packaging materials and its application in food packaging is given in Table 1.

Oxygen scavenger

An oxygen scavenging system provides an environment which is free from oxygen to prevent oxidation of food; rancidity; and the growth of microorganisms. In food industries, oxygen scavenging system is widely used because they can extend the shelf life of food products up to 14 days or more. There are many forms of oxygen scavengers, currently films, sachet and labels are commercially used. Incorporating oxygen scavenging polymers (Organic or inorganic) have more advantages in food packaging system (23).

Carbon dioxide scavenger

Carbon dioxide scavenging system prevents the food packages from inflating due to formation of carbon dioxide which is present inside after packaging and is beneficial for food preservation. Carbon di oxide at relatively high concentration inhibits the microbial activity, thus helping to maintain the quality and freshness of packed food thereby increasing its shelf life. Even at lower temperature, CO_2 gas tends to readily soluble in aqueous and fatty foods (24).

Ethylene scavenger

Ethelene acts as a hormone which triggers ripening, accelerates softening, increase chlorophyll degradation, accelerates senescence, and reduces shelf life of the processed foods. There are several ethylene scavengers available among which potassium permanganate is not directly integrated in contact with food products due to its toxicity, instead it is placed as sachets inside the packages. The efficiency and scavenging capacity of ethylene scavengers strongly depends on the surface area of the substrate and the content of potassium permanganate (25).

Moisture scavenger

Moisture scavenging system has been used for a very long time to pack the pharmaceutical products, electronic devices, dried and moisture sensitive foods. The moisture scavengers are placed inside the packages in the form of sachets filled with absorbing materials such as zeolites, silica gel, sodium chloride, or cellulose fibers. These desiccants help in controlling the humidity inside the packages by absorbing and releasing the moisture (26).

Antimicrobial packaging system

Antimicrobial packaging systems involves incorporation of antimicrobial agents directly into packaging films, coating packaging films with antimicrobial substances, and developing packaging materials out of polymers (27). Chemical antimicrobials, antioxidants, biotechnology products, antimicrobial polymers, natural antimicrobials, and gaseous antimicrobials are some of the antimicrobial agents that can be used in the antimicrobial packaging system (28). Antimicrobial compounds improve the quality and safety of processed foods by reducing surface contamination as the direct contact of the packaging with the surface of the foods and beverages slows the growth of bacteria. Sanitizing or self-sterilizing antimicrobial packaging materials minimizes the risk of recontamination of processed food products. Thus, antimicrobial packaging systems may have a continuous active antimicrobial activity that functions as an additional barrier to kill or prevent the growth of undesired microorganisms throughout storage and distribution (29). Moreno et al., (2018) used starch gelatin to create an antimicrobial packaging material to improve the shelf life of chicken breast fillets. The findings revealed that starch gelatin films containing LAE significantly increased the shelf life of chicken breast fillets.

Improved packaging through nanocomposite

In the food packaging industry, nanocomposites, which combine traditional food packaging materials with nanoparticles, are gaining popularity. In addition to its outstanding antibacterial spectrum, it has strong resistance and excellent mechanical properties (31). Metals such as silver, copper, gold, platinum, and their alloys and metallic oxides are generally categorized as food safety materials and are used as food preservatives. However, the development of materials with novel physicochemical properties for use as effective biocidal agents, nano-biosensors, and nano-oriented formulations for the detection of food-vital analytes such as gases, organic molecules, and food-borne pathogens has resulted from the emergence of nanotechnology (32). Donglu et al., (2016) created a nano composite packaging material with nano - Ag, nano - TiO_2, nano - SiO_2, and attapulgite for mushroom preservation. The findings revealed that the nanocomposite-based packaging material (Nano-PM) controlled oxygen and carbon dioxide levels, removed ethylene, and inhibited microbial growth, resulting in improved mushroom preservation quality.

Vacuum packaging

Vacuum packaging prevents oxidative reactions, lipid oxidation, and browning caused by oxidation. It also protects against damage caused by aerobic microbes, particularly moulds. Vacuum packaging is a well-known and widely used method for packaging a wide range of items (32). The process of vacuum packaging involves removing air from a product before closing it. Its main goal is to remove oxygen from the package and bringing the packing material into contact with the food product (34). The main benefits of this approach include extended product shelf life, protection from external risks, and easier handling (35). Due to the oxygen barrier properties of the packaging material, vacuum packaging in gas impermeable and heat stable materials has many advantages, including no or low risks of post pasteurization contamination, ease of handling, inhibition of aerobic organism's growth, and slowing of deleterious oxidative reactions in the food during storage. Microorganisms such as bacteria, mould, and yeast cannot develop in a vacuum, thus foods retain their texture and appearance (36). Duran & Kahve, (2020) applied vacuum packaging with chitosan for beef packaging and found that chitosan prevented the increase of lactic acid bacteria counts.

Table 1: Smart Packaging materials and its application in food

Type of Smart Packaging	Substances used for Packaging	Application in Food	Reference
Active packaging - Antimicrobial Packaging	Pullulan/Ag NPs/EOs	Meat	(38)
Intelligent packaging - Temperature indicators	Soybean oil & Tetradecane	Fresh beef	(39)
Active packaging - Antioxidant Packaging	Wheat gluten modified with chlorophyll	Sesame oil	(40)
Active packaging - Oxygen Scavenger	Pyrogallic acid	Peeled garlic	(41)
Active packaging - Ethylene Scavenger	Thermoplastic Cassava starch/ TiO_2NP/poly (butylene adipate - co – terephthalate)	Banana	(42)
Active packaging Carbon di oxide and Ethylene Scavenger	CO_2 and C_2H_4 Absorbent	Pear	(43)
Active packaging - Moisture Scavenger	Silica gel	Guava	(44)
Intelligent packaging - Freshness indicator	pH Based	Kimchi	(45)
Intelligent packaging - Sensors	Calorimetric gas sensors	Meat	(46)
Intelligent packaging - Freshness indicator	Sugarcane bagasse nanocellulose hydrogel	Chicken breast	(47)

INTELLIGENT PACKAGING

Intelligent packaging combines traditional packaging technologies with an intelligent function. It provides information to consumers based on the product's ability to sense, detect, or record external or internal changes (48). Intelligent packaging is primarily focused on the use of interactive indicators, which are frequently colourful and enable assessment of a product's present quality (49). Permanent food product monitoring reduces wasteful food waste while also protecting consumers from food poisoning, increasing the efficiency of the food industry, and improving quality. Intelligent packaging has the potential to improve product safety, minimize environmental impact, and raise the attractiveness of packaged products and food companies (50). Indicators, sensors, and data carriers are the three basic technologies used in intelligent packaging systems. The primary function of indicators and sensors is to provide information about product quality, whereas the class of data carriers is more involved in supply chain logistics management (8). Intelligent packaging systems is designed in such a way to monitor the conditions and the surrounding environment of the packed foods. So, intelligent packaging is a great initiative in preventing food waste thereby meeting consumer demands (51).

Food Quality Indicators

Food quality indicators are required to depict the state of a food product quantitatively or qualitatively. Food quality indicators are usually related with physical or chemical changes in the features of the individual food. Early detection of these markers can help to prevent the consumption of contaminated food, lowering the risk of food-borne illness in consumers and preventing outbreaks. Oxygen, carbon dioxide, pH change, humidity, and temperature are the most often utilized indicators for food quality and safety (3). These Indicators are a simple tool for decreasing the risk of losses and limiting the costs associated with replacement, or disposal of damaged products (49). Kuswandi et al., (2020) developed an edible pH sensor using anthocyanins immobilized on the bacterial cellulose membrane to detect pH of the beverage and freshness of milk. The freshness of milk is monitored based on the change if colour in sensor from blue-gray to Pinkish-gray which is visual to naked eye. This type of sensor is applied as intelligent packaging system in rapid detection of freshness. Another exciting development was more recently reported by Ghorbani & Rabbani, (2021) by fabricating time temperature indicators using an office thermal inkjet printer to print a bio-based ink which detects colour changes occurring with variations in time and temperature of the product. Another key finding in this study is that guar gum coated TTI was able to show excellent colour changing contrast which is very much suitable to evaluate the safety of the product. The author says that bio-based time temperature indicators can be modified accordingly and can be used in various food applications.

Data Carriers

Data carrier devices are a sort of intelligent packaging that serves a specific purpose to trace the package's whole history. The traceability of food packages enables improved food safety and a better market for consumers (8). Automatic identification devices, also known as data carrier devices, facilitate the transfer of information across the food supply chain and, as a result, indirectly aid in the preservation of food quality and safety. These devices are crucial for connecting industry and consumers. The most essential data carrier devices in the food packaging sector are barcode labels and radiofrequency identification (RFID) tags (54). Furthermore, data carriers are frequently placed on secondary packaging (e.g., multi-box 214 containers, shipping crates, pallets, large paperboard packages) (55).

Sensors

A sensor is an electronic device that is considered as the most progressive and promising technology for the upcoming intelligent packaging device which is placed inside the packages to detect and to control the physical and chemical changes inside the packed foods (56). A sensor can detect an event or changes in the surrounding environment on a regular basis. Sensors usually consist of a receptor and a transducer. A receptor converts physical or chemical information into energy, which is then transformed into an analytical signal by a transducer (57). There are various kinds of sensors used to analyse different parameters of food which includes gas sensors, biosensors, resistance sensor, conductance sensors, and chemical sensor (58) & (50). Gas sensors monitor the gases which is formed at some stage in the spoilage of food. These gas sensors can be divided as oxygen sensor, carbon dioxide sensor, sulphur dioxide sensor, ethylene sensor, water vapour sensor, and volatile amine sensor (59). Biosensors are sensors in which the biological analytes detect the changes and further converts the changes into an electrical signal using transducer. Chen et al., (2020) developed a biosensor to detect the freshness of aquatic products. The novel fluorescence biosensor was fabricated based on the catalytic activity of platinum nanoparticles. This biosensor was able to detect hypoxanthine content in aquatic products. Another new concept in food packaging system is the edible sensor to detect the spoilage of food by non-destructive method. The edible sensors are based on the use of biodegradable films and natural colorants as it is eco-friendly, non-toxic, easily available, biodegradable, renewable and, easily prepared. Natural colorants like anthocyanin, curcumin, betacyanin, carotenoids, carminic acid and, chlorophyll can be naturally obtained from plants and vegetables or fruits. It is reported that these natural colorants can act as an potential sensors as their color changes according to different conditions like temperature, humidity etc., thereby enhancing the nutrient value of food products (61).

Metal-organic frameworks (MOFs)

MOFs are a type of porous polymeric material made up of organic bridge ligands (dicarboxylic acid, tricarboxylic acid, tetracarboxylic acid, and imidazolate) coupled together with metal ions such as alkaline earth metals to form an open crystalline framework with stable porosity (62). MOF topologies and porosity can be determined by choosing organic ligands with the right size, shape, and connectivity (63). MOFs are made up of two primary components called connectors and linkers. Linkers provide a wide range of connection sites that provide binding strength and directionality, while connectors appear as transition metal ions with varying oxidation states (64). Food contaminants (e.g., heavy metals, hormones, and poisonous colors) adsorbents, bioactive molecule carriers, catalysts, food packaging, gas storage, detecting volatile organic molecules, and separation and purification of substances are some of the applications for these materials (65). Min et al., (2021) developed polyvinyl alcohol nanofibers incorporated with thymol-loaded porphyrin metal-organic framework nanoparticles (THY@PCN-224 NPs) for antibacterial food packaging against *E. coli*, *S. aureus*, and *Botrytis cinerea*. The nanofibers exhibited superior antimicrobial activities against *E. coli*, *S. aureus*, and *Botrytis cinerea*.

CONCLUSION

Smart packaging technology is a great key to a wide scope of use in food industries. Usage of these advanced packaging materials in observing the food items, improving the grade of food, decreasing food waste, and expanding its shelf life is a developing field of study. Although the potential benefits of such technologies have been extensively researched and documented, there is still a market applicability gap. As a result, future research must take into account a few key factors in order to make active and intelligent systems commercially feasible and, eventually, into ordinary packaging commodities. Further advancements in food packaging innovation could assist consumers as well as manufacturers. Even though, the old packaging techniques are broadly utilized these days, however in future smart packaging technologies like active and intelligent systems will be most ordinarily utilized. The latest advancements mentioned in this study can help food and packaging scientists a better understanding of the potential and benefits of active and intelligent packaging solutions.

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CONFLICT OF INTEREST

The authors certify that they have no conflict of interest exist in the subject matter or materials discussed in this manuscript.

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