Research on the Application of Vacuum Freeze-drying Technology for Food

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Abstract: Vacuum freeze-drying technology is the best way to preserve the quality of food at present, which can maintain the nutrition and flavor of food to the maximum extent. It has the characteristics of being green, convenient, and nutritious. This paper analyses the principle of vacuum freeze-drying technology and introduces its application in the processing of fruits and vegetables, meat food, aquatic products, and drinks, discusses the four operation processes of pre-treatment, pre-freezing, freeze-drying, and post-treatment, and finally summarizes the existing problems, deficiencies and development prospects.

1. Introduction

During processing, storage, transportation, and other processes, fruits and vegetables are prone to various physical and chemical changes, resulting in changes in taste, nutrition, morphology, and other aspects [1]. Therefore, carrying on the deep processing of fruits and vegetables is necessary. The drying methods of fruits and vegetables mainly include microwaves, heat pumps, hot air, and variable temperature and pressure difference extrudation technology [2]. Vacuum freeze-drying technology is the best way to preserve the quality of fruits and vegetables, which can retain nutrients greatly, and the structure is not easy to deform [3]. It combines vacuum and freezing applied to food processing to form freeze-dried food. In daily life, this kind of food is not added preservatives. It is stored for a long time and can maintain the initial shape of the food but also retain its color, fragrance, taste, nutrition, etc [4]. Vacuum freeze-drying technology has also become a very important food processing technology. In recent years, it has been paid attention to and developed rapidly.

2. The principle of vacuum freeze-drying technology

If the freezing point of water is constant, the boiling point will also decrease as the pressure decreases. When the pressure is low enough that water's boiling and melting points are almost the same, ice can be vaporized into a gas without going through the liquid phase [5]. This process is called sublimation. The vacuum freeze-drying technology transforms the three forms of water through the processing technology to balance the three. Further, it applies the sublimation principle to achieve the purpose of food freezing.

Since the food is in a low temperature and vacuum environment, most biological reactions will be stagnant, which has a good drying effect on food with high heat sensitivity and easy oxidation. The material structure after vacuum lyophilization is porous, and its solubility and rewaterability are ideal [6]. In the sublimation process, substances dissolved in water can precipitate quickly, which is a good way to slow down the loss of inorganic salts in food. The vacuum freeze-drying technology can remove 95% ~ 98% of the water in the raw material, and the dehydration is relatively thorough. In addition, the freshness of the food after rehydration is higher than that of other drying methods.

3. Application of the vacuum freeze-drying technology

3.1. Application in fruits and vegetables

The nutritional value of vegetables and fruits is high, but their disadvantages are easy to rot and deteriorate and not easy to store and transport [7]. The vacuum freeze-drying technology can change fruits and vegetables into dehydrated and freeze-dried fruits and vegetables, remove the water in fruits and vegetables, but still retain the chlorophyll, vitamins, and other nutrients in fruits and vegetables. When eating, we only need to soak the freeze-dried food in water to recover to maximize the retention of the original color, taste, and nutrition. The technology has been applied to dozens of fruits and vegetables, including carrots, tomatoes, peppers, mushrooms, apples, bananas, strawberries, peaches, cantaloupes, and so on. As a new food, freeze-dried fruits and vegetables are becoming more popular among consumers.

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3.2. Application in meat food and aquatic products

China is a big consumer country of meat food and aquatic products, with wide varieties. The researchers also studied the application of vacuum freeze-drying technology to meat and aquatic products [8]. The study found that the technology can improve the quality, extend the shelf life, increase the acceptance rate of consumers, expand the variety of freeze-dried food, and increase the added value and sales channels of meat and aquatic products. Currently, the existing freeze-dried meat products and aquatic products are beef, pork, chicken, shrimp, kelp, squid, sea cucumber, shellfish, and so on. Nowadays, frozen-dried meat and aquatic products have reached a high proportion in the international market. The Chinese market has also begun to develop rapidly with considerable economic benefits.

3.3. Application in drinks

Coffee, juice, tea, and other drinks are dehydrated and dried by vacuum freeze-drying technology to form blended drinks to meet the needs of consumers for nutrition and health in fast-paced life [9]. Lyophilized rinsing and mixing drinks are nutritious and convenient, lightweight, small, easy to carry, and easy to preserve. They have good solubility, very low water content, and inhibit microbial growth.

4. The operation process of the vacuum freeze-drying technology

The operation process of the vacuum freeze-drying technology is pre-treatment → pre-freezing → freeze-drying → post-treatment [10, 11].

4.1. Pre-treatment

The pre-treatment includes cleaning, sterilization, reagent addition, and other operations, mainly to ensure the quality of raw materials and the high efficiency of raw materials in subsequent operations. In addition, the initial temperature of the food is directly related to the temperature after freezing, so it should be pre-cooled. Due to the variety of raw materials, there are many ways to operate the pre-treatment. For example, in the processing of raw materials of fruits and vegetables, to avoid the loss of nutrients and vitamins in fruits and vegetables, they are generally processed or refrigerated for 2 ~ 8 h after picking. As a second example, when cutting raw food materials into sheets, they should be cut according to the direction of the fiber tissue of the food. At the same time, the thickness should be thinner so that the water vapor can be better spilled in the subsequent processing and the food can be frozen quickly. The third example is that in the process of beef slicing, a slice of beef with a thickness of 0.1 m needs about 10 hours to be completely frozen, while a slice of beef with a thickness of 0.2 m needs at least 24 hours.

4.2. Pre-freezing

Pre-freezing is to freeze the liquid water in the raw material, reduce the damage, shrinkage, and loss of nutrients of the raw material during vacuum lyophilization, and ensure that the physical and chemical properties of the product after lyophilization are consistent with those before lyophilization. Because the raw material is easily oxidized in the air, which leads to deterioration, the initial temperature of the raw material itself will also have a non-negligible impact on the average temperature set by freezing. Therefore, the pre-freezing treatment of raw materials should be scientific and rigorous. Three factors should be considered in the pre-freezing process: time, temperature, and rate. Pre-freezing ensures the liquid is freezing thoroughly to prevent the freeze-drying vacuum due to uneven force damage and solute loss. Generally, the vacuum can be started after reaching the lowest temperature of pre-freezing for 1 ~ 2 h. The pre-freezing treatment can improve the water in the raw material overflow and further improve the freeze-drying efficiency of the raw material.

4.3. Freeze drying

Freeze drying, or lyophilization, is the most important and complex step in the whole process. Lyophilization is divided into sublimation drying and analytical drying. Sublimation drying is heating the pre-frozen raw material in a vacuum to remove the sublimated water. The lyophilized product has good rehydration because of the voids left by the sublimation of solid water. But sublimation drying removes only 90 percent of the water in the raw material. In the raw material, there is still a portion of water in the capillary tissue that has not been frozen. To increase the water removal rate, the temperature in the device should be raised to the highest temperature acceptable to the product through analytical drying and maintained until the end of lyophilization so that the residual water evaporates into steam. At the same time, the lyophilization unit is in a high vacuum state, allowing water vapor to escape through the push generated by internal and external gas pressure. After analytical drying, the product moisture residue is generally only 0.5% ~ 4.0%. In the process of vacuum lyophilization, food mainly absorbs heat. The freeze-drying heating methods include conduction heating, microwave heating, and radiation heating.

4.4. Post-processing

The purpose of packaging is to facilitate the transportation and storage of food. Freeze-dried food has a porous and loose structure, which allows it to have excellent rehydration and easily oxidized and easy-to-breed microorganisms. Therefore, freeze-dried food packaging and sterilization treatment are stricter. According to the characteristics of food and transportation requirements, the packaging of freeze-dried food is usually oxygen-free, waterproof, and light-free, so aluminum-coated film, PET, and PP composite materials can be selected to meet the

above three points. The packing form can be vacuum or gas (nitrogen or carbon dioxide). The sterilization method of freeze-dried food generally uses ultraviolet and radiation sterilization. The sterilization effect is good, mainly for most bacteria, bacteria. Ultraviolet sterilization can achieve almost 100% sterilization rate in a very short time. In addition, ultraviolet and radiation sterilization system does not have toxic or flammable safety risks. It has a high-cost performance and low cost.

5. Problems and shortcomings

There are four main problems in vacuum freeze-drying technology. The first problem is high energy consumption and high cost. How to reduce energy consumption and cost is the next important research direction. Secondly, lyophilized food absorbs water quickly, the rehydrating ability is strong, and food absorbs moisture easily, resulting in oxidative degradation. Thirdly, the lyophilized food is large and fragile, which is unsuitable for packaging, transportation, and sales. Fourthly, there are a few types of lyophilized food, and most of them are dried for raw materials without deep processing.

Therefore, vacuum freeze-drying technology should be closely linked with deep food processing in the future. A new research direction can be formed by combining fashion, health, fast food, and other hot issues.

6. Development trend of vacuum freeze-drying products

The future vacuum freeze-drying products will be precise and customized. This generation of products is the most cutting-edge vacuum freeze-drying product at present. It uses the most advanced technological means, and big data analysis means to achieve the purpose of precise and personalized nutrition and health regulation. Compared with the existing vacuum lyophilized products, more attention is paid to the effects, culture, taste, and other attributes of the products, and the food presentation is more diversified and modern. This kind of vacuum freeze-dried product is bound to become the development direction of the future freeze-dried products market.

7. Conclusions

Vacuum food freeze-drying technology is widely used and plays an important role in the future development of food preservation in China. In the future, practitioners will combine advanced international technology and equipment to make it more economical. It is necessary to conduct more in-depth research on the equipment, process, and theory level. Food vacuum freeze-drying technology can also be integrated with other technologies to promote the further development of this technology. In conclusion, with the deepening of research and the continuous development of the market, vacuum food freeze-drying technology will have a broad development space and application prospect.

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