STUDIES ON TRANSIENT HEAT TRANSFER AND THERMAL PROPERTIES OF FOODS DURING FREEZING

A THESIS SUBMITTED TO THE
INDIAN INSTITUTE OF TECHNOLOGY, DELHI
FOR THE AWARD OF THE DEGREE OF
DOCTOR OF PHILOSOPHY

BY
BABURAO KRISHNA KUMBHAR

DEPARTMENT OF MECHANICAL ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY, DELHI

JULY 1984

CERTIFICATE

This is to certify that the thesis entitled "Studies on Transient Heat Transfer and Thermal Properties of Foods During Freezing" by Baburao Krishna Kumbhar has been prepared under our supervision in confirmity with the rules and regulations of the Indian Institute of Technology, Delhi. We further certify that the thesis has attained a standard required for a Ph.D. degree of the Institute. The results contained in this thesis have not been submitted, in part or full, to any other university for any degree or diploma.

(Dr. K. Das)
Associate Professor
Chemical Engineering Dept.,
I.I.T. New Delhi-110016.

(Dr. R.S. Agarwal)
Assistant Professor
Mechanical Engineering Dept.,
I.I.T. New Delhi-110016.

ACKNOWLEDGEMENTS

It is indeed a great pleasure to acknowledge the highly professional manner of guidance of Dr. R.S. Agarwal and Dr. K. Das which was instrumental in the present work being completed successfully.

In course of my research work there were many people who contributed a lot-academically and otherwise. Their association will be cherished for a long time to come. However, I cannot but specially acknowledge Dr. S.L. Bapat, V.L. Gokhale, Vijay Harwalkar, S.K. Nanda, Dr. M.S. Das, Dr. V.K. Jain, Dr. D.K. Banwet and Dr. Subash Babu for their efforts in ways more than one.

I am grateful to the staff of the Refrigeration and Airconditioning Laboratory, Workshop and the Computer Centre.

Last but not the least, thanks are due to Mr. Narendra Kumar for the tracings and Mr. V.P. Gulati for the meticulous typing.

(B.K. Kumbhar)

ABSTRACT

Freezing preservation of perishable food products has assumed greater importance in the recent years because low temperature processing of food materials reduces microbiological activities, and chemical and biochemical reactions in the food material which lead to increasing shelf life and maintaining good quality.

The air-blast and contact plate freezers are most commonly used for freezing of the food materials. The quality of the frozen food mainly depends on the rate of freezing. It is well known that faster the freezing,better is the quality. Thus, it is important to study the transient heat transfer during freezing to predict the freezing time under various processing conditions. However, to predict the freezing time accurately, precise knowledge of thermal properties of material is essential.

In the present work, thermal conductivity and thermal diffusivity have been measured for twelve fish varieties, viz., saman, sol, black, bhitki, black pomphret, mackerel, red bhitki, singra, hilsa, surama, white pomphret, malli and rohu over a range of temperature . Mathematical models have been developed to analyse the freezing processand to predict the freezing time in the air-blast and contact plate freezers.

The line heat source method has been employed since it is simple, accurate and enables simultaneous measurement of thermal conductivity and thermal diffusivity. The reliability

and accuracy of data was ascertained by repeated measurements and comparing them with the available data. Simple correlations for thermal conductivity and thermal diffusivity have been presented. Further, the fat, protein and moisture content of all the varieties of fish have been measured by extraction, Kjeldhal and the oven method respectively.

The mathematical model developed to analyse the freezing process and to predict freezing time of food material is comprehensive and takes into account all probable stages which may occur during freezing under various processing conditions. It considers the solid fraction distribution in the freezing zone (which is a mixture of frozen and unfrozen material) as a function of temperature. Further, freezing is assumed to take place over a range of temperatures.

The computed results of the proposed model have been compared with the available experimental data and with the calculated values using empirical correlation. The comparison shows a good agreement.

Two separate models developed for calculating freezing time of food material in the contact plate freezer consider constant and variable thermal properties. These models take into account the simultaneous occurrence of frozen, freezing and unfrozen zones and solid fraction distribution in the freezing zone as a function of temperature. Although the variable thermal property model is slightly complicated, it is more realistic. Finally, the effect of various parameters on freezing time has been studied.

CONTENTS

CONTENTS (Contd.)

CONTENTS (Contd.)

CONTENTS (Contd.)

CONTENTS (Contd.)