ABSTRACT

Frozen marine products constitute one of the major export items of India, contributing about 4% of her total foreign exchange earnings. Among different marine products, frozen shrimps account for about 90% of the total export in these items (MPEDA,1983; Manay and Shadaksharaswamy, 1987). For the production of high quality frozen shrimps and retention of quality as demanded in the international markets, it is essential to maintain a cold chain, with temperature maintained at required level right from the catch up to the consumer's store. It is particularly important to maintain the temperature below a certain desired level after the products are frozen, particularly during transport and storage as the damage to the quality caused by the temperature rise is additive. Therefore it is important to identify the weak points in the processing-storage-transportation chain and to provide necessary remedial measures.

Among the several ways of refrigeration liquid nitrogen(LN_2) refrigeration has been used extensively in developed countries. One of the methods of maintaining cold by LN_2 is by its intermittent spray (Polar Stream) within the cargo space. There are some practical difficulties in the use of this system, such as carrying the LN_2 dewars on the vehicle, decreasing the net pay-load, requiring trained personnel for operation and maintenance. Because of these practical difficulties the Polar Stream system has not found ready acceptance in Indian Industry. But, if the above difficulties could be overcome, the use of liquid nitrogen as a refrigerant in the transport of frozen foods would have distinct advantages. Studies on liquid nitrogen dump-charge-refrigeration technique in the transport of frozen shrimp have been taken up as the subject of this dessertation.

The basic principle of this mode of refrigeration is that all the refrigeration that would be needed to encounter the heat in-leak during the transportation period would be supplied once for all before the commencement of the journey by spraying liquid nitrogen over the frozen cargo in an insulated vehicle. This system of transportation would eliminate the need of carrying any refrigeration system on the vehicle. Apart from this, no trained personnel will be required during transit because of the absence of refrigerating machine on the vehicle. From the available literature it is apparent that no detailed study of this technique has been made so far.

If this system is adopted, the engineer at the warehouse needs to know the amount of liquid nitrogen to be sprayed and the corresponding rate of spray for a particular cargo, depending on the duration of transit and atmospheric condition. To establish these performance parameters, a theoretical model backed by laboratory experiments and field experience is needed.

Therefore, the objectives of the present study are ;

1. Formulation of a theoretical model based on the heat transfer analysis of dump charging method in order to find (i) time temperature history of the frozen food material during charging and transportation, and (ii) consumption of liquid nitrogen for a particular transit time.

2. Experimental study of the chilling and transportaion process using a laboratory scale uinit.

Basically the whole process of transportation is divided into two parts. The first part is the spraying of liquid nitrogen, i.e., supply of refrigeration and the second part is the actual hauling of

frozen food material, i.e., utilization of the accumulated refrigeration to encounter the heat leakage. During both these steps the heat transfer process is described by the familier Fourier's conduction equation :

$$\frac{\partial T}{\partial t} = \alpha \nabla^2 T$$

α being the thermal diffusivity of the frozen shrimp. The initial and boundary conditions during the period of charging and transportation are however quite different.

Model calculations using the solution of the theoretical model have been made on frozen material kept in a standard truck widely used in India. The cargo space is filled with master cartons containing frozen shimp blocks in such a way that there is a gap between these cartons and the side walls and the ceiling. Assuming that these master cartons are in perfect contact the whole cargo is considered to be a single homogeneous block. The thermophysical properties of this block have been determined by properly averaging the corresponding properties of shrimp, ice, and packaging material present in the master carton.

It is assumed that the liquid nitrogen is sprayed from all the sides in order to provide uniform cooling . The time temperature history, transporation time corresponding to a definite amount of liquid nitrogen sprayed have been found out.

The calculations made on the prototype vehicle should be verified by experiments using standard truck. But because of the reasons of cost, it was not possible to carry out experiment with a

standard vehicle in the laboratory. It was also not possible to do experiments on a commercially operating vehicle. So a small scale model of the truck was constructed. If the proposed theoretical model explains the experimental results, it is expected that the model can be used to predict the temperature profiles and the operating parameters for the standard truck. Temperatures at several locations were measured using a set of copper-constantan thermocouples. The data aquisition consisted of a 9 channel scanner and a microvolt DMM which were controlled by a computer (IBM-PC compatable). Interfacing was provided by a microprocessor kit based on Intel 8085. The software for the microprocessor and the computer were developed to facilitate automatic aquisition of temperature data. The thermocouple emfs were inverted and processed by the computer. All theoretical analysis was made on a HP 1000 computer system.

The general agreement between the experimentally observed and the computed temperatures suggests that our model may be used to predict the temperature profiles in the standard truck. The shipper may use our computed results to determine the amount of liquid nitrogen to be sprayed for a particular duty. The computation will also help in design of refrigerated transport vehicles using liquid nitrogen as refrigerant.