MODIFICATION OF AIR FLOWS WITHIN AN INDUSTRIAL CARCASS CHILLER USING DELTA WING VORTEX GENERATORS

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ABSTRACT

The chilling of carcasses after slaughter has a considerable bearing on process costs and quality of the meat. Uniform air distribution is essential for the optimal operation of carcass chillers, yet many existing chillers have highly variable and ineffective air flow. This directly affects the uniformity of evaporative weight loss and carcass cooling rates within the chiller.

Delta plan aerofoils are known to convert a unidirectional air stream, progressively into a rotational and then turbulent multidirectional fragments of moving air. The aim of this research was to evaluate the use of delta wings to improve air flows inside a venison carcass chiller of typical design used in the New Zealand meat industry.

Air flow patterns within the chiller were characterised by measuring mean air speeds with a hot-wire anemometer over 61 grid points at 4 levels in height. Air speeds were found to be highly time-variable so the mean, standard deviation and range of 60 one second air speed measurements were used to represent the air flow at each point on the grid. The measurement of air velocity (speed and direction) using three othoganally mounted propeller anemometers had limited success, as air speeds within the chiller were often below the threshold of the anemometer.

Measurements before the installation of the delta wings indicated that a poor air flow distribution existed within the chiller as the majority of air was found to circulate around the walls and floor, producing near stagnant conditions between the carcasses.

Delta wings were constructed in two sizes from thin aluminium sheets. Wings were installed into the chiller by suspending them from the ceiling within the evaporator fan delivery air stream. Two wing configurations were trialed: The first wing configuration utilised 3 large delta wings mounted in front of the evaporator fans followed by a row of 6 small wings then a row of 7 small wings (3,6,7). The second delta wing configuration utilised a row of 6 large wings closest to the evaporator fans followed by a row of 9 small wings then a row of 13 small wings (6,9,13).

The second delta wing configuration showed superior performance over the first. In comparison to the unmodified chiller without wings, the mean air speeds in the critical region amongst the carcasses increased from 0.4 m/s to 0.6 m/s; the standard deviation of mean air speeds decreased from 0.33 m/s to 0.22 m/s and the percentage of mean

air speeds between half and twice the mean increased from 84% to 95%. The second configuration of delta wings also produced a 14% increase in the mean air turbulence intensity (measure of the time-variability in air speed) and reduced the variability of evaporative weight loss within the chiller.

Overall, the delta wings were found to be an economic way to improve the performance of a chiller by providing a more uniform and effective air distribution without increasing fan power. This can result in a reduction in chilling times and less potential for weight loss. Their use in both new and existing chillers is recommended.

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Chapter 1

INTRODUCTION

The New Zealand meat industry continues to be a major contributor to New Zealand's economy. Since the 1880's it has been responsible for a large proportion of New Zealand's gross domestic product and foreign exchange earnings; in 1996 contributing 16.3 percent to the total value of exports (Beattie, 1996).

New Zealand produces around 1 million tonnes of meat per year, most of which is destined for overseas markets. Although, this makes up only 0.4 percent of the worlds total meat protein output, it equates to approximately 17 percent of all internationally traded meat. This can be broken down into a 7 percent share of world beef and veal exports and a 44 percent share of world sheep meat exports (Willis, 1992).

New Zealand still faces strong tariff and non-tariff barriers to free trade of agricultural products. These have restricted the volume growth of exports and real increases in prices. Subsidised returns to farmers in the US and OECD countries encourages excess production. This surplus competes directly with New Zealand's exports. When this occurs, New Zealand farmers receive artificially low returns for their produce. The significant cost of long distance transportation to many of New Zealand's major markets and barriers to free trade means that New Zealand's agricultural products must be produced at a lower cost, more efficiently and be of superior quality to compete with those of its competitors.

The refrigeration of meat makes up a significant proportion of the products final cost, as it is used extensively in the processing, transport and storage of meat. Capital investment, fan power, compressor energy and product weight loss all contribute to the cost of refrigeration. Refrigeration also has a significant impact on the final quality characteristics of the product. The microbial condition, tenderness and appearance are all affected by the environment, prior to and throughout the "cold-chain".

Increased competition has led to a larger range of product choice for the overseas consumer. The market for frozen meat is declining as more consumers demand chilled

"fresh meat" cuts. This trend has forced a change in the meat industry towards the further processing of meat before it reaches the point of sale. Higher prices due to increased demand for further processed chilled meat have driven this shift which has resulted in dramatic changes in the export of sheep and beef.

In the year ended June 1992, 3 percent of New Zealand's sheep meat was exported in the unfrozen form. Since 1992 the quantity of chilled, fresh lamb exports has doubled, contributing to 7 percent of the total sheep meat exports in 1996. The volume of chilled lamb exports is expected to continue to grow and command premium prices (Lynch, 1996). These shifts have also been evident in beef processing where the export of traditional frozen beef quarters have been replaced by chilled, boneless, plastic wrapped primal cuts.

Such changes have been made possible by developments in the technology associated with the commercial refrigeration of meat. In particular, developments to better control the environment in refrigerated shipping facilities has enabled the transport of chilled meat cuts to distant markets, replacing the need to transport whole frozen carcasses. The introduction of vacuum and modified atmosphere packaging has also contributed to this change by extending the products shelf life.

Temperature, relative humidity, air velocity and air distribution make up the environmental conditions inside a refrigerated space. The effects of temperature and relative humidity on product characteristics are well understood and both can be controlled relatively easily. In contrast, the effects of air velocity over the product and air distribution within the room are less well understood and tend to be more difficult to control. However, adequate air velocity and a uniform air distribution are crucial to effective chilling and the holding of product in a chilled state. The products microbial quality, chilling rate, weight loss and uniformity of chilling are all directly affected.

The overall aim of this research is to consider meat carcass chiller design and operation from an air velocity and distribution perspective. In particular, the objective is to improve the uniformity of air flow across the product and increase chilling rates whilst minimising the rate of evaporative weight loss and fan energy requirements.