THEORETICAL AND EXPERIMENTAL INVESTIGATION OF FREEZE-DEHYDRATION PROCESS

THESIS SUBMITTED FOR THE AWARD OF
THE DEGREE OF DOCTOR OF PHILOSOPHY

By

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CERTIFICATE

This is to certify that this thesis "Theoretical and Experimental Investigation of Freeze-Dehydration Process" being submitted by Mrs. L.I. Trifonova (Grigorova) to the Indian Institute of Technology, Delhi, for the award of the degree of Doctor of Philosophy in Mechanical Engineering, is a record of bonafide research work carried out by her under my supervision and guidance for the last three years, and to my knowledge, it has reached the standard fulfilling the requirements of the regulations relating to the degree.

The results contained in this work have not been submitted in part or in full, to any other University or Institute for the award of any degree or diploma.

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ABSTRACT

The thesis presents the results of analytical and numerical solutions and experimental investigation of the sublimation-dehydration process and the thermophysical properties involved. A physico-mathematical conceptual system for representing the actual process under conditions of heat supply with distant and contact heating, and their combinations of symmetrical and unsymmetrical heating, is developed.

The sets of differential equationsare first solved analytically, accepting parabolic dependence of dried thickness with respect to time, thus, describing a process of change of state with moving boundary. The solutions are obtained in closed form assuming the radiator, surface and ice-front temperatures and the parabola coefficient as constant.

The numerical Newton-Raphson solution of the surface and ice-front energy balance equations, following the analytical solution, makes an improved approach by parabola coefficient to vary with time. The simulation procedure developed makes it possible to use Newton-Raphson iterative technique and programming in FORTRAN IV on a ICL 1900 Computer. The results obtained represent typical freeze-drying behaviour and are in fair agreement with the experimental results presented here. The effect of a large number of parameters and properties involved, and their combinations, is studied.

The results show a flexible method for the prediction of process parameters and optimization based on the main requirements of the surface temperature not exceeding the scorching temperature, and the ice-front temperature not exceeding the thawing temperature of the material.

A simulation procedure, taking into account the variation of thermal conductivity and thermal diffusivity of the dried material with temperature is also presented.

A finite difference method for solving the partial differential equations for the case of freeze-drying with distant heating is also developed. The results, again, show typical freeze-dehydration behaviour but show departure from the analytical and experimental results due to a number of unavoidable assumptions.

A compilation of property data is also presented. An experimental study on properties of yoghurt prepared from standardized DMS buffalo milk is made. The unsteady-state 'line heat source method', for the measurement of thermal conductivity and thermal diffusivity of this bio-nutritive freeze-dried material, has been used.

The experiments on freeze-drying of yoghurt are performed in the presence of air or nitrogen under various total chamber pressures and solid contents. The surface temperature, which is an important parameter for optimization, is found to depend prevailingly on the radiator temperature, the ice-front

temperature (or chamber pressure) and the resistance of the dried material. The ice-front temperature is found to be constant during the process, represented by a sharp plane. The effect of thermal conductivity, thermal diffusivity and porosity, representing the initial moisture content, is prominent on the process.

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