Chapter: 09

CONCEPTS IN SMART AND SUSTAINABLE FOOD PACKAGING

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ABSTRACT

Smart and sustainable food packaging integrates cutting-edge materials, intelligent design, and advanced technologies to revolutionize the food industry's approach to packaging. This concept emphasizes the use of eco-friendly materials such as biodegradables and recyclables, coupled with innovations like smart sensors and active packaging solutions. These technologies ensure real-time monitoring of food freshness, reduction of waste, and extended shelf life. Additionally, the focus extends to optimizing supply chains, minimizing packaging waste, and engaging consumers through informative labels, fostering a holistic and responsible packaging ecosystem that aligns with environmental stewardship and resource efficiency. This chapter overviews onto smart and sustainable food packaging to enhance food's quality, freshness and other consumer essential demands.

Keywords: *Food Packaging, Smart packaging, Food-shelf life, Sustainable Packaging.*

1. INTRODUCTION

Food packaging plays a pivotal role in the contemporary food industry, serving as a critical bridge between producers and consumers. Emerging food packaging technologies are continually evolving to meet the ever-changing demands of both consumers and industrial stakeholders [1-2]. This dynamic transformation is driven by a confluence of factors, including shifts in food production methods, evolving sales practices, changing consumer lifestyles, heightened environmental awareness, and the rapid advancement of cutting-edge fields like nanotechnology and biotechnology [3]. The profound changes in food production methods have led to an increased need for innovative packaging solutions. As food production becomes more sophisticated, packaging must keep pace to ensure that products are not only preserved but also delivered to consumers in their optimal state. Smart packaging solutions are at the forefront of this evolution, offering the ability to extend the shelf life of food products while concurrently monitoring their safety and quality throughout their journey from production to consumption [4]. Consumer lifestyles have undergone significant transformations, characterized by an increased demand for convenience and on-the-go food options. Consequently, food packaging has had to adapt to accommodate these shifting preferences, with features such as resealable closures, single-serving portions, and microwaveable materials becoming increasingly commonplace.

Traditionally, food packaging serves several essential functions, which are summarized including:

- **Protection:** Packaging shields food products from external contaminants, such as dust, moisture, and bacteria, helping to maintain their quality and safety.
- **Preservation:** It extends the shelf life of perishable foods by creating a barrier against air, light, and microorganisms that can cause spoilage and degradation.
- **Containment:** Packaging provides a convenient and hygienic way to hold and transport food, preventing spillage and ensuring portion control.
- **Branding and Marketing:** Packaging serves as a branding tool, helping to differentiate products, build brand identity, and attract consumers through eye-catching designs and logos.
- **Convenience:** Packaging offers ease of use, allowing consumers to open, reseal, and store food products conveniently, especially in the case of snacks, ready-to-eat meals, and beverages.
- **Transportation:** It facilitates the safe and efficient distribution of food products from manufacturers to retailers and ultimately to consumers, reducing the risk of damage during transit.
- **Safety:** Tamper-evident packaging ensures that food products remain untouched and uncontaminated before reaching the consumer.

Moreover, environmental awareness has become a paramount concern in recent years. Consumers are becoming more conscious of the environmental impact of packaging materials, leading to a growing demand for sustainable and eco-friendly alternatives. In response, the food packaging industry is exploring various options, including biodegradable materials, reduced packaging waste, and recyclable designs, all aimed at minimizing the ecological footprint of packaging. Additionally, the relentless progress in nanotechnology and biotechnology has opened up exciting new avenues in food packaging innovation. Nanotechnology offers the potential for creating nanostructured materials that enhance the barrier properties of packaging, thereby extending the shelf life of perishable foods. Biotechnology advancements enable the development of biodegradable and edible packaging materials, reducing waste and offering unique possibilities for food preservation.

2. CONCEPTS IN SMART AND SUSTAINABLE FOOD PACKAGING

Smart and sustainable food packaging represents a significant evolution in the packaging industry, driven by the need to address environmental concerns, reduce food waste, and cater to changing consumer preferences. Below are key concepts and ideas associated with smart and sustainable food packaging:

- **Active Packaging:** Active packaging systems are designed to interact with the food product they contain. These packages often incorporate elements such as oxygen scavengers, moisture absorbers, and antimicrobial agents to extend the shelf life and freshness of the food. For example, oxygen-absorbing packets help prevent the oxidation of packaged food [5-7]. This is achieved through various means, sometimes relying on the inherent properties of the packaging material and at other times by incorporating specific additives into the packaging material or the headspace, with the goal of achieving superior packaging performance. In accordance with European Community regulations, active materials and components are defined as those designed to extend the shelf life of packaged foods, preserve or enhance their condition, and intentionally include components that release or absorb substances into or from the packaged foods and the surrounding environment. It's worth noting that while bioactive packaging falls under this category, its primary purpose is distinct to directly and positively impact consumers' health by promoting the creation of healthier packaged foods.

- **Intelligent Packaging:** Intelligent or smart packaging goes beyond passive containment. It incorporates sensors, indicators, or RFID (Radio-Frequency Identification) technology to provide real-time information about the condition of the packaged food. This includes data on temperature, freshness, and shelf life. Consumers can use this information to make informed decisions about the safety and quality of the product. represents a packaging system with the capability to perform intelligent functions such as detection, registration, location tracking, communication, and application of scientific logic. Its primary purpose is to facilitate decision-making, enhance shelf life, improve safety and quality, provide information, and alert to potential issues in food products. Recognized by the European Community Framework Regulation (Framework Regulation on Food Contact Materials 1935/2004 and 450/2009, 2020) [7-9], these systems can control the state of packaged foods or their surrounding environment. Integrated as labels or within packaging materials, they offer advanced capabilities for monitoring product quality, tracking critical parameters, and providing detailed information throughout the food supply chain, from storage to sale. Unlike active packaging,

which directly influences shelf life, intelligent packages focus on conveying food quality information to manufacturers, retailers, and consumers.

- **Edible Packaging:** An innovative approach involves creating edible packaging materials, often from ingredients like seaweed or rice starch. These edible wrappers can be consumed along with the food, eliminating packaging waste entirely.
- **Recycled and Recyclable Packaging:** Sustainable packaging also involves using recycled materials in the production process and creating packaging that can be easily recycled after use. This approach reduces the demand for virgin materials and minimizes the amount of waste sent to landfills.
- **Biodegradable and Compostable Materials:** Sustainable packaging materials are being developed from renewable sources like cornstarch, sugarcane, or algae. These materials break down naturally, reducing the environmental impact of packaging waste. Some are even compostable, meaning they can be turned into nutrient-rich compost.
- **Minimalist and Eco-Friendly Design:** Packaging design is evolving to use fewer materials while maintaining functionality and aesthetics. Smaller and more efficient packaging reduces resource consumption, transportation costs, and waste.

These concepts represent the forefront of innovation in food packaging, with the aim of reducing the environmental footprint of packaging materials, extending the shelf life of products, and providing consumers with valuable information and convenience. Smart and sustainable food packaging is a critical element in the broader efforts to create a more environmentally friendly and resource-efficient food supply chain.

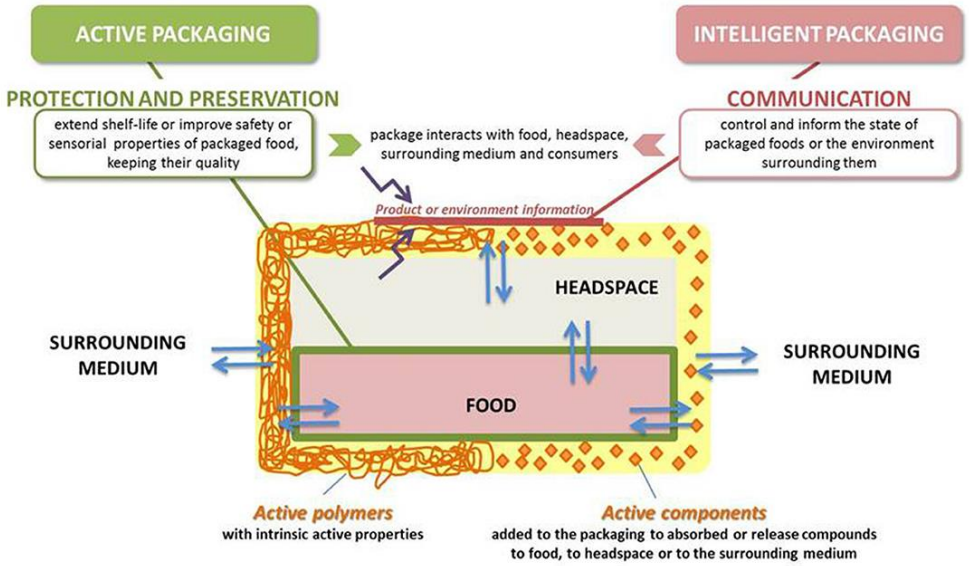

Fig. 1. Representation of active and intelligent packaging concepts (Reproduced from ref. [9] under CCBY License Copyright 2021, Frontiers).

3. CONCLUSION

In summary, food packaging is not merely a utilitarian necessity but a dynamic field that responds to the evolving landscape of food production, changing consumer behaviours, environmental concerns, and the ever-expanding horizons of scientific knowledge. The development of smart packaging solutions that ensure food safety, quality, and sustainability is at the forefront of this ongoing revolution, heralding a more efficient, consumer-friendly, and environmentally responsible future for the food industry.

REFERENCES

1. *Borisov, S. M., Waldhier, M. C., Klimant, I., &Wolfbeis, O. S. (2007). Optical carbon dioxide sensors based on silicone-encapsulated room-temperature ionic liquids, Chem. Mater., 19, pp. 6187–6194.*

2. *Borchert, N. B., Kerry, J. P., &Papkovsky, D. B. (2013). A CO2 sensor based on Pt porphyrin dye and FRET scheme for food packaging applications, Sensors Actuators B: Chem., 176, pp. 157–165.*

3. *McFarlane, D., & Sheffi, Y. (2003). The impact of automatic identification on supply chain operations, Int. J. Logistics Managem., 14, pp. 1–17.*

4. *Robertson, G. L. (2012). Food Packaging: Principles and Practice 3 ed., (CRC Press, Boca Raton US).*

5. *Manthou, V., & Vlachopoulou, M. (2001). Bar-code technology for inventory and marketing management systems: A model for its development and implementation, Int. J. Prod. Econom., 71, pp. 157–164.*

6. *Kim, J. U., Ghafoor, K., Ahn, J., Shin, S., Lee, S. H., Shahbaz, H. M., Shin, H. H., Kim, S., and Park, J. (2016). Kinetic modeling and characterization of a diffusion-based time-temperature indicator (TTI) for monitoring microbial quality of non-pasteurized angelica juice, LWT-Food Sci. Technol., 67, pp. 143-150.*

7. *Drobnik, O. (2015). Barcodes with IOS: Bringing Together the Digital and Physical Worlds, (IOS Press, Manning US).*

8. *Yam, K. L., Takhistov, P. T. W., & Miltz, J. W. (2009). The Wiley Encyclopedia of Packaging Technology 3 ed., ed. Yam, K., Chapter (I) "Intelligent packaging," (John Wiley & Sons, New York), pp. 605-616.*

9. *Salgado, P.R., Di Giorgio, L., Musso, Y.S. and Mauri, A.N., (2021). Recent developments in smart food packaging focused on biobased and biodegradable polymers. Frontiers in Sustainable Food Systems, 5, p.630393.*