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THE IMPACT OF PACKAGING ON THE PRESERVATION OF FRUIT FRESHNESS

DOI: 10.5937/PIM26246B

Abstract:
Fruit spoils quickly because it has a lot of water and continues to change after being picked. The packaging serves as a vital element which protects freshness. It also extends product shelf life and decreases product waste. The packaging serves three main functions which protect products from physical harm while it controls moisture levels and gas exchange, and preserves product quality. Different materials, like plastic, cardboard, and wood, affect fruit preservation in various ways. The packaging material controls two main environmental elements which include temperature and humidity levels, together with gas exposure to oxygen and ethylene that affects fruit ripening. The selection of appropriate packaging materials stands as a vital step because it protects fruit quality from degradation while preventing product waste during storage and transportation.

Keywords: *Fruit packaging, freshness preservation, shelf life extension, post-harvest losses, storage conditions, ethylene control, quality maintenance*

Introduction

Fruit, due to its chemical composition (88% water, 8.6% carbohydrates, 1.9% proteins, 0.3% fats, and 0.84% ash), provides a favorable environment for the growth of bacteria, yeasts, and molds. Freshly harvested fruit has a natural surface epiphytic microflora containing a small number of bacteria from the genera *Flavobacterium*, *Achromobacterium*, *Alcaligenes*, and *Micrococcus*. Fruit spoilage is also caused by molds such as *Aspergillus niger*, *Botrytis cinerea*, *Cladosporium*, and *Penicillium*.

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After harvesting, fruits remain metabolically active, meaning they continue to respire, lose moisture, and undergo biochemical changes that over time lead to ripening and eventually spoilage.

Properly selected packaging can significantly slow down spoilage processes and help preserve the nutritional and sensory properties of fruit during transport and storage, making it safe for human consumption [1], [2].

The aim of this paper is to analyze the impact of different types of packaging on maintaining fruit freshness, with a particular focus on the importance of modern packaging technologies in extending shelf life and reducing post-harvest losses.

1. The role of Packing

Packaging has a complex and multi-layered role in preserving the quality of fruit. Its function is not limited to physical protection, but also includes the regulation of microclimatic conditions that directly affect product stability.

One of the key aspects is protection against mechanical damage. During transport and handling, impacts and pressure can occur, causing damage to the fruit tissue. These damages accelerate respiration and enable the growth of microorganisms, leading to faster spoilage [3].

In addition to protection, packaging also has an informational function, as it provides consumers with details about the product, including its origin, shelf life, and storage conditions. It also influences consumer choice at the point of purchase through its appearance and design. Packaging facilitates easy transport, storage, and handling of fruit by offering solutions for efficient packing, safe transportation, and long-term preservation without damage. Its functionality is reflected in practical features such as easy opening and the possibility of resealing after initial use. Packaging ensures proper placement of fruit without damage or spillage.

Modern requirements demand that packaging also fulfills ecological functions, as producers must design packaging from recyclable and biodegradable materials in order to reduce environmental impact [4], [5].

2. Types of Packing Materials and Their Impact

Plastic packaging is the most commonly used material due to its ability to enable controlled gas exchange and moisture retention. Materials such as polyethylene and polypropylene allow the adjustment of conditions inside the package to meet the specific needs of certain types of fruit. However, despite their functional advantages, their use is limited due to their negative environmental impact [6].

Cardboard packaging is often used for transport because of its low weight and good protection against mechanical damage. It represents a more environmentally friendly alternative to plastic, but its weakness lies in its sensitivity to moisture, which can affect packaging stability [2].

Wooden packaging has a long tradition in fruit transport and is characterized by good ventilation and strength. However, its greater weight and potential for contamination present certain disadvantages that limit its wider application [6]. Different types of packaging are shown in Picture 1.

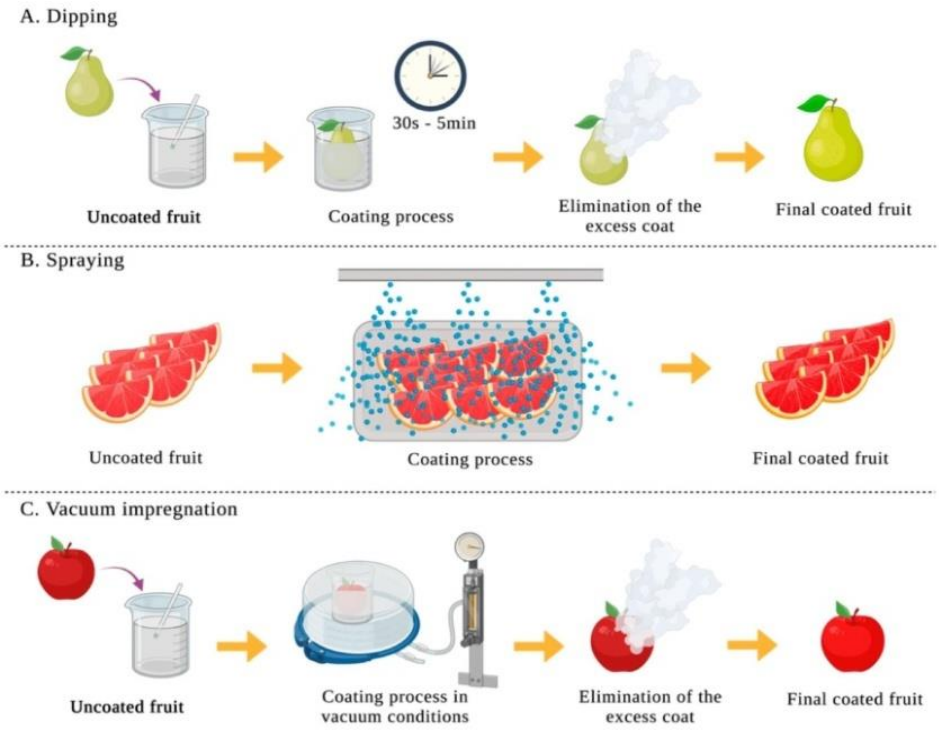


Picture 1. *Plastic, wooden, and cardboard packaging for fruit [11]*

Special attention in modern research is given to edible packaging (Picture 2), which represents an innovative and environmentally

friendly solution. This type of packaging is made from natural materials such as polysaccharides, proteins, and lipids, and can be applied directly to the surface of the fruit in the form of a thin film or coating. Its main function is to reduce water loss, slow down respiration, and limit contact with oxygen, thereby extending the freshness of the product.

Biodegradable materials based on starch, cellulose, and chitosan are also gaining increasing importance. In addition to chitosan, there are edible coatings made from alginate and gellan. Alginate and gellan coatings reduce ethylene production and help preserve the quality of apples [12].



Picture 2. *The process of producing edible packaging[12]*

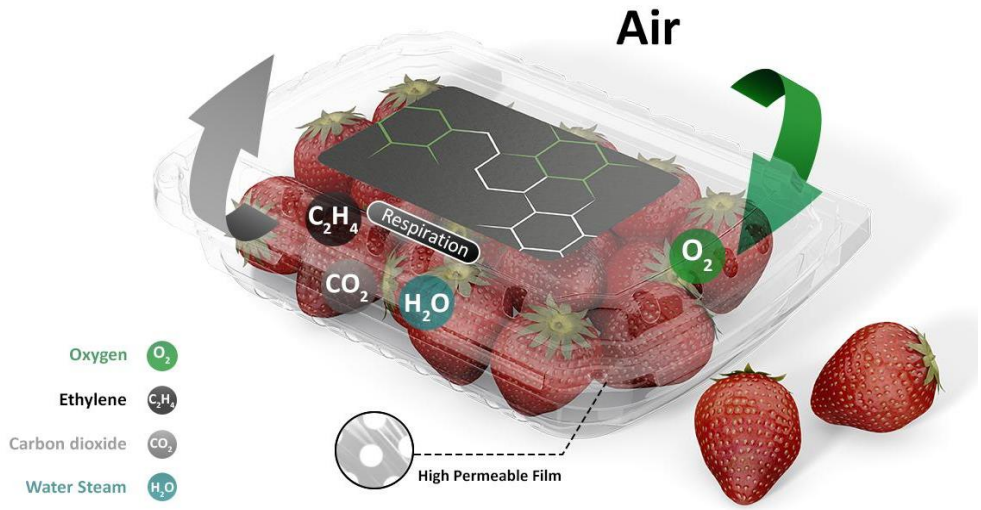
3. Modern Packing Tehnologies

The development of technology has led to improvements in packaging, which today no longer represents only passive protection but actively participates in preserving product quality.

Modified Atmosphere Packaging (MAP) is a modern packaging technology that involves altering the composition of gases within the package in order to slow down physiological and microbiological processes in food. This method is based on reducing the concentration of oxygen and increasing the concentration of carbon dioxide, while nitrogen is used as an inert gas to fill the space inside the packaging. In this way, biochemical reactions and the growth of microorganisms are slowed down, thereby extending the product's shelf life.

Controlled Atmosphere Packaging (CAP) represents a more advanced form of this technology, in which the gas composition is not only adjusted at the beginning but is also continuously monitored and maintained at an optimal level during storage. This approach enables even more efficient preservation of freshness, quality, and nutritional properties of food, especially in highly perishable products [4], [5].

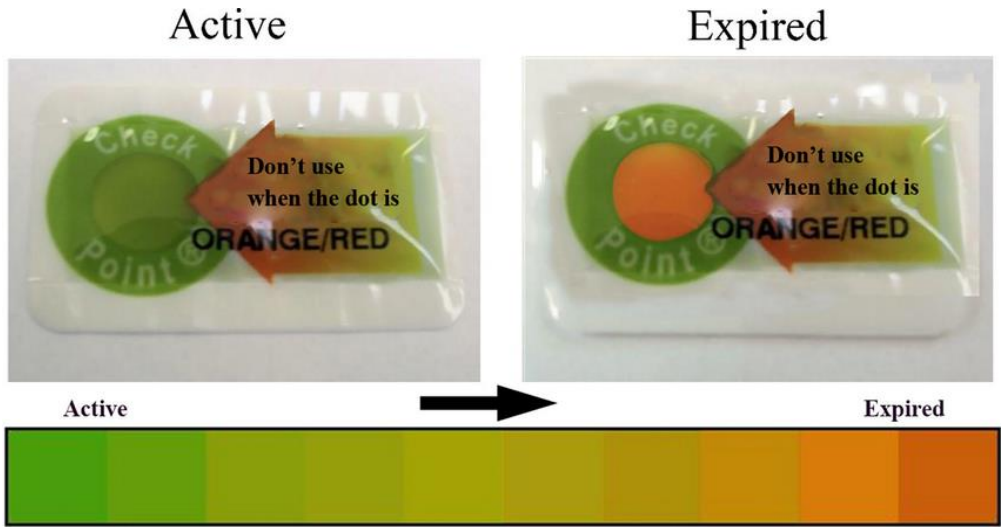
Picture 4. shows the principle of Modified Atmosphere Packaging for strawberries, where a semi-permeable film enables controlled gas exchange (O_2, CO_2, C_2H_4, and H_2O), thereby slowing down the respiration process and extending the freshness of the product.



Picture 4. *Modified Atmosphere Packaging (MAP) [13]*

Active packaging represents a more advanced approach, as it includes components that directly influence the internal environment of the package. These may include oxygen or ethylene absorbers, as well as antimicrobial substances that prevent the growth of microorganisms [8].

Intelligent packaging, shown in Picture 5., enables real-time monitoring of product condition through sensors that detect changes in temperature or gas composition [9].



Picture 5. *Intelligent packaging [14]*

4. Conclusion

Packaging plays a key role in preserving the freshness of fruit, as it affects all the fundamental factors that determine its quality and shelf life. Through protection against mechanical damage, regulation of the gaseous environment, and control of moisture, packaging enables the slowing down of physiological processes and the extension of product shelf life.

Modern approaches to packaging development are focused on integrating functionality and sustainability, with the aim of reducing losses and protecting the environment. In this way, fruit retains its nutritional and sensory properties for a longer period of time. At the same time, distribution efficiency is improved and the amount of waste in the supply chain is reduced.

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