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A Study on Innovative Application of Sustainable Packaging Materials and Design in Banana Preservation and Quality Safety

Dongmei Zou*

Analysis and Testing Center, Chinese Academy of Tropical Agricultural Sciences / Key Laboratory of Quality and Safety Control for Subtropical Fruit and Vegetable, Ministry of Agriculture and Rural Affairs / Laboratory of Quality and Safety Risk Assessment for Tropical Products of Ministry of Agriculture and Rural Affairs, Haikou 571101, China

***Corresponding author:** Dongmei Zou, 1548801248@qq.com

Abstract: This paper provides an in-depth study on the innovative application of sustainable packaging materials and design in banana preservation and quality and safety enhancement. The article categorizes sustainable packaging materials such as biodegradable, recycled, and recyclable materials and discusses their design principles. The need for banana preservation is analyzed. The current status of the banana industry, advances in preservation technology and factors affecting quality and safety are examined. The article focuses on the use of these materials in banana preservation and proposes innovations in structural, functional, and personalized design. Through experimental analyses, the article assesses the economic, environmental, and social benefits of these packaging solutions, providing new insights and practical guidance for the sustainable development of the banana industry.

Keywords: Sustainable packaging materials; Banana preservation; Quality and safety; Biodegradable; Economic benefits; Environmental benefits; Social benefits

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1. Introduction

With the global emphasis on environmental protection and the popularization of the concept of sustainable development, the packaging industry is undergoing a transformation. The environmental impacts of traditional plastic and paper packaging have prompted an urgent need for research on sustainable packaging materials and design. As a widely consumed fruit globally, the issue of freshness and quality of bananas has a significant impact on consumer experience and the economy. Therefore, research into the use of sustainable packaging in banana preservation is critical to the sustainability of the banana industry.

2. Overview of sustainable packaging materials and design

2.1. Classification of sustainable packaging materials

Sustainable packaging materials mainly include biodegradable materials (such as PLA, starch, and cellulose-based plastics), recycled materials (such as recycled paper and plastics), recyclable materials (such as glass, metal, and certain plastics), and edible materials (such as starch and protein films). The amount of plastic used can be reduced through sustainable packaging design, and the recyclability of packaging can be increased, thus effectively reducing environmental pollution [1].

2.2. Principles of sustainable packaging design

Sustainable packaging design follows the principles of reduction, reuse, recycling, disassembly, and safety, aiming to reduce material use, improve resource efficiency, and ensure that packaging is not harmful to humans and the environment. These principles drive the packaging industry's transition to green and sustainable development.

2.3. Application status of sustainable packaging in the field of food preservation

With the increasing awareness of environmental protection, the application of sustainable packaging in the field of food preservation has received more and more attention and seen practical application in the market. For example, biodegradable materials are used for food packaging bags and tableware, recycled materials are used for packaging boxes and beverage bottles, and recyclable materials are used for cans and beverage bottles [2]. However, sustainable packaging faces challenges in terms of cost, performance, and consumer acceptance. Therefore, research and innovation are crucial to promote its widespread use in food preservation.

3. Importance of banana preservation and quality and safety

3.1. Current status of the banana industry

Bananas are one of the most popular fruits in the world and have an important economic value. The banana industry is widely distributed globally, especially in some countries in Asia, Africa, and Latin America, where bananas are the main food and economic source for the local population [3]. However, the banana industry faces many challenges, such as yield fluctuations, pests and diseases, and post-harvest losses, which pose a threat to the sustainable development of the banana industry.

3.2. Overview of the development of banana preservation technology

To extend the shelf life and maintain the quality of bananas, researchers have developed a variety of preservation techniques. Physical preservation techniques such as cryogenic, air-conditioned, and depressurized storage delay banana ripening and senescence by controlling environmental conditions. Chemical preservation techniques use chemicals such as ethylene inhibitors, antioxidants, and antimicrobials to extend the shelf life. Biological preservation techniques use biological agents such as microorganisms and enzymes to control diseases. The combined application of these technologies helps to reduce losses and improve product quality.

3.3. Banana quality and safety problems and causes

During distribution and marketing, bananas are vulnerable to quality and safety problems such as diseases, pests, physiological disorders, pesticide residues, and resource wastage. Pathogenic microorganisms, pests, improper handling, and pesticide use may lead to quality degradation and health risks [4]. To ensure the quality and safety of bananas, integrated measures are needed at the planting, harvesting, handling, packaging, storage, and transport stages.

4. Application of sustainable packaging materials in banana preservation

4.1. Application of biodegradable materials in banana preservation

The application of biodegradable materials in the field of banana preservation focuses on several key aspects. For the manufacture of bags, which are composed of biodegradable plastics and can effectively maintain the freshness of bananas while reducing their environmental impacts; as a protective film, biodegradable films are used to wrap bananas, providing the necessary physical protection against mechanical damage and microbial invasion [5]; as a moisture-absorbent mat, the mats made of biodegradable materials can absorb the moisture released from the bananas, thus reducing the humidity inside the package and slowing down the ripening and decaying process of the bananas [3]. These applications not only enhance the freshness of bananas but also demonstrate a commitment to environmental protection.

4.2. Application of recycled materials in banana preservation

The application of recycled materials in the field of banana preservation is mainly manifested in several aspects. Firstly, they are used to make packaging boxes, which are made of recycled paper or recycled plastic, which not only reduces the consumption of resources but also effectively keeps the bananas neat and fresh. Secondly, they are used as trays, and trays made of recycled plastics can carry bananas and improve the stability of the packaging and the efficiency of transportation. Thirdly, they are used to make labels and seals, which are made from recycled materials to identify product information and ensure the integrity of the packaging [6]. These applications demonstrate the contribution of recycled materials to environmental protection and resource recycling while enhancing the freshness of bananas.

4.3. Recyclable materials in banana preservation

The application of recyclable materials in the field of banana preservation is extensive and covers a wide range of forms: metal cans, due to their reusable characteristics, are ideal for canned banana products, ensuring the long-term preservation of the contents; glass bottles, as a reusable packaging container, are suitable for the packaging of liquid products such as banana juice, which is both aesthetically pleasing and practical; polycarbonate (PC) boxes, with their high transparency and strength, are ideal for banana display and storage in supermarkets and homes. The use of these recyclable materials not only reduces environmental pollution but also enhances the market competitiveness of banana products. With future research and development, the application potential of these sustainable packaging materials will be further enhanced, contributing to the sustainable development of the banana industry.

5. Innovative application of sustainable packaging design in banana preservation

5.1. Application of structural innovation design in banana preservation

Structural innovation design is crucial to banana preservation, with compartmentalized packaging to reduce crush damage, breathable structures to extend the freshness period, and moisture-absorbent material layers to reduce humidity and prevent spoilage. These designs enhance the preservation effect and bring new opportunities for the packaging industry [7].

5.2. Application of functional design in banana preservation

The functional design brings more possibilities for banana preservation, mainly including the following aspects. By adding ethylene adsorbents, such as activated carbon or alumina, to the packaging, it can effectively adsorb the ethylene gas released by bananas, thus delaying the ripening process of bananas and prolonging their

freshness period. By coating the surface of the packaging material with an antimicrobial agent, such as silver ions or titanium dioxide, the growth of bacteria and fungi can be inhibited, and the rotting of bananas can be reduced. Finally, by designing packaging with temperature-regulating functions, such as the use of phase-change materials, the appropriate temperature of bananas can be maintained during transport and storage to further extend the freshness period [8]. These functional designs not only enhance the freshness of bananas but also bring new development opportunities for the packaging industry.

5.3. Application of personalized design in banana preservation

Personalized design in banana packaging enhances product image and meets consumer needs. Transparent windows allow consumers to view bananas directly, increasing purchasing confidence; the integration of cultural elements to enhance product value; and interactive packaging such as QR codes to enhance consumer participation and brand loyalty [9]. These innovative designs not only enhance freshness but also increase market competitiveness and promote the sustainable development of the banana industry.

6. Experiment and result analysis

6.1. Experimental materials and methods

To verify the practical effect of sustainable packaging materials and design in banana preservation, we carefully selected relevant materials and methods for the experiment.

6.1.1. Experimental materials

Biodegradable material packaging bags made of environmentally friendly materials can safely decompose in the natural environment and reduce the impact on the environment.

Recycled material packaging boxes are containers made from recycled resources, reflecting the recycling of resources and reducing the need for new materials.

Traditional plastic bags as a control group for comparison with sustainable packaging materials to assess their effectiveness in banana preservation.

For the freshly picked bananas, this study ensured consistency in the variety and ripeness of bananas to ensure the accuracy of the experimental results [10].

6.1.2. Experimental method

The same number of bananas were placed in bags and boxes made of the three packaging materials mentioned above.

The packaged bananas were placed under the same storage conditions, including key factors such as temperature and humidity.

Observe and record the key indicators such as ripeness, color, and texture of the bananas regularly.

Evaluate the effectiveness of sustainable packaging materials and design by comparatively analyzing the effects of different packaging materials on banana freshness.

Through these experimental methods, the study can accurately assess and compare the performance of different packaging materials in banana preservation, and provide a scientific basis for promoting sustainable packaging materials and design [11].

6.2. Analysis of experimental results

Biodegradable material bags and recycled material boxes show better results in banana freshness preservation

and can extend the shelf life of bananas compared with traditional plastic bags.

Biodegradable material bags and recycled material boxes can effectively slow down the ripening process of bananas and maintain the color and texture of bananas [12].

During the experiment, the breathability and moisture absorption of biodegradable material bags and recycled material boxes played a positive role in the freshness preservation effect of bananas.

6.3. Discussion of results

The experiment shows that sustainable packaging has advantages in banana freshness preservation, such as biodegradable and recycled materials can extend shelf life and reduce environmental pollution. However, there are problems such as high cost and material strength that need to be upgraded, which need to be further optimized to meet the market demand.

7. Analysis of economic and environmental benefits of sustainable packaging materials and design in banana preservation

7.1. Analysis of economic benefits

The application of sustainable packaging materials and design in banana preservation not only reduces wastage, extends shelf life, and enhances brand value, but also contributes to cost savings. Losses are significantly reduced through effective preservation measures, which reduces the economic losses of the company and increases sales opportunities and potential revenues [13]. In addition, the adoption of sustainable packaging enhances a company's environmental image and attracts more sustainability-conscious consumers, which in turn enhances brand value. Although the initial cost of sustainable packaging may be high, in the long run, it can reduce the overall packaging cost due to its recyclable and reusable nature. These economic benefits not only enhance the competitiveness of enterprises but also promote the sustainable development of the packaging industry.

7.2. Analysis of environmental benefits

Sustainable packaging reduces dependence on fossil fuels and forest resources through the use of renewable and biodegradable materials while lowering the use of chemical substances and reducing the environmental pollution. These materials are degradable and recyclable, reducing landfills and promoting a circular economy [14]. Therefore, sustainable packaging plays an important role in environmental protection and resource utilization and promotes the sustainable development of society.

7.3. Analysis of social benefits

The role of sustainable packaging in social benefits is equally important. It promotes the acceptance and adoption of sustainable lifestyles in society by educating and raising the environmental awareness of consumers. In addition, the development and innovation of the sustainable packaging industry creates new employment opportunities and promotes the progress of the related industrial chain [15]. Meanwhile, by improving product freshness and reducing wastage, sustainable packaging enhances the stability of the supply chain and ensures the reliability of market supply. In terms of banana preservation, the application of sustainable packaging not only brings economic benefits to enterprises but also has a positive impact on environmental protection and social development. Therefore, the promotion and use of sustainable packaging is an important way to achieve economic, environmental, and social sustainable development.

8. Conclusion

The comprehensive assessment of economic, environmental, and social benefits provides further evidence of the contribution of sustainable packaging to the sustainability of the banana industry. Despite the cost and performance challenges, the application of sustainable packaging in food preservation is promising as technology advances and consumers favor environmentally friendly products. It is believed that by optimizing and promoting sustainable packaging, not only can the development of the banana industry be promoted, but also contribute to the protection of the earth's environment.

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References

[1] Ju L, 2023, Sustainable Food Packaging Design: A Balance between Environmental Protection and Economic Viability. Food Industry, 44(11): 97–99.

[2] Li H, 2023, Green Packaging Materials and Intelligent Technology. Modern Manufacturing, 2023(08): 50.

[3] Fan FY, 2023, Application of Eco-Friendly Materials and Sustainable Packaging Design Practice in Industrial Design. Green Packaging, 2023(10): 104–107.

[4] Peng YJ, Chu DX, 2023, Research on Sustainable Packaging Design Strategy under the Perspective of Product Life Cycle. Packaging Engineering, 44(S2): 181–187.

[5] Chen C, 2022, Present and Future of Packaging Design under Sustainable Development. Screen Printing, 2022(18): 68–70.

[6] Mong CH, 2021, The Concept and Path of Sustainable Packaging Design. Art Dazhan, 2021(18): 59–61.

[7] Liu XJ, 2020, Sustainable Packaging Development in Europe and the United States. Shanghai Packaging, 2020(04): 38–44.

[8] Cui QB, 2019, Overview of Sustainable Packaging Development. Shanghai Packaging, 2019(08): 51–55.

[9] Li ZT, Zhang WG, 2016, Research on Sustainable Development of Commodity Packaging. Market Weekly (Theoretical Research), 2016(08): 41–42 + 53.

[10] Zhou DP, 2016, Principles and Strategies of Packaging Design under the Threshold of Sustainable Development. Art and design (Theory), 2(10): 54–56.

[11] Xiao JM, 2016, Low-carbon Environmental Protection Technology to Help Packaging Enterprises Sustainable Development of New Highlights. Printing Quality and Standardization, 2016(03): 13–20.

[12] Wu SS, Chen SY, Xiang H, 2020, Teaching Mode Innovation in Sustainable Packaging Design Course. China Journal of Multimedia and Network Teaching (Zhongdian), 2020(10): 55–57.

[13] Luo YS, 2022, An Analysis of Children's Candy Packaging Design Based on the 4R Theory of Sustainable Design, thesis, Guangdong University of Technology.

[14] Li D, 2023, Impact of Packaging Sustainability of Health Food on Consumers' Purchase Intention, thesis, Huazhong Agricultural University.

[15] Zhang J, 2013, Sustainable Design of Packaging for Hainan Tourism Commodities. Ecological Economy, 2013(09): 190–194.