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# Innovative Application of Fermentation Technology in Post-Processing of Bananas: Improving Quality and Prolonging Shelf Life

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**Abstract:** This study focuses on the application of fermentation technology to improve banana quality and prolong shelf life. First, the current status of the post-processing of bananas, including post-harvest processes, means of freshness preservation, and shelf life, is summarized. Then, the principles and advantages of fermentation technology and the conditions under which it affects banana quality were described in detail. Emphasis is placed on the application of fermentation technology in banana treatment, including the effect of fermentation pretreatment on quality, changes in nutrient composition during fermentation, enhancement of antioxidant activity, and improvement of quality and flavor. In addition, the role of fermentation technology in prolonging freshness, such as its effects on microbial communities, disease suppression, ethylene production, and respiration, is discussed. The article also assesses the effectiveness of fermentation technology in enhancing the quality of bananas, including color, nutrient improvement, and food safety assurance.

**Keywords:** Banana; Fermentation technology; Post-processing; Quality; Shelf life

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## 1. Introduction

Banana is one of the most popular fruits in the world, and it is loved by consumers for its high nutritional value and delicious taste. However, bananas are susceptible to problems such as disease, decay, and quality deterioration during post-harvest handling, transportation, and storage, leading to economic losses and resource wastage. Therefore, how to improve the quality and extend the freshness period of bananas has become an urgent problem to be solved. In recent years, fermentation technology, as an emerging food processing technology, has achieved remarkable results in many fields. This study aims to explore the innovative application of fermentation technology in banana post-processing to improve banana quality and extend the freshness period.

## 2. Current situation of banana post-processing

Banana is the most important fruit in the tropics, and the Asian, African, and American regions have become the main producing areas of bananas, with its production and trade volume ranking the first in the world fruit. China is one of the countries where bananas originated, and one of the countries with the longest history of banana cultivation in the world. China's banana production ranked second in the world in 2020. China, India, and other developing countries account for more than half of the world's total banana planting area and production. In China, banana cultivation is mainly distributed in five provinces, including Guangdong, Guangxi, Fujian, Yunnan, and Hainan [1]. As one of the major cash crops in the tropical region of China, the post-harvest treatment of bananas is crucial for their freshness and shelf-life maintenance. In this paper, the post-harvest treatment process of bananas, preservation methods, and their freshness period will be elaborated in detail.

### 2.1. Banana post-harvest treatment process

In banana post-harvest treatment, it is necessary to select fruits with a fullness of about 75% to 80% and without mechanical damage to ensure quality. Next, pre-treatment is carried out to remove pests, diseases, and damaged parts, and prune the fruit stalks to enhance the appearance and reduce water loss. The washing stage involves gentle scrubbing with water to remove dirt and pesticides, and preservative treatment with a banana preservative to kill microorganisms and prolong freshness. Bananas are graded according to size, color, and shape to ensure product consistency. Vacuum packaging was done using polyethylene film bags to maintain the freshness of the bananas [2–4]. Finally, the packaged bananas were stored in a cool, ventilated, and dry environment to protect them from sunlight and heat damage to ensure that consumers enjoy fresh, high-quality bananas. This series of processing steps aims to maintain the quality and nutritional value of bananas from farm to table.

### 2.2. Banana preservation methods and freshness period

Various strategies such as low-temperature preservation, air-conditioning preservation, film-coating preservation, and chemical preservatives are used in post-harvest treatments to maintain the freshness of bananas and prolong their market life. Cryopreservation utilizes a low-temperature environment to slow down fruit metabolism, air conditioning regulates fruit respiration by precisely controlling oxygen and carbon dioxide concentrations, film coating reduces water evaporation and microbial invasion through physical barriers, and chemical preservatives such as 1-methylcyclopropene are highly effective in slowing down fruit respiration [5]. Each technology has its own advantages and applicable scenarios, and the selection should take into account the cost, feasibility, fruit characteristics, and consumer demand to achieve the best balance of banana quality and freshness.

## 3. Principles and advantages of fermentation technology

Fermentation technology is a process that utilizes the metabolic activities of microorganisms under aerobic or anaerobic conditions to change the characteristics of food. In banana processing, fermentation technology can not only improve the taste and flavor of banana products but also enhance their nutritional value and functionality. The following is a detailed analysis of the overview of fermentation technology.

Banana fermentation is the conversion of large molecules into small molecules through microbial action under aerobic or anaerobic conditions, adding flavor and improving texture. This process enhances the bioavailability of nutrients, breaks down anti-nutritional factors, and makes dietary fiber more digestible. Fermentation also promotes the production of vitamins and amino acids, which enhances the nutritional value, as well as the production of probiotics and prebiotics, which contribute to intestinal health and immunity [6]. Therefore, fermentation not only enriches the flavor and texture of banana but also enhances its nutritional

value and health benefits.

To optimize banana fermentation, it is crucial to select appropriate microbial strains such as yeast, lactobacilli, and acetic acid bacteria, which produce alcohol, sour, and vinegar flavors, respectively. Fermentation conditions, including temperature, humidity, and oxygen, need to be precisely controlled to promote microbial growth. The addition of fermentation agents accelerates the process and ensures consistent product quality. The length of fermentation significantly impacts the final product's flavor and texture, with longer fermentation times tending to result in more intense flavors. The unique flavor and nutritional value of fermented banana products can be greatly enhanced through a combination of these techniques.

## 4. Application of fermentation technology in banana post-processing

Fermentation technology plays a key role in the post-processing stage of bananas, which not only improves the taste and extends the shelf life of bananas, but also increases the nutritional value and functionality of bananas. The following is a detailed analysis of the application of fermentation technology in banana post-processing.

### 4.1. Effect of fermentation pretreatment on banana quality

Fermentation pretreatment can optimize the texture and taste of bananas, reduce starch and sugar through the action of microorganisms, improve digestion and absorption, and adjust pH to enhance flavor [7]. To keep bananas fresh and extend shelf life, the key is to precisely control fermentation conditions, such as temperature, humidity, and oxygen, to promote beneficial microbial activity, while utilizing natural preservatives, such as citric and ascorbic acids, to inhibit undesirable biological and oxidative processes. Management of gas concentration in packaging combined with cold chain logistics slows down the respiration and microbial growth of bananas, thus maintaining their quality during distribution and storage.

### 4.2. Changes in the nutrient composition of bananas during the fermentation process

During the fermentation process, a series of changes occur in the nutrient composition of bananas. During the fermentation process, microorganisms act on the starch and sugar in bananas, converting them into organic acids and alcohols with health care functions. Next, the microorganisms continue to break down the proteins and fats in bananas to produce small molecules such as amino acids and fatty acids that are easier for the human body to absorb. These transformation processes not only enrich the flavor of bananas but also improve their nutritional bioavailability [8]. In addition, fermentation can increase the content of B vitamins and vitamin K in bananas and improve their nutritional value.

### 4.3. Effect of fermentation on the antioxidant activity of banana

The antioxidant activity of bananas was significantly enhanced during fermentation. This is mainly due to the microbial activity that promotes the formation of antioxidant substances such as polyphenols and flavonoids, which are effective in scavenging free radicals and providing cellular protection against oxidative stress damage [9]. In addition, fermentation improves the bioavailability of the original antioxidant components within the banana, making them more effective in exerting antioxidant effects in the human body. Thus, fermentation not only enhances the nutritional value of bananas but also demonstrates its great potential for enhancing the health properties of products in food processing.

### 4.4. Application of fermentation technology in banana post-processing

Fermentation technology is crucial for the post-processing of bananas to enhance product quality and prolong

shelf life. Through the application of pre-treatment enzymes, the physicochemical properties, bioactivity, sensory characteristics, and antioxidant activity of bananas are enhanced and the taste is improved. Banana processing techniques, including the production of banana pulp, powder, and beverages, retained the nutritional value and enriched the product range [10]. Low-temperature fermentation was used for banana fruit wine production, preserving flavor and aroma. Combined with post-harvest preservation measures, banana quality was effectively maintained, and ripening and diseases were delayed. The application of these technologies enhances the value of banana products and promotes the sustainable development of the industry.

## 5. Application of fermentation technology in extending the freshness period of banana

The application of fermentation technology in banana freshness preservation mainly extends the freshness period of bananas by changing the microbial environment of bananas, inhibiting the occurrence of diseases, and regulating the mechanisms of ethylene production and respiration. The following is a detailed analysis of the specific application of fermentation technology in extending the freshness period of bananas.

### 5.1. Microbial fermentation and banana freshness preservation

During the fermentation process, microorganisms produce antimicrobial substances (such as bacteriocins and organic acids), which effectively inhibit or kill pathogenic microorganisms that may infest bananas. Liu Yaping et al. used laboratory *Bacillus amyloliquefaciens* for fermentation to study its bacteriostatic components and found that bananas treated with 400 mg/mL *Bacillus amyloliquefaciens* CGMCC 1.936 bacteriostatic active substance in pure form in combination with preservation film had a weight loss of 1.13%, a change in hardness of 41.72%, a decrease in titratable acid of 36.69%, and an increase in soluble solids of 18.18% [11]. It can effectively delay the ripening and deterioration of bananas and maintain good quality. Meanwhile, the beneficial substances (including vitamins and amino acids) synthesized by microorganisms can improve the physiological state of banana and enhance its ability to fight against pathogenic microorganisms. The organic acids produced during fermentation also lower the pH of bananas, creating an environment unfavorable to the growth of pathogenic microorganisms, thus protecting bananas from spoilage and disease. To achieve optimal freshness, the appropriate microorganisms and fermentation conditions need to be selected on a case-by-case basis. Fermentation technology has thus become an important means of improving the quality of bananas and extending their freshness.

### 5.2. Role of probiotics in banana preservation

Fermentation technology uses probiotics to enhance the quality of bananas and extend their freshness. Probiotics slow down the ripening and aging of bananas by breaking down harmful substances (such as ethylene) in bananas while producing beneficial metabolites that enhance banana nutrition and improve taste and quality. To achieve the best results, probiotic screening, fermentation conditions, and their interactions with other factors need to be optimized according to the specific situation. Qi Kangru et al. showed that the freshness preservative compounded with 1.25% lyophilized powder of bacteriostatic agent, 1.5% chitosan, and 0.03% natamycin could slow down the ripening of banana and prolong the shelf-life for 4 days [12].

### 5.3. Improvement of banana quality by enzymes produced by fermentation

Enzymes produced by microorganisms during the fermentation process are very crucial to improving the quality of bananas, including enzymes that break down the cell wall, antioxidant enzymes, and lysozyme with

antibacterial effects. These enzymes soften banana tissues, release nutrients, improve taste, scavenge free radicals, slow down aging, and inhibit bacterial growth. To utilize these enzymes effectively, fermentation conditions such as temperature, pH, and oxygen supply need to be strictly controlled. Genetic engineering techniques can also be used to enhance the ability of probiotics to produce beneficial enzymes, further improving banana quality and freshness.

### 5.4. Effect of antimicrobial substances produced during fermentation on banana preservation

Antimicrobial substances produced by microorganisms during fermentation are very important for banana preservation and quality enhancement. These substances inhibit or kill pathogenic microorganisms, create an acidic environment, reduce oxidative stress, and stimulate the defense mechanisms of bananas [13]. To maximize the effect of these antimicrobial substances, the fermentation process needs to be tightly controlled, including conditions such as temperature, time, microbial inoculum, and oxygen supply. Different banana varieties may require specific fermentation strategies for optimal preservation.

## 6. Application of fermentation technology in improving banana quality

Fermentation technology plays an important role in improving the quality of bananas by improving the overall quality of bananas in terms of color, nutrient content, and safety. The following is a detailed analysis of the specific applications of fermentation technology in improving banana quality.

### 6.1. Immobilized fermentation technology

Immobilized fermentation technology plays an important role in improving banana quality. By immobilizing probiotics on carriers to form immobilized probiotics, as well as immobilized enzyme technology to enhance the stability and reusability of enzymes, this technology not only improves the safety of the fermentation process and reduces microbial contamination, but also speeds up the generation of metabolites and realizes the continuity and automation of the fermentation process [14]. These comprehensive benefits make the immobilized fermentation technology a key tool for improving banana quality and promoting the development of the banana industry.

### 6.2. Microbial genome editing

Microbial genome editing technology has great potential to enhance the quality of bananas. The technology enhances the production of antimicrobial compounds and beneficial metabolites by microorganisms, inhibits pathogenic microorganisms, extends shelf life, and improves quality. It also improves microbial adaptation to environmental stresses, ensures the stability of the fermentation process, reduces harmful metabolites, improves safety, and develops new fermentation strains that reduce energy and resource consumption and promote the sustainability of the fermentation process. These roles provide strong support for quality improvement and sustainable development of the banana industry.

### 6.3. Combination of fermentation and physical preservation technology

The combination of fermentation technology and traditional physical preservation methods provides an efficient and integrated preservation strategy for the long-term storage and transportation of bananas. The metabolism and microbial growth of bananas are slowed down by low-temperature preservation, combined with fermentation treatments to improve antimicrobial capacity, air-conditioned preservation to change the gas

composition of the package to slow down respiration and microbial growth, as well as radiation preservation to kill or inhibit microorganisms and vacuum packaging to remove oxygen [15]. These methods work together to significantly extend the freshness period of bananas, improve the quality and safety of bananas, reduce food waste, and enhance market competitiveness.

## 7. Conclusion

This study comprehensively investigated the innovative application of fermentation technology in the post-processing of bananas and deeply analyzed its effect on improving banana quality and extending the freshness period. The study reveals the potential of fermentation technology in the banana industry and provides a scientific basis and practical guidance for future applications. Despite the limited scale and scope of the experiment, fermentation technology shows great potential and application value in banana post-processing. It is expected that through further research and development, fermentation technology can be more widely applied in the banana industry, revolutionizing global banana production and consumption and becoming an important force for innovation and sustainable development of the food industry.

## Disclosure statement

The author declares no conflict of interest.

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