Calorimetry in Food Processing

Analysis and Design of Food Systems

EDITOR
Gönül Kaletunç

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Dedication

For my parents, my son, and my husband for their patience and encouragement.

Hayatta en hakiki mürşit ilimdir. "The truest guide in life is science."

—Mustafa Kemal Atatürk, September 22, 1924

Dedication

This book is also dedicated to the memory of the late Professor Michel Ollivon, a great scientist and an exceptional human being, who passed away on June 16th, 2007, during the preparation of the book.

Preface

The global food industry is very large, producing sales worldwide on the order of approximately U.S. $1 trillion. To remain competitive in this complex industry, it is vital that manufacturers optimize food-processing conditions, most importantly not only to ensure the safety of food products but also to produce affordable, healthy, and convenient products, with desired sensory attributes. The global scale of the food industry brings the new challenges of increasing transport and export and in turn new requirements for increased shelf life. Optimization of food-processing conditions as well as development of new products requires knowledge of the physical properties of the food products and their components as the variables that are relevant to processing and storage conditions. Detailed knowledge of physical properties enables manufacturers to prevent waste of time and resources caused by trial and error during product formulation and process design.

Many food-processing protocols involve application of heating or cooling over a broad range of temperature. Knowledge of a food's thermal properties as a function of temperature and composition is necessary for heat transfer and energy balance calculations used to rationally design these thermal-processing protocols. During processing, the food components go through conformational and phase changes that affect the state and texture of the final food product.

Temperature-scanning calorimetry provides a useful tool for detecting, monitoring, and characterizing thermal processes in food materials. Moreover, calorimetry can be used to evaluate the effects of various physical and chemical stresses, including nonthermal treatments, on specific components by comparing the thermal profiles of pre- and post-treated food and biological materials to develop an

understanding of the mechanism of processing-induced changes. The data generated from thermal analysis techniques also can be used to develop equations that predict the physical properties of pre- and post-processed foods as a function of processing and storage conditions.

Although the use of calorimetry to measure the physical properties of food materials has increased both in academia and in industry over the past 20 years, the analysis of data frequently is complicated by multiple overlapping transitions and kinetically controlled events that occur in food materials.

This book is designed to introduce the basic principles of calorimetry, applications of calorimetry to characterize food products, interpretation of the resultant data, and the use of these data for process optimization and product development. The book is organized in two sections. The first section, consisting of eight chapters, focuses on the basic principles of calorimetry and its use for a wide range of materials from dilute solutions to solids. The second section, consisting of seven chapters, emphasizes the use of calorimetric data as a tool for process design and product development.

Chapter 1 provides an overview of calorimetry and the organization of the book. Chapters 2 and 3 focus on experimental design principles, calibration, data collection and analysis for microcalorimetry and high-pressure calorimetry. Chapter 4 addresses applications of ultrasensitive calorimetry to proteins and their interactions in dilute solution to characterize the thermal and thermodynamic stability and the thermodynamic origins of that stability. Chapters 5, 6, and 7 undertake the characterization of concentrated, multicomponent systems that are commonly observed in foods and complex biological systems such as bacteria. The final chapter in this section, Chapter 8, focuses on the use of an instrument that combines X-ray diffraction and high-sensitivity differential scanning calorimetry (DSC) in the same apparatus to simultaneously obtain complementary thermal and structural information for a sample.

Section Two of the book comprises Chapters 9 through 15. Chapter 9 provides an overview of the use of phase transition information in development of phase diagrams that can be used for efficient process design. Chapter 10 covers application of isothermal calorimetry for analysis of food stability, shelf life, and isothermal cooking processes. Chapter 11 describes application of thermal analysis to cereal-based products and mathematical treatment of the complex thermograms to

deconvolute the contributions from different components of the system. Chapter 12 reviews the use of calorimetric data for selection of dehydration parameters to produce products with improved storage stability. Chapter 13 describes the relatively new technique of scanning transitiometry and its specific application to gelatinization of wheat starch dispersions and for investigation of pressure shift freezing. Chapter 14 covers the application of calorimetry to characterize the impact of nonthermal treatment and to determine kinetic parameters during storage. Chapter 15 reviews the use of calorimetry to quantify the probability and potential severity of exothermic events such as formation of hot spots in dryers and to establish safe conditions for handling materials to prevent accidents in the food industry.

This book is designed to explain the capabilities of calorimetry for characterization of food and biological systems, which can range from single component, single-phase systems to multicomponent, multiphase systems. Therefore, information described in the book will provide comprehensive insight for scientists who have experience with calorimetry as well as a basic understanding for beginners. This text may also be used as a textbook for a graduate-level course. The book is also intended to serve as a resource for food scientists, food technologists, and food engineers working in the area of process design, optimization, and product development. The descriptions of the basic principles and potential uses of calorimetry to provide critical information for their respective areas and will serve as a bridge between these workers and specialists in calorimetry.

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