Extraction Optimization in Food Engineering

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Library of Congress Cataloging-in-Publication Data
A catalog record for this book is available from the Library of Congress.

ISBN: 0-8247-4108-0

This book is printed on acid-free paper.

Headquarters
Marcel Dekker, Inc., 270 Madison Avenue, New York, NY 10016, U.S.A.
tel: 212-696-9000; fax: 212-685-4540

Distribution and Customer Service
Marcel Dekker, Inc., Cimarron Road, Monticello, New York 12701, U.S.A.
tel: 800-228-1160; fax: 845-796-1772

Eastern Hemisphere Distribution
Marcel Dekker AG, Hutgasse 4, Postfach 812, CH-4001 Basel, Switzerland
tel: 41-61-260-6300; fax: 41-61-260-6333

World Wide Web
http://www.dekker.com

The publisher offers discounts on this book when ordered in bulk quantities. For more information, write to Special Sales/Professional Marketing at the headquarters address above.

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10 9 8 7 6 5 4 3 2 1

PRINTED IN THE UNITED STATES OF AMERICA

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Preface

Extraction is an important separation process that is extensively used in various applications in food engineering. Extraction is used either to recover important food components, being a main processing stage for the production of certain food products (sugar, oils, proteins), or to isolate desired components (antioxidants, flavors). It also removes contaminants and other undesirable components (alkaloids, cholesterol) from food sources.

Extraction, as a major operation of the manufacturing process in many food industries, requires a food engineer to have knowledge of the thermodynamics, theory, methods, and systems of extraction, while the feasible design and efficient operation of an extraction process requires knowledge of the technological parameters of the process and of optimization methods respectively.

Solvent or water extraction, liquid–liquid extraction, and leaching have already been incorporated in basic food processing, while supercritical fluid extraction (SFE) is a promising alternative method for new or improved applications in food engineering; SFE is recommended for the production of high-value food components as natural food products.

Despite the great variety of extraction applications already in use, it is difficult to interpret and transfer theory to application at the industrial scale. Even in recent applications of extraction, optimal extraction or separation conditions are obtained empirically. One primary goal of food process engineering is finding out how an extraction process works best—achieving the optimum in respect of yield, quality, or cost—and consequently finding the adjustable processing factor values that produce the optimum.

Optimization of extraction processes is needed either for extraction processes that are already in use or for future process designs for certain applications in food engineering. Consequently, it is important for the food industry to optimize food extraction processes; that is, to attain the optimum operating conditions (yield, quality, operation time, and cost) using appropriate methods and techniques.

In this book, we review the extraction methods used in food processing from fundamental theory to optimum practical application using the relevant equipment and the appropriate methods of optimization. All of the contributors are experts in the field of extraction, in research as well as in applications in industrial food processes. This book will be useful for food process engineers who employ extraction processes.

In order to introduce and apply an extraction process in the food industry, the knowledge of thermodynamic principles and the existing extractive systems is necessary. Irrespective of the extraction method used, the feasibility of the process or the system is affected by the operation parameters of the process or system. Consequently, the best result in respect of yield or quality characteristics of the final product should be achieved. That is the objective of the optimization of a process or a system.

An elementary review of thermodynamics is presented in Chapter 1, containing the basic laws, glossary, concepts, and relations of thermodynamics, particularly of chemical thermodynamics covering mixtures, solutions, phase equalibria, chemical reactions, etc. Chapter 1 presents fundamental knowledge useful for the understanding of extraction theory, operation, and applications in food processing.

Solid–liquid extraction or the leaching proces is described in Chapter 2. The characteristics and steps, as well as the basic variables affecting the extraction operation in relation to the solvent and the microstructure of the solid being extracted, are described. The relationship between the solid microstructure and the extraction rate based on the mass transfer mechanism due to liquid diffusion inside the solid is also explained.

Supercritical fluid extraction (SFE) using supercritical fluids (SCFs), a novel method providing the possibility for "green" processing of foods, is reviewed in Chapter 3. The basic (physical and chemical) properties of SCFs, particularly of the commonly used SC-CO_2, and the key factors that play significant roles in the success of the SFE operation (as solubility of solutes in SCFs, phase equilibria, mass transfer) are discussed; the effective use of SCFs in extraction and fractionation of food-related materials is also discussed.

The methods and equipment used in conventional solvent extraction and the relative extraction systems that have been applied in food industrial processes are presented in Chapter 4 with the equipment required for solid pretreat-

ment and solvent recovery. Similarly, for the alternative SFE method the selection and design of the required equipment are discussed.

Optimization theory and appropriate methods involved in design and process operation having economical and technological interest for food engineers are discussed in Chapter 5. An extraction process should operate efficiently by determining the operation time in order to achieve the best yield. The applications of optimization in food engineering and especially in food extraction (conventional or SFE) processing are reviewed.

In the following chapters, the most important applications of extraction processes in food production industry are presented under the aspect of optimization of the already operating extraction systems; novel and alternative operations and case studies are also presented.

Vegetable oil extraction of oil-bearing materials is covered in Chapter 6. The most efficient method of solvent extraction and the factors affecting the operation such as the solvent characteristics, extraction temperature, solid pretreatment, modes of operation, and equipment are discussed. Commercial units used for oil extraction and extraction technology for oilseeds with the pre- and post-treatment are presented; extraction of essential oils is also discussed.

Extraction processes for protein isolation from various edible protein sources (oilseeds, cereals, etc.) and production of protein products with many applications in food systems are covered in Chapter 7. Commercial processing and advanced methods of vegetable protein isolates are discussed from the viewpoint of yield and quality (nutritional, organoleptic, functional properties) of protein products.

Sugar extraction from sugar beet and sugar cane is presented in Chapter 8, as extraction is one of the major stages in the sugar manufacturing industry. Characteristics of sugar beet and cane, parameters affecting the extraction processes, and the optimization of the industrial process of beet sugar are discussed. Techniques of extraction, extractors, and other equipment required for industrial sugar production are presented. Extraction of starch and carbohydrates from corn is also discussed.

The extraction processes for isolation of desired components such as flavor and aroma substances or compounds with antioxidant activity (natural antioxidants) from plant sources are reported in Chapters 9 and 10, respectively. The main sources of natural antioxidants and synergists, the relative extraction processes, and the effect of processing parameters, as well as the conventional or SFE extraction procedures and purification of extracts, are discussed. Solvent extraction is one of the most important methods for producing natural extracts of aroma and flavor compounds; extraction solvents used, SFE processes, and applications of solvent extraction of flavor and aroma compounds are discussed.

The extraction processes for removal of undesirable or toxic constituents,

such as alkaloids from natural products, or compounds with adverse effect on human health (e.g., cholesterol) from various food products with emphasis on SFE processes are covered in Chapters 11 and 12, respectively. The physiological effects and applications of alkaloids, the commercial-scale operations for extraction and isolation of the most valuable alkaloids, especially the decaffeination of coffee and black tea using conventional extraction or SFE, are described. Similarly, the physiological effects of cholesterol on health and the extraction and fractionation processes of cholesterol from milk, fat, eggs, and meats are described. Both for alkaloids and cholesterol removal, future prospects using SFE are offered.

The safety, health, and environmental issues of solvent extraction, concerning mainly the edible oil and fat extraction industry, are described in Chapter 13, along with regulatory concerns and toxicity of solvents (hexane or alternative solvents) in commercial processes.

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