Comparative Study of Air and Plate Freezing Techniques for Meat Preservation

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Abstract

This review provides a detailed comparison between air freezing and plate freezing methods used for preserving meat. It emphasizes how each technique affects important quality aspects of meat, including texture, color, drip loss, microbial stability, and energy usage. While both methods are commonly applied in the meat industry, they vary notably in terms of their effect on meat quality and cost-efficiency. The review also highlights recent technological developments in freezing methods such as plate and air blast freezing. In conclusion, the paper offers recommendations on how to best apply these techniques to achieve optimal results in meat processing and preservation.

Keywords: Air freezing; Plate freezing; Meat preservation; Drip loss; Texture; Freezing rate

I. INTRODUCTION

Freezing is one of the most widely used preservation techniques in the meat industry, serving to significantly extend shelf life, reduce microbial activity, and maintain the nutritional and sensory attributes of meat products. By lowering the temperature of meat below its freezing point, microbial growth and enzymatic reactions are considerably slowed, ensuring safer consumption and broader market distribution. Among the various freezing techniques employed, air freezing and plate freezing stand out as the most commonly adopted methods in industrial settings due to their practicality, energy efficiency, and compatibility with different meat products.

Air freezing, which includes methods such as still air and blast freezing, operates by circulating cold air over the meat surface. It is flexible and suitable for a variety of product sizes and shapes, although it may require longer freezing times and can lead to greater dehydration or freezer burn. In contrast, plate freezing involves placing

meat between two refrigerated metal plates, allowing for faster heat transfer through direct contact. This method is particularly advantageous for flat, uniformly shaped products and offers more rapid and uniform freezing, often resulting in reduced ice crystal formation and improved product quality (Zhang et al., 2009).

The choice between air and plate freezing has a direct impact on the physicochemical and sensory properties of meat, including texture, water-holding capacity, color, and drip loss during thawing. Additionally, freezing kinetics, energy consumption, equipment cost, and processing time differ significantly between the two methods, influencing the overall economic feasibility and operational efficiency in industrial applications (Farouk et al., 2014).

This paper provides a detailed comparative analysis of air and plate freezing techniques with a focus on their operational principles, freezing kinetics, effects on meat quality parameters, and economic considerations. Understanding these factors is essential for optimizing meat preservation strategies and ensuring high-quality end products in the food industry (Leygonie et al., 2012).

II. PRINCIPLE AND OPERATION OF FREEZING TECHNIQUES

A. Air Freezing

Air freezing, also known as blast freezing, involves circulating cold air (typically between -18°C to -40°C) around meat products. The method is versatile and suitable for irregular shapes. However, due to slower freezing rates, it often results in the formation of large extracellular ice crystals that damage muscle fibers (Wang et al., 2010).

B. Plate Freezing

Plate freezing employs metal plates cooled by refrigerants that make direct contact with meat. This contact freezing significantly accelerates the process, often achieving freezing temperatures within minutes. Rapid freezing minimizes ice crystal growth, preserving muscle integrity and juiciness (James et al., 2002).

III. EFFECT ON MEAT QUALITY

A. TEXTURE AND MICROSTRUCTURE

Air freezing tends to produce coarse ice crystals, causing muscle fiber rupture and resulting in tougher texture post-

thaw. Plate freezing forms smaller crystals, maintaining better structural integrity. Microscopy studies confirm less cellular damage in plate-frozen meat.

B. DRIP LOSS

Drip loss is a critical indicator of meat quality. Studies have shown air-frozen meat exhibits higher drip loss (4–6%) compared to plate-frozen meat (1.5–3%). This is attributed to greater exudation due to structural damage in air freezing.

C. COLOR STABILITY

Color is a key sensory attribute affected by myoglobin oxidation. Plate freezing maintains better color stability due to limited oxidative reactions during rapid temperature reduction. Air freezing may result in browning or pale discoloration (Li et al., 2019).

D. MICROBIAL STABILITY

Both methods lower microbial activity by reducing temperature below the microbial growth threshold. However, plate freezing is marginally more effective due to quicker attainment of safe core temperatures, reducing microbial load faster.

IV. ENERGY EFFICIENCY AND OPERATIONAL COST

A. ENERGY CONSUMPTION

Air freezing systems require continuous air circulation, leading to higher energy usage. Plate freezers, with direct contact heat exchange, are more energy efficient, particularly for large-scale batch freezing.

B. EQUIPMENT AND MAINTENANCE

Air freezers are less complex and have lower initial costs but require more energy and time. Plate freezers have higher capital investment but offer lower operational costs and better energy utilization in the long run (Sun et al., 2011).

V. RECENT TECHNOLOGICAL ADVANCEMENTS

Modern freezing technologies integrate cryogenic and hybrid methods, combining air and contact freezing. Innovations in plate freezer design include enhanced refrigerant distribution and surface conductivity coatings for even faster freezing. Air freezing improvements focus on airflow dynamics and humidity control.

VI. APPLICATIONS IN MEAT INDUSTRY

Plate freezing is highly suited for standardized meat blocks used in industrial processing, whereas air freezing is

preferred for whole carcasses and irregular cuts. Meat exporters choose methods based on logistics, scale, and required shelf life.

VII. CONCLUSION

Both freezing methods offer distinct advantages. Air freezing is flexible and cost-effective for small operations, while plate freezing ensures superior meat quality and is ideal for bulk processing. An integrated approach, utilizing both techniques where appropriate, can maximize quality retention and operational efficiency in meat preservation.

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