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The art of air blast freezing: Design and efficiency considerations

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ABSTRACT

Air blast freezing is a common freezing technique used throughout the world to freeze various food commodities from carcasses to packaged goods. The New Zealand Cold Storage industry identified blast freezing as the most energy intensive operation in the frozen food storage industry, consuming 8.1 GWh of electricity in New Zealand in 2005. This paper presents an overview of various types of blast freezers, their common design flaws, common energy saving measures and a best practice guide. A simulation model has also been presented to predict the performance and to design an optimal system under range of operating conditions.

1. Introduction

Air blast freezing is the process of taking a product at a temperature (usually chilled but sometimes at ambient temperature) and freezing it rapidly, between 12 and 48 h, to its desired storage temperature which varies from product to product (e.g. fish = −20 °C, beef = −18 °C). Typically, the evaporator temperature in a blast freezer refrigeration system ranges between −35 °C and −52 °C. Slow freezing produces large ice crystals, which grow through cell walls, permitting an accelerated penetration of oxygen, causing rancidity and browning of meat and enhancing the danger of higher drip on thawing. Therefore, rapid freezing is required to maintain food quality as it produces small ice crystals due to a higher number of nucleation points from which ice crystals form.

Air Blast freezing is classified as a forced convection phenomenon where the use of fans increases the products surface heat transfer coefficient and produces a more uniform air temperature throughout the freezer. The air velocity, and hence heat transfer coefficient, can be altered with the use of variable speed drives (VSD's). The main detriment of forced convection in blast freezers is the use of large fans that add significantly to the total heat load on the refrigeration system and running costs. Also, unwrapped foods are prone to moisture loss during blast freezing as the absolute humidity of the bulk air is usually lower than that of the air at the surface of the food.

Although air blast freezers have been used in industry since the 1950's, limited number of technical studies have been published on specific aspects of the topic in the open literature [1,3,12,24,26,31,42,51,52], and there is hardly any study that summarises all aspects of blast freezers at one point in a single study. Therefore, this paper presents an overview of blast freezers of their working principle, historical background, different designs, efficiency issues, a modelling perspective and a best practice guide.

2. Origin of air blast freezers

The early freezing rooms typically consisted of bare pipe grids in the ceiling above rails on which sheep carcasses and beef quarters were hung. These freezing rooms relied on the natural convection of cold air, typically around −15 °C, and resulted in freezing times up to three days. Following World War II the world faced a serious food shortage. A major New Zealand innovation was the air blast freezer which enabled rapid freezing for high export quantities. The air blast freezer used fans to blow air at low temperatures (down to −30 °C) over carcasses reducing freezing times to between 10 and 24 h. This ability to freeze and transport food to distant markets made refrigeration a highly profitable trade and in fact made New Zealand one of the richest countries in the world in the 1950's and 1960's.

The New Zealand company Ellis Hardie Syminton Ltd patented the A189 air-blast freezer in about 1950 [1]. The concept was to use

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