ASEAN Journal for Science and Engineering in Materials

Journal homepage: https://ejournal.bumipublikasinusantara.id/index.php/ajsem

Smart Packaging Innovation for Food: Enhancing Shelf Life and Quality of Perishable Goods

Keisha Rafina Rahman[1], Salzabila Ramdhani[2], Viola Gracelia Sanyoto[1], Zheeva Nawareza[1]*

[1]Universitas Pendidikan Indonesia, Indonesia
[2]Universitas Negeri Makasar, Indonesia
Correspondence: E-mail: keisharafina@upi.edu

ABSTRACT

Smart packaging has become a key factor in efforts to improve the shelf life and quality of perishable products. The purpose of this study is to analyze the importance of innovation in smart packaging to improve the shelf life and quality of perishable products. The research method used includes an in-depth literature study to gather relevant information to collect data on existing smart packaging innovations. To date, very few studies have been conducted specifically to discuss or propose innovative smart packaging development solutions to improve the shelf life and quality of perishable products. Hopefully, this paper can provide information on various new technologies and materials that can be used in smart packaging to extend the shelf life and maintain the quality of perishable products.

ARTICLE INFO

Article History:
Submitted/Received 01 Sep 2023
First Revised 03 Nov 2023
Accepted 20 Dec 2023
First Available online 21 Dec 2023
Publication Date 01 Sep 2024

Keyword:
Innovation,
Shelf life,
Smart packaging.

1. INTRODUCTION

Increasingly, efforts to increase the shelf life and caliber of perishable goods depend heavily on smart packaging. This study aims to examine how innovative smart packaging can extend the shelf life and enhance the quality of perishable goods. A thorough review of the literature is one of the research methods utilized to obtain pertinent data about the advances in smart packaging that are currently in use.

Less research has been done expressly to address or suggest cutting-edge smart packaging development strategies to extend the shelf life and enhance the quality of perishable goods as of yet. With any luck, this paper will shine a light on many novel materials and technologies that can be applied to smart packaging to preserve the quality and increase the shelf life of perishable goods.

2. LITERATURE REVIEW

2.1. Vegetables as Perishable Quality Products

Vegetables are quality products that are easily lost or perishable, so their shelf life does not last long. Damage can occur due to physiological, physical, chemical, parasitic, and microbiological factors. The loss of productivity of vegetable crops is still high enough, and the consequences of such damage will result in economic losses. The size of the loss of horticultural products, reviewed in terms of quality and quantity between harvesters and consumers, ranges from 20 to 50% in developing countries and up to 5 to 25% in developed countries. In Indonesia, the average post-harvest loss is 25–40% (Waryat & Handayani, 2020). Producers and traders must be aware of the biological and environmental factors that cause the quality to decrease and use post-harvest techniques to maintain quality (Novianti & Sutrisno, 2021).

Horticulture products, especially vegetables, are living products that remain active in metabolic activity after harvesting. It is characterized by the presence of continuous breathing, which happens before the harvest of the product. The change in the respiratory rate of the n is often used as an indicator of the reporting rate of product damage. The higher the level of respiration, the faster the rate of degradation and the quicker death. Vegetables and fruits have a fairly high-water content (55–85%) at the time of harvest (Mareta & Awami, 2011). Besides still going through the respiratory process, especially the vegetables will go through the fluid process. This physiological feature causes vegetables to have a hazard rate of up to 40%.

The metabolic processes in post-harvest vegetables, especially respiration, cannot be stopped, but the process can be reduced. One way to reduce or inhibit vegetable respiration is to store it at low temperatures and use appropriate packaging. The use of the refrigerator is appropriate to preserve the pepper because it can keep the product fresh longer. The optimal conditions for storing fresh vegetables are between 5°C and 10°C with a relative humidity of 95%.

2.2. Packaging History

Food packaging has been known and used to serve human needs for a long time. In prehistoric times, people still used packaging materials made of natural materials such as leaves, fruit skins, peelings, holes, shells, and animal skins. The shape and function of the packaging are still very simple, i.e., only to transport food residue to other areas.

For centuries, the function of packaging was only limited to protecting goods or streamlining their transportation; packaging still looked simple, and there were many more

DOI:
p-ISSN: 2828-3309X e-ISSN: 2828-3236

functions to protect goods from the influences of weather or other natural processes. It can damage the goods. With increasingly complex developments, new functional values were added, and the role of packaging in marketing began to be recognized as a leading force in market competition. The role of new packaging became apparent around the 1950s when many supermarkets or markets emerged.

Here, the packaging should be able to attract attention, describe the characteristics of the product, and "convince" the consumer. Packaging supports sales tasks when transactions occur. The rules of packaging include not only a minimum of packaging and protecting the product but also the beauty of its packaging (Mukhtar & Nurif, 2015). In other words, packaging no longer serves as a protector or container but must be able to sell the product it packages. The development of the world's science and technology is happening very quickly.

2.3. Smart Packaging

It is worth noting that intelligent systems in this era aim to make human life easier. A rather innovative development in the food industry is smart packaging. Smart packaging is designed for monitoring and providing information on the condition of packaged food products without having to open the packaging from time to time (Mardhiah *et al.,* 2023).

Examples of smart packaging applications for food products include indicators and freshness sensors. This type of indicator is intended to monitor changes in food quality in packaging due to microbe growth and reactions due to the presence of enzymes in food products. The principle of operation is based on a change in the color of the packaging indicator due to a microorganism's metabolic reaction.

Microbial metabolites can be glucose, organic acids (e.g., lactic acid), ethanol, carbon dioxide, biogenic amines, evaporative nitrogen compounds, or sulfur compounds. The level of freshness or counterfeiting of products such as meat and fruit can be detected (David, 2018). Here's an example of a package that uses a freshness sensor. Designed to be inert, which means rejecting the interaction between food and packaging, while smart packaging uses interactions between the environment of the food product and even the food.

3. METHODS

The research method used is the study of literature to analyze the innovation of smart packaging in the context of improving the shelf life and quality of goods that are vulnerable to damage.In this study, the keyword "smart packaging" is the main focus in identifying the suitability of the storage life and the quality of the commodity. A literature study is used to find out the impact of the lifetime and quality of commodities on the safety of foodstuffs, quality, storage processes, and influence on fresh products.

The study uses a method of literary study to explain how smart packaging innovations make a positive contribution to improving the duration of storage and quality of goods, in particular in dealing with the freshness of products, product duration, quality, and content of products. This research is expected to give in-depth insight into smart packages for achieving the quality and safety objectives of food products.

4. RESULTS AND DISCUSSION

Vegetables are commodities that are prone to perishability or decaying quality. (2-4 days). Damage can be caused by physiological, physical, chemical, parasitic, or microbiological factors. Vegetables and fruits have a fairly high water content (55–85%) at the time of harvest. Besides still undergoing respiratory processes, vegetables will also undergo flatulence

DOI:
p-ISSN : 2828-3309X e-ISSN: 2828-3236

processes. These physiological properties cause vegetables to have a rate of damage that can reach 40%.

The process of vegetable metabolism after harvest, especially respiration, cannot be stopped, but the process can be reduced. One way to reduce or inhibit the process of vegetable respiration is to store at low temperatures and use proper packaging. It is known that storing vegetables at cold temperatures is relatively better than storing them at room temperature. It is evident from the visibility, smell, and texture of vegetables that those stored at a cold temperature are better and more awake than those stored at room temperature.

Nevertheless, storage with too-low temperature treatment on fruit or vegetables for a long time can cause chilling injuries. Chilling damage occurs cumulatively from temperature and time factors. The tissue undergoing the chilling injury will look brown. Chilling will degrade quality and reduce storage life. Chilling will affect the disintegration of the vacuola and turn ammonia into glucose. (Tampubolon *et al.,* 2017).

In the development of technology, the distribution process with product quality control is carried out in an attempt to guarantee the quality of the product received by the consumer. Quality control is an effort aimed at improving product quality and reducing the amount of material that is broken. It becomes crucial to the survival of a company, especially in the horticulture industry, where post-harvest handling is a first step towards product quality. The horticultural material is perishable, so it has a short shelf life.

Permeability is an important factor that can affect product quality in the distribution process. Permeability can be observed from the characteristics of the packaging material (Prasad *et al.,* 2018). For example, a material made of a polymer containing chlorine has a low water vapor permeability. Permeability measurement can be done by calculating the permeability constant through the relationship between weight gain and time. Permeability is often measured as grams of H2O per hour in one package unit per square meter of package surface area in an environment with a temperature of 30 C and an RH of 90% (Reinas *et al.,* 2016).

Plastic packaging materials have properties that are permeable to water vapors and gases such as O2, CO2, N2, etc. The ease of plastic packaging material and packaging to be permeated by certain types of gases is greatly influenced by the type and quantity of plastic, air humidity, temperature, type and quality of coating material, and the degree of crystallization of material (Song *et al.,* 2020). Therefore, the selection of packing material becomes crucial in ensuring the sustainability of product quality during the distribution process.

Packaging materials, whether still in the form of raw materials or that have become finished packaging, need to know their properties to fit the purposes of material conditions, processes, and marketing (Zhao *et al.,* 2020). The permeability rate of the packaging material becomes an important indicator, where the higher the permeability rate, the greater the velocity of water vapor movement that can pass through the surface of the packaging material. The use of this understanding of permeability is to estimate the life of the product and to maintain the quality of the product in the packaging so that it can last a long time with quality that remains good and acceptable to the consumer. Quality control through an understanding of permeability becomes one of the key strategies for maintaining the integrity of horticultural products throughout the distribution chain (Mahajan *et al.,* 2017).

One of the main functions of packaging is to protect the product from damage by creating a container or envelope that can prevent or reduce the risk of damage during the distribution process. Packaging also plays a role in protecting products from the dangers of pollution and

DOI:
p-ISSN: 2828-3309X e-ISSN: 2828-3236

physical disturbances such as friction, impact, and vibration. The existence of packaging not only helps maintain the integrity of the product but can also increase its shelf life (Lin *et al.,* 2023). Therefore, in designing packaging, it is necessary to pay attention to the characteristics of the packaging material that can provide maximum protection against factors that may adversely affect the quality of the product.

In addition, packaging also plays an important role in facilitating the storage, transportation, and distribution of products. By giving specific shapes and structures to products, packing can facilitate the process of storage in warehouses, transport through various modes of transport, and distribution to various points of sale (Boysen *et al.,* 2019). Efficiency in logistics and supply chains can be enhanced through packaging designs tailored to distribution and storage needs.

From a marketing perspective, packaging is not only a protective and storage tool but also a promotional tool. The wardrobe or wrapper serves as a stimulant or buyer's attraction. Packaging design, including shape, color, and decoration, became an important factor in attracting consumer attention on shop shelves. Attractive packaging can create a brand identity, distinguish products from competitors, and influence consumer purchasing decisions. Thus, packaging is not only a means of physical protection but also a strategic element in the product value chain (Lydekaityte & Tambo, 2020).

Good packaging not only ensures product safety and sustainability during the distribution process but also contributes to brand image and consumer satisfaction. Therefore, packaging planning and design must be considered holistically to achieve a comprehensive goal in marketing a product (Kim & Sullivan, 2019). Product packaging techniques Choosing the right packaging for vegetables involves not only functional and technical aspects but also considering ecological aspects by choosing environmentally friendly packaging materials. Taking these factors into account, choosing the right packaging can provide great benefits for producers, traders, and consumers in terms of the quality and freshness of vegetables. Good vegetable packaging is essential for maintaining the quality and freshness of the product, avoiding damage, and prolonging its storage life (De Corato, 2020).

Here are some factors and strategies to create effective vegetable packaging (Amit *et al.,* 2017):

(i) Choosing the right packaging material. For example, green leafy vegetables may be better packed in pressure containers, while root vegetables can be placed in porous bags. We make sure the packaging material has proper permeability properties to allow for proper gas exchange, including oxygen and carbon dioxide, which can affect vegetable respiratory processes.

(ii) Humidity control. The moisture in the packaging should be carefully regulated to avoid degradation and mushroom growth. The use of a porous bag or the addition of a desiccant (moisture dryer) can help maintain proper moisturization.

(iii) Temperature control. We make sure the packing temperature fits the needs of each type of vegetable. Some vegetables may require cold temperatures to slow the aging process and growth of microorganisms.

(iv) Prevention of impact and friction. The packaging design is to protect vegetables from impact and friction during transportation. Using a protective layer or a solid container can help prevent physical damage.

(v) Selection of suitable packaging method. We consider a suitable packaging method for a vegetable type. For example, vacuum packaging is suitable for some vegetables to extend their storage life.

DOI:
p-ISSN : 2828-3309X e-ISSN: 2828-3236

(vi) Include Clear Label. We include labels that provide information about harvest dates, expiry dates, and storage instructions. This helps consumers make more informed purchasing decisions.
(vii) Interesting packaging design. An attractive packaging design can enhance the appeal of products. Using fresh colors and pictures that show the freshness of vegetables can attract consumers.
(viii) Selection of the correct package size. We choose packaging sizes that match the needs of the consumer. Different sizes can help reduce waste and meet different consumer needs.
(ix) Monitoring and Quality Control. We implement a quality monitoring system to periodically check the quality of products in the packaging. It is important to identify and address potential problems quickly.

Smart packaging gives manufacturers the ability to optimize vegetable distribution by designing packaging that matches product characteristics (Chen *et al.,* 2020). The role of proper packaging is crucial in protecting vegetables from physical damage and temperature changes during the transportation process. In reality, supply chain managers are faced with a variety of complex problems due to the dynamic and interconnected nature of many elements in supply chains (Ivanov *et al.,* 2021). Decision-makers need to be able to produce the best decisions in a short time, so it is important to have tools that can provide information to support the decision-making process quickly, briefly, and informatively.

5. CONCLUSION

Vegetables and fruits have a fairly high water content (55–85%) at the time of harvest. The metabolism of vegetables after harvest, especially respiration, cannot be stopped, but the process can be reduced. It is known that storing vegetables at cold temperatures is relatively better than storing them at room temperature. In the development of technology, the distribution process with product quality control is carried out in an attempt to guarantee the quality of the product received by the consumer. Quality control is an effort aimed at improving product quality and reducing the amount of material that is broken. According to Harper (1975), permeability is an important factor that can affect product quality in the distribution process.

6. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. The authors confirmed that the paper was free of plagiarism.

7. REFERENCES

Amit, S. K., Uddin, M. M., Rahman, R., Islam, S. R., and Khan, M. S. (2017). A review on mechanisms and commercial aspects of food preservation and processing. *Agriculture and Food Security*, *6*, 1-22.

Boysen, N., De Koster, R., and Weidinger, F. (2019). Warehousing in the e-commerce era: A survey. *European Journal of Operational Research*, *277*(2), 396-411.

Chen, S., Brahma, S., Mackay, J., Cao, C., and Aliakbarian, B. (2020). The role of smart packaging system in food supply chain. *Journal of Food Science*, *85*(3), 517-525.

David, J. (2018). Technology to lengthen of storage of chili. *Jurnal Pertanian Agros*, *20*(1), 22-28.

De Corato, U. (2020). Improving the shelf-life and quality of fresh and minimally-processed fruits and vegetables for a modern food industry: A comprehensive critical review from the traditional technologies into the most promising advancements. *Critical Reviews in Food Science and Nutrition*, *60*(6), 940-975.

Ivanov, D., Tang, C. S., Dolgui, A., Battini, D., and Das, A. (2021). Researchers' perspectives on Industry 4.0: multi-disciplinary analysis and opportunities for operations management. *International Journal of Production Research*, *59*(7), 2055-2078.

Kim, Y. K., and Sullivan, P. (2019). Emotional branding speaks to consumers' heart: the case of fashion brands. *Fashion and Textiles*, *6*(1), 1-16.

Lin, M., Fawole, O. A., Saeys, W., Wu, D., Wang, J., Opara, U. L., and Chen, K. (2023). Mechanical damages and packaging methods along the fresh fruit supply chain: A review. *Critical Reviews in Food Science and Nutrition*, *63*(30), 10283-10302.

Lydekaityte, J., and Tambo, T. (2020). Smart packaging: Definitions, models and packaging as an intermediator between digital and physical product management. *The International Review of Retail, Distribution and Consumer Research*, *30*(4), 377-410.

Mahajan, P. V., Caleb, O. J., Gil, M. I., Izumi, H., Colelli, G., Watkins, C. B., and Zude, M. (2017). Quality and safety of fresh horticultural commodities: Recent advances and future perspectives. *Food Packaging and Shelf Life*, *14*, 2-11.

Mardhiah, A., Musran, M., and Handayani, L. (2023). Intelligent packaging dalam perspektif filsafat ilmu. *Jurnal Sains Riset*, *13*(1), 125-133.

Mareta, D. T., and Awami, S. N. (2011). Pengemasan produk sayuran dengan bahan kemas plastik pada penyimpanan suhu ruang dan suhu dingin. *Mediagro*, *7*(1),26-40.

Mukhtar, S., and Nurif, M. (2015). Peranan packaging dalam meningkatkan hasil produksi terhadap konsumen. *Jurnal Sosial Humaniora (JSH)*, *8*(2), 181-191.

Prasad, K., Nikzad, M., and Sbarski, I. (2018). Permeability control in polymeric systems: A review. *Journal of Polymer Research*, *25*, 1-20.

Reinas, I., Oliveira, J., Pereira, J., Mahajan, P., and Poças, F. (2016). A quantitative approach to assess the contribution of seals to the permeability of water vapour and oxygen in thermosealed packages. *Food Packaging and Shelf Life*, *7*, 34-40.

Song, E., Li, J., Won, S. M., Bai, W., and Rogers, J. A. (2020). Materials for flexible bioelectronic systems as chronic neural interfaces. *Nature Materials*, *19*(6), 590-603.

Tampubolon, Mirnasen, Sukewijaya, I. M., and Gunadi, I. G. A. (2017). Pengaruh precooling dan suhu simpan terhadap kualitas pascapanen tanaman gonda (Sphenoclea zeylanica Gaertn). *E-Jurnal Agroekoteknologi Tropika*, *6*(2), 194-205.

DOI:
p-ISSN : 2828-3309X e-ISSN: 2828-3236

Waryat, W., and Handayani, Y. (2020). Implementasi jenis kemasan untuk memperpanjang umur simpan sayuran pakcoy. *Jurnal Ilmiah Respati*, *11*(1), 33-45.

Zhao, X., Cornish, K., and Vodovotz, Y. (2020). Narrowing the gap for bioplastic use in food packaging: An update. *Environmental Science and Technology*, *54*(8), 4712-4732.

DOI:
p-ISSN: 2828-3309X e-ISSN: 2828-3236