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ANALYSIS OF THE PROCESS OF DEHYDRATION OF FRUITS BY VACUUM SUBLIMATION METHOD

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Abstract: The dehydration of fruits has been a popular method for preserving fruits and enhancing their shelf life for centuries. One of the most innovative and promising techniques in this field is the vacuum sublimation method. This process involves the conversion of water from its solid form (ice) to gas (water vapor) without passing through the liquid phase. This article aims to analyze the process of dehydration of fruits using the vacuum sublimation method, highlighting its benefits, applications, and potential for future developments.

Key words: Dehydration of fruits, shelf life, conversion of water, vacuum sublimation, future developments.

Introduction. Understanding Vacuum Sublimation Method. Vacuum sublimation is a process that takes advantage of the principle of sublimation, which occurs at low pressure and temperature conditions. In the case of fruits, this method involves placing the fruit in a vacuum chamber and subjecting it to low pressure and controlled temperature conditions. Under these conditions, the ice within the fruit sublimes directly into water vapor, effectively removing the water content from the fruit without causing any damage to its texture, flavor, or nutritional value.

The average initial water content ranged from 62.2% wb to 63.1% wb. Freeze-drying at various vacuum pressures and drying time resulted in the moisture content of freeze-dried strawberries ranging from 9.6 %wb to 43.9%wb. The lower the pressure and the longer the drying time, the lower the moisture content of freeze-dried strawberries. This happens because the lower the pressure and the longer the drying time, the more water molecules that evaporate from the strawberries and the free water on the surface of the material can be easily evaporated during the drying process so that the water content in the material is getting lower. The lower the pressure and the longer the drying time also result in the greater of heat energy in the air so that the amount of mass of liquid that is evaporated from the surface of the freeze-dried strawberries increases. Freeze-dried strawberries with a drying time of 36 hours produced a moisture content of 15.9% and 9.6%, respectively, for a vacuum pressure of 0.5 mBar and 0.1 mBar. This is consistent with the value of weight loss in the fruit, where drying time for 36 hours for a vacuum pressure of 0.5 mBar and 0.1 mBar resulted in the highest weight loss, namely 67.5% and 81.5%, respectively. Moisture content has a correlation with weight loss because both are affected by water loss from the inside of the material. The pressure and time of drying had a significant effect on the firmness of the fruit. The longer the drying time and the lower the pressure, the lower the fruit hardness [1]. The highest fruit hardness value occurred at a drying time of 12 hours, which was 8.17 kgf and 6.45 kgf for a vacuum pressure of 0.5 mBar and 0.1 mBar, respectively. This happens because the frozen water before drying has not been completely sublimated so that the porous nature of the strawberries has not been formed. This also indicates that the primary drying process in which frozen water and solvent are

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removed by sublimation has not yet ended. Vacuum freeze-drying of biological materials is one of the best methods of water removal, with final products of highest quality. The solid state of water during freeze-drying protects the primary structure and the shape of the products with minimal volume reduction. In addition, the lower temperatures in the process allow maximal nutrient and bioactive compound retention. This technique has been successfully applied to diverse biological materials, such as meats, coffee, juices, dairy products, cells, and bacteria, and is standard practice for penicillin, hormones, blood plasma, vitamin preparations [2]. Despite its many advantages, having four to ten times more energy requirements than regular hot air drying, freeze-drying has always been recognized as the most expensive process for manufacturing a dehydrated product. The application of the freeze-drying process to plant-based foods has been traditionally dedicated to the production of space shuttle goods, military or extreme-sport foodstuffs, and specialty foods such as coffee or spices. Recently, the market for 'natural' and 'organic' products is, however, strongly growing as well as the consumer's demand for foods with minimal processing and high quality. From this perspective, the market for freeze-dried plant-based foods is not only increasing but also diversifying. Freeze-dried fruits and vegetables chunks, pieces, or slices are nowadays majorly used in a wide range of food products such as confectionaries, morning cereals, soups, bakeries, meal boxes, etc. Instant drinks are prepared out of freeze-dried tea, coffee, or even from maple syrup enriched with polyphenol concentrated extracts from trees [3]. The possibilities are endless. In this review, the application of freeze-drying to transform plant-based foods was analyzed, based on the recent research publications on the subject and personal unpublished data. The review is structured around the following related topics: latest applications of freeze-drying to plant-based foods, specific technological problems that could be found when freeze-drying such products (i.e., presence of cuticle; high sugar or lipid concentration), pretreatments and intensification technologies employed in freeze-drying of plant-based foods, and quality issues of these freeze-dried products. The more recent freeze granulation technology involves spraying droplets of a liquid slurry or suspension into liquid nitrogen followed by freeze-drying of the frozen droplets.

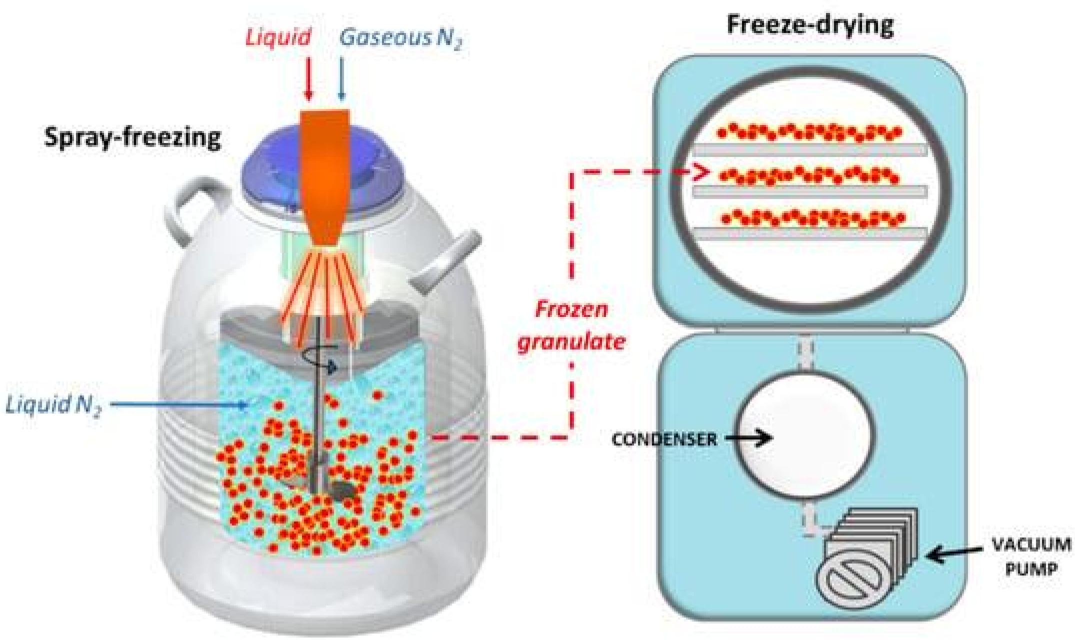

Figure 1. Freeze-granulation process.

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Benefits of Vacuum Sublimation Method. The vacuum sublimation method offers several advantages over traditional dehydration techniques. Firstly, it allows for the preservation of a fruit's original taste, color, and nutritional properties due to the gentle and controlled removal of water. This is in contrast to conventional methods such as sun drying or hot air drying, which can often result in the degradation of the fruit's natural attributes [4]. Secondly, the vacuum sublimation method can significantly reduce the processing time required for dehydration, making it a more efficient and cost-effective technique for large-scale production. Furthermore, this method minimizes the risk of contamination and microbial growth, thereby enhancing the overall quality and safety of the dehydrated fruits. Applications and Future Developments. The application of the vacuum sublimation method extends beyond fruit dehydration. This technique has found relevance in various industries, including food processing, pharmaceuticals, and space research. In the food industry, it can be utilized to produce high-quality dried fruits, powders, and concentrates. In the pharmaceutical sector, the vacuum sublimation method is employed for the dehydration of sensitive compounds and the production of pharmaceutical products with enhanced stability and bioavailability. Looking to the future, ongoing research and advancements in vacuum sublimation technology are likely to further optimize the process, enabling the dehydration of a wider range of fruits and potentially introducing new applications in fields such as nanotechnology and advanced materials. Challenges and Considerations. Despite its numerous advantages, the vacuum sublimation method presents certain challenges, particularly in terms of initial investment cost and specialized equipment requirements. Additionally, the process parameters, including pressure and temperature, need to be meticulously controlled to achieve optimal results. Moreover, the scalability of the method for industrial use and its compatibility with different fruit types require further investigation and refinement. Addressing these challenges will be crucial for expanding the commercial viability and widespread adoption of this innovative dehydration technique. Plant-based foods, including fruits, vegetables, seeds, beans, spices, etc., are important components of a healthy diet, and their sufficient regular consumption could help to prevent certain major diseases such as cancer and cardiovascular diseases, etc. According to the combined report of World Health Organization and Food and Agriculture Organization, it was recommended that a daily minimum consumption of 400 g of fruits and vegetables may help to minimize the occurrence of chronic diseases along with the mitigation of micronutrient deficiencies. Fresh plant-based foods may not available all year round for consumption and the long-term storage of fresh foods could be challenging due to high water content, unavailability of cold-storage facilities (particularly in underdeveloped and developing countries), and possibility of nutritional deterioration. Consequently, drying of such foods may allow their long-term consumption and eases handling, transportation, and storage [5]. Lately, the application of microwave energy to intensify freeze-drying regained attention. Microwave heating has been studied since the 1970s in relation to the acceleration of freeze-drying. The attractive aspect of this heating source is that it is an energy input that not only is essentially unaffected by the dry layers of the material undergoing freeze-drying, but also that is absorbed mainly in the frozen region. Since the frozen region has a high thermal conductivity, microwave energy helps sublimation to decrease freeze-drying times up to 60–75%. In addition, when compared to conventional freeze-drying, microwave assisted freeze-drying may lead to products of similar/better quality. Although microwave freeze-drying can offer unique advantages, the inherent problem preventing its commercialization is the difficulty in controlling the final product quality and assuring its uniformity, resulting from corona discharge and nonuniform heating, which cause ice melting and overheating

Conclusion. In conclusion, the vacuum sublimation method offers a promising approach to the dehydration of fruits, providing numerous benefits in terms of product quality, processing efficiency,

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and versatility across various industries. As research and development in this field continue to progress, the potential for further advancements and applications of this method appears substantial. By addressing the current challenges and harnessing the full potential of vacuum sublimation, we may witness a significant transformation in the way fruits are dehydrated and preserved, ultimately benefiting consumers, producers, and industries alike.

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