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THE EFFECT OF PRECISE TEMPERATURE CONTROL IN REFRIGERATED CONTAINERS ON THE EXTENSION OF SHELF LIFE IN CHILLED MEATS

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Background:

In most areas of the globe, chilled red meats, poultry, fish and game meats are preferred over frozen meats by consumers who are willing to pay a premium for these products. Many processors and distribution systems are gearing now to provide high quality, safe and highly palatable fresh, precooked chilled meat products for retail or food service operations. However, when long range shipment is involved, most of these products are transported in a frozen state or chilled in expensive air freight. Therefore, precise temperature control through shipping, storing and retail displaying of chilled meats is the challenge for the 9O's in order to extend shelf life and improve quality and safety of chilled meats and meat products.

Objectives:

The objectives of this work were the following:

1. To improve The temperature control system in standard marine frozen foods containers used for trans-oceanic shipment of meats into Superchill system performance or better, as to temperature fluctuation, elimination of hot and cold spots, improved insulation, etc..

2. To develop a portable system which could be removed at the end of the voyage, thus providing flexibility as to the next usage of the container.

3. To develop an insulation system which could be installed in part of the container, thus enabling the usage of the container for several chilled and frozen products kept apart and maintained at different temperatures.

4. To accurately control microbial growth, rancidity and enzymatic reaction in meats, thus, allowing extended shelf life and retaining quality of chilled meats, enough for transoceanic shipment or for long range land distribution.

Materials and Methods:

A batch of 4000-7000 lbs of vacuum packaged chilled venison meat was loaded together with up to 13,000-16,000 lbs of frozen venison into 20 marine containers which can maintain -18°F temperatures (Mutsubishi, Nippon Fruehauf). The chilled venison meat was separated from the frozen venison meat by experimental insulation made of 1" foamed polystyrene plates which were laminated by sheets of Foilpak 926, made by Omega MFG and Marketing Ltd., Greenmount, New Zealand. The insulation layer was not hermetically sealed. The location of the chilled venison in the container, and the structure of the insulation material were tested in seven voyages from Auckland, New Zealand to San Francisco, California which lasted around three weeks from loading at the venison processing plant until unloading at Durham Meat Co., San Jose, California.

Temperature monitoring of both chilled and frozen venison meats, as well as air temperature in the two sections, was conducted by AUTOLOG - Time Temperature Monitor, Remonsys Ltd. Bristol, England. Temperature data were transmitted through satellite to the IQ Exports headquarters in Auckland, New Zealand on the hour and if needed, instruction to the ship to intervene with the refrigeration schedule was made by marine telephone. Temperature control of the chilled meat was evaluated as to temperature fluctuation and uniformity (hot and cold spots) throughout the container. The effective temperature control was evaluated as to The following: A. Location of the chilled meat in the container. B. Structure of the insulation. C. Microbial growth expressed as total plate count and as total psychiophiles growth as determined by AOAC standard methods. D. Lipid oxidation as expressed by TBA Values (mg of malonaldehyde/Kg of meat) were deterrnined by the methods of Salih, et al. (1987). E. Sensory evaluation. Preliminary evaluation was conducted by questioning chefs who used the product regularly and by complain monitoring. The chefs evaluated the chilled marine transported product vs. air freighted chilled product.

Results and discussion: In refrigerated marine containers and in refrigerated trucks, the refrigeration unit is located in the front of the container, while the doors are located in the back. The cold air stream is moving from the top front backwards as well as vertically from ceiling or floor ducts. The inconsistent operation of the refrigeration system, is created by on/off compressor activity and by startup and shutdown of the evaporator during defrosting cycles, resulting in continuous temperature fluctuation within the container during operation. Furthermore, the refrigerated container is not completely sealed and therefore external heat, air and humidity

penetrate into the container adding to the cooling load and to the non-uniformity of internal temperatures in different parts of the container. This penetration increases with the speed of traveling. Heat is also penetrating through the container's insulated walls. As a result, the temperature in the container is not uniform and constantly must be kept down by the refrigerating unit. A 36°F (20°C) difference between the front and back of the container were reported. The amount of cargo and its arrangement in the container also add to the problem due to restriction of airflow, which can result in hot and cold spots in different parts of the container. In order to minimize the temperature inconsistency and variability in the container that contains the chilled venison meat a special insulation was constructed to separate it from the frozen meat as well as from the influence of doors, walls, ceiling and floor. The structure of the insulation and the location of the chilled meat in the container were found to have major effects on temperature control within the chilled meat compartment.

1. **Insulation structure:** Three structures were evaluated. A. Foamed polystyrene sheets (FPS). B. FPS with external layer of Foilpak 926. This new insulation material consists of two sheets of aluminum foil, laminated by polyethylene to both sides of heavy duty kraft paper, and reinforced with glass fibers running in the long direction. C. FPS with external and internal layers of Foilpak 926. It was found that insulation C performed the best as to reducing temperature fluctuation.

Foilpak 926 is an extremely effective thermal insulation material when used with an air space, because of the high thermal reflectivity and low emmisivity of its aluminum foil surfaces, making the combination an excellent barrier to heat flow by radiation and convection. The combination of foamed polystyrene and Foilpak 926 created effective low cost insulating systems which could be specifically installed to the size of the chilled meat load and be removed at the end of the voyage providing full flexibility to usage of the container on the way back.

Three configurations for chilled meat location were tested: A. Back of the truck. B. Center of the truck. C. Surrounded with frozen meat.

Better temperature control was achieved when the chilled meat was placed in the back of the truck (configuration A). Furthermore, when insulation structure C was used together with configuration A, the chilled meat held at 28°F fluctuated by only +2°F thruought the container during a three week trip after reaching equilibrium. However the neighboring frozen meat which was held at 0°F experienced significant temperature fluctuations of +4°F before it settled down. Temperature uniformity was also significantly improved and probes at three different locations in the chilled meat compartment demonstrated similar time/temperature profiles.

The interaction between the frozen and the insulated chilled meat located in the other side of the insulation barrier was kept to a minimum. It seems the frozen meat serves as a cushion in absorbing the uneven airflow and the fluctuations due to the compressor off/on cycles and the evaporator's defrosting cycles. Where the chilled meat in the back of the container was well protected.

Microbial Growth: Venison meat is more resistant to microbial spoilage than beef, chicken, or fish, partially due to leaner meat and lower pH. Yet microbial growth of chilled venison meat could reach 10^7 levels during three weeks in transit in standard refrigerated containers as affected by the degree of temperature control, packaging and initial microbial contamination. When the insulation system was used and precise temperature control was achieved, microbial growth of vacuum packaged venison was significantly retarded, leaving considerable shelf life for local distribution. (Table 1)

TABLE 1. Expressed as Total Plate Count

Initial Insulation	Pre-Shipment Microbial Count	Post Shipment Count (Chilled)	Post Shipment Count (Frozen)
Foamed Polystyrene (FP)	$9.8x10^4$	$9.2x10^6$	$1.3x10^5$
FP & External Foilpak 926	1.3×10^4	$8.4x10^4$	4.2×10^3
FP & External & Internal Foilpak	$1.2x10^4$	$2.3x10^4$	
" (Second Shipment)	3.2×10^3	$3.5x10^4$	
Airfreight		$3.2x10^5$	

1. Three weeks of marine shipment, one week airfreight delivery
2. The chilled meat in the marine testing was located at the back of the container

It is worthwhile to notice that no modified atmosphere or organic acid was needed to keep microbial growth down. However, as initial microbial growth varied greatly from plant to plant, strict sanitation practices of plant, cutting knives, personnel and the refrigerated containers are advisable as well as rapid chilling of the slaughtered animals in order to keep initial microbial growth at low levels. It is

also interesting to find that the new marine system provided better microbial growth control than the air freighted system where shipment is completed in shorter time, but without temperature control system.

Lipid Oxidation: The TBA number has been the most extensively used for measurements for lipid oxidation during processing or storage of meats. It is expressed as milligrams of malonaldehyde (or malondialdehyde) per kilogram of tissue. Lipid oxidation shortens the shelf life of meats and foods due to development of rancid off flavor and off odor, sometimes associated with indescribable changes in color, texture and nutritional values. Venison meat is naturally low in fat and therefore it is less sensitive to rancidity and the vacuum packaging which reduces oxygen content further protects it. Table 2 indicates that all chilled and frozen pmducts arrived in good shape. Lipid oxidation of chilled meat behaved similarly to frozen meat and to air freighted meat. Lipid oxidation of the venison saddle was higher than in the deboned Denver leg. For comparison, a survey of content of malonaldehyde in variety fresh meats and cuts (beef, pork and chicken) in retail supermarkets showed that 60% of the samples ranged between 1.0-6.0 mg/kg where 38% contained less than 1.0 mg/kg (Siv and Draper, 1978). In the meat industry, 2.0 mg/kg and lower are considered as very good values.

TABLE 2. The Effect of Transoceanic Marine and Airfreight Transportation on Oxidative Rancidity of Venison Meat.

Milligrams of Malonaldehyde/Kg Meat

	Steamship		Airfreighted
	Chilled	Frozen	Chilled
Denver Leg (Deboned)	1.08	0.83	
Saddled	1.61	2.04	1.66
Average	1.35	1.44	1.66

Airfreighted shipment was tested one week after slaughtering

Sensory Evaluation: Chefs who constantly use airfreighted venison were questioned about the marine shipped chilled venison meat. Most of them preferred the chilled venison over frozen and over air freighted meat due to the prolonged aging that took place during shipment. The pH of the meat was found to be 5.7 upon arrival and drip losses were also small (around 1.5- 1.7%).

Conclusions: 1. A system for long-range transportation of chilled meats was developed by minimizing temperature fluctuations inside the refrigerated container to +2°F. enabling reduction of the meat temperature to 28 °F without freezing it during transportation and therefore greatly increasing its shelf life 2. The remote temperature monitoring via satellite enabled the producer to effectively monitor the product temperature during shipment and to make necessary corrections when needed. 3. The portable mature of the system enabled the use of less expensive standard refrigerated containers which proved more cost effective for the returning cargo. 4. The long range shipment of chilled meat enabled the aging process to take place while maintaining better microbial control than air-freight. 5. The process proved to have 80% lower cost than airfreight with better quality and safety results.

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