Preface

This work is intended mainly as an introduction to the field for specialists and researchers in food freezing. It may also contain some new or recent materials that would be of interest to more experienced researchers, while industry practitioners may gain from it important insights that would help them solve practical problems or optimise their processes. The first five chapters, which cover property estimation and heat transfer calculations, are sufficiently detailed to enable the reader to carry out these calculations with confidence and get a full understanding of the assumptions involved. Chapter 6, which reviews the modelling of heat transfer coupled with other processes, is necessarily less detailed due to the wide scope of coverage. In this chapter, rather than providing a comprehensive but superficial review, the main lines of approach for each topic are described, together with illustrative examples, so that the reader can get a feel of the methodologies.

Most of the content in this work is from previous literature, but where it is felt that improvements could be made or the development could be more rigorous, new material has been introduced. This is the case for dynamic heat load calculations, heat and mass transfer in porous materials and calorimetric properties and freezing calculations at high pressure.

Freezing occupies a special place in food preservation technology as it combines the benefits of long shelf life—months or years—with excellent retention of nutrients and sensory qualities and complete absence of microbial growth. With the advent of industrial food freezing, which began when frozen meat started being shipped to Europe from southern hemisphere countries (Argentina in 1877, Australia in 1879, New Zealand in 1882), there came a demand for scientifically based design and calculation techniques that would maximize the economic benefits. The accurate prediction of food freezing time is essential for the design of efficient freezing equipment and processes, since over-design is expensive and under-design, which may cause health risks and product losses, is even more so.

For decades, practically the only generic method available for calculating freezing time was Plank's equation, presented in 1913, which gives significant under-prediction. Over the years, many product-specific empirical equations were developed, until Cleland and Earle presented their generic empirical equation, still inspired by Plank's theoretical one, in 1977. In subsequent years, a large number of freezing time formulas was proposed. Simultaneously, computers became widely available and numerical methods such as finite difference and finite element were widely applied. The rigorousness and flexibility of the numerical methods allow foods with complex structures, properties and geometries to be modelled to any required precision. Their predictions were at first regarded with suspicion by industry practitioners and even some researchers, who were more used to empiricism than computer modelling and were often distrusting of "theory". Over the years, however, with rapidly evolving computer power and modelling techniques, many physical phenomena could be accurately modelled and numerical predictions are now generally regarded as reliable, at least when the underlying physical phenomena are well understood and their effect rigorously modelled (one case where these conditions are still not fulfilled is computational fluid dynamics, where turbulent flow must still be modelled with the aid of highly empirical relationships).

In 1990, Andrew Cleland wrote his book *Food Refrigeration Processes Analysis, Design and Simulation*, which summarised progress in the development of analytical, approximate, empirical and numerical methods for food refrigeration calculations to that date. Since then, there have been many other developments in the field. While the basic methodology of numerical modelling remain the same, more accurate data and models of thermophysical properties of food have become available, improving the accuracy of the numerical predictions. The increase in computer power, improvements in modelling techniques and wide availability of commercial numerical packages have allowed phenomena such as mass transfer, ice nucleation, crystal growth and mechanical effects to be modelled alongside heat transfer. In the future, more attention may be paid to multi-scale modelling including the modelling of crystallisation and mass transfer on the microscopic or cellular level, which have important effects on food quality.

It must be said, however, that one can still easily put too much trust in the computer, as no amount of computer power or numerical technique can compensate for a faulty understanding of physical phenomena or incorrect input data. On the contrary, computers can amplify the effects of conceptual shortcomings. In many cases, simple analytical, approximate or empirical methods still have their use in modelling and prediction. They can also quickly provide insights into the physical phenomena or guidance for potential process improvements. Whatever the method used, the best results can only be obtained if its underlying theory, assumptions and limitations are thoroughly understood. This work has been written with this point in mind: the emphasis is not so much on comprehensiveness, although an attempt has been made to provide balanced coverage, than on highlighting the physical principles and reasoning behind the methods considered, so that the reader can apply them judiciously and get a reasonable idea of their reliability.

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