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Factors that Impact Small-Scale Freeze Dryer Effectiveness

Authored by Matthew Zimmerman, Undergraduate Research Assistant, Department of Food Science and Technology, Virginia Tech; Theeratart (DJ) Sukthavorn, Graduate Research Assistant, Department of Food Science and Technology, Virginia Tech; Melissa Wright, Director, Food Producer Technical Assistance Network, Department of Food Science and Technology, Virginia Tech; and Alexis M. Hamilton, Assistant Professor and Extension Specialist, Department of Food Science and Technology, Virginia Tech

Introduction

Freeze drying is a food processing method used to extend the shelf-life of foods while maintaining more of their nutrient content when compared with traditional drying methods (such as heat-based drying). Freeze drying works by freezing a food product solid and then pulling a vacuum to remove water through sublimation (Figure 1), decreasing the available water in the food for microorganisms to use (water activity).

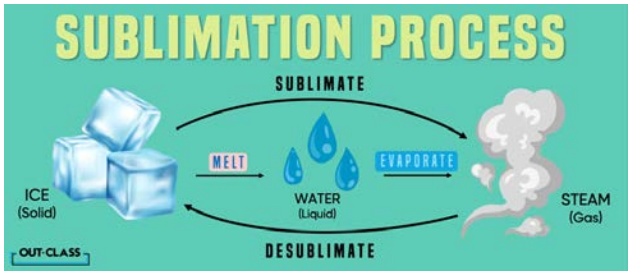

Figure 1. Diagram of the sublimation process (Khan).

Water activity (measured on a scale of 0-1) is an important parameter when assessing food product stability and safety. It is a measure of the water available for microorganisms to use. By decreasing the water activity within the food matrix, microbial growth is slowed or stopped, making the food shelf-stable. In general, reducing the water activity below 0.85 renders the product a water activity-controlled food, but reducing it below 0.6 can significantly extend the shelf-life of a product by preventing any microorganisms from growing in the food, including spoilage organisms (for example, yeasts and molds).

To provide support for food producers involved in food production with small-scale freeze dryers (for example, those commonly used in home- or commercial kitchen-based businesses), the following results and recommendations are provided to ensure safe, high-quality freeze-dried foods.

Study Design

Four fresh produce commodities (apples, bananas, bell peppers, and onions) were evaluated over a 24-hour period under two sizes (small or large dice) when stored in two types of containers (plastic, zip-sealed bags and glass jars with two-piece lids) to determine how these variables could impact the decrease in water activity that occurs in the freeze-drying process (Figure 2).

Figure 2. Example of diced apples placed on stainless steel trays prior to freeze-drying.

Each freeze-drying event evaluated one commodity at two timepoints (immediately after freeze-drying and 24 hours after freeze-drying) stored in one type of container. Immediately after freeze-drying, half of the samples were crushed and water activity

measured. The remaining samples were stored in a container for 24 hours before being crushed and measuring water activity.

Study Findings

In general, water activity differed by commodity, with bell peppers having the highest. The water activity of large diced produce (14 millimeters by 14 millimeters) produce was also higher than small diced (7 mm by 7 mm).

After storage for 24 hours, water activity increased for all commodities except apples (Figure 3). Samples stored in glass containers showed less variability in water activity after 24 hours, except onions (Figure 3).

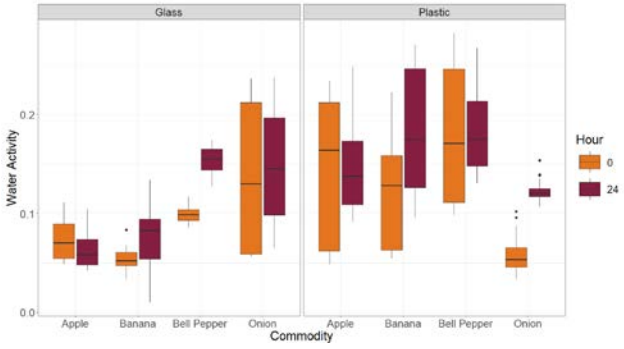

Figure 3. Boxplot showing the variability in water activity in four commodities over 24 hours when stored in glass jars or plastic bags.

Even though water activity appeared to shift over time when in different storage containers, the water activity did not ever rise above 0.6, indicating that no food safety or spoilage risk occurred.

Recommendation

While all commodities of all dice sizes could be freeze-dried to a final water activity below 0.6, it is important for producers to prioritize consistency in product preparation to ensure an even freeze-drying process so that all components of the foods can be dried to an appropriate water activity to preserve the safety and quality of their products.

If food producers want to minimize product variability related to water activity when storing freeze-dried products, they should store the products in containers that minimize gas exchange between the product and the external environment (for example, glass jars or insulated packaging) and/or consider adding a moisture-absorbing pouch to products that are intended to be continually opened and resealed for prolonged consumption.

Additional Resources

Danao, M-G. C. Freeze Drying and Potential Food Safety Challenges. 2025. https://www.afdo.org/wp-content/uploads/2025/01/Freeze_Drying_and_Potential_Food_Safety_Challenges.pdf.

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Labuza, Ted P., K. Acott, S. R. Tatinl, R. Y. Lee, Jv Flink, and W. McCall. “Water activity determination: a collaborative study of different methods.” *Journal of Food Science* 41, no. 4 (1976): 910-917.

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