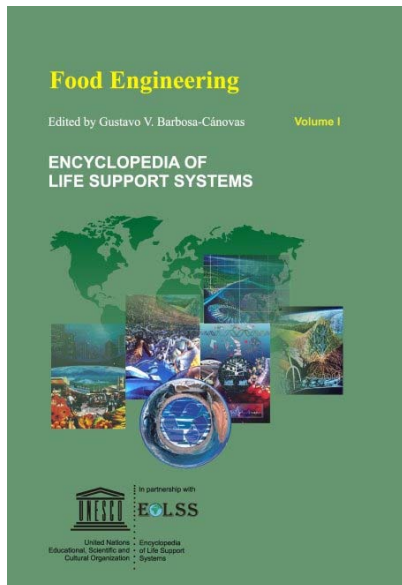


CONTENTS

FOOD ENGINEERING



Food Engineering - Volume 1

No. of Pages: 510

ISBN: 978-1-905839-44-5 (eBook)

ISBN: 978-1-84826-944-6 (Print Volume)

Food Engineering - Volume 2

No. of Pages: 334

ISBN: 978-1-905839-45-2 (eBook)

ISBN: 978-1-84826-945-3 (Print Volume)

Food Engineering - Volume 3

No. of Pages: 542

ISBN: 978-1-905839-46-9 (eBook)

ISBN: 978-1-84826-946-0 (Print Volume)

Food Engineering - Volume 4

No. of Pages: 244

ISBN: 978-1-905839-47-6 (eBook)

ISBN: 978-1-84826-947-7 (Print Volume)

For more information of e-book and Print Volume(s) order, please [click here](#)

[Or contact : eolssunesco@gmail.com](mailto:eolssunesco@gmail.com)

CONTENTS

Preface

xxvi

VOLUME I

Food Engineering **1**

Gustavo V. Barbosa-Canovas, *Department of Biological Systems Engineering, Washington State University, USA*

Pablo Juliano, *Department of Biological Systems Engineering, Washington State University, USA*

1. Introduction
2. The History and Future Trends of Food Engineering
3. Food Engineering: The Profession
 - 3.1. Food Engineering Education
 - 3.2. Professional Development of a Food Engineer
4. Engineering Properties of Foods
 - 4.1. Optical Properties
 - 4.2. Physical and Mechanical Properties of Foods
 - 4.2.1. Properties for Characterization in Process Design and Modeling
 - 4.2.2. Physical Properties of Food Powders and Ingredients
 - 4.2.3. Food Microstructure
 - 4.2.4. Electrical Properties
 - 4.3. Rheology of Foods
 - 4.4. Food Texture
5. Thermodynamics in Food Engineering
 - 5.1. Thermal Properties in Food Processing
 - 5.2. Kinetics in Food Processing and Food Stability
 - 5.3. Refrigeration and Its Importance in Food Processing
6. Food Process Engineering
 - 6.1. Historical Perspective and Advances
 - 6.2. Food Processing Operations: Some Examples
 - 6.3. Emerging Technologies and New Strategies in Processing
7. Design and Ultimate Technology in Food Engineering
 - 7.1. Food Plant Design and Process Simulation
 - 7.2. Process Control for Quality Assurance, Maintenance, and Optimization

Engineering Properties of Foods **39**

Gustavo V. Barbosa-Canovas, *Department of Biological Systems Engineering, Washington State University, USA*

Pablo Juliano, *Department of Biological Systems Engineering, Washington State University, USA*

Micha Peleg, *University of Massachusetts, USA*

1. Introduction
2. Thermal Properties
 - 2.1. Definitions
 - 2.2. Thermal Variations in Properties and Methods of Determination
 - 2.3. Food Processing Applications
3. Optical Properties
 - 3.1. Definitions
 - 3.2. Methods and Applications
4. Electrical Properties
 - 4.1. Electrical Conductivity and Permittivity
 - 4.2. Methods and Applications
5. Mechanical Properties

- 5.1. Structural and Geometrical Properties
 - 5.1.1. Density
 - 5.1.2. Porosity
 - 5.1.3. Shrinkage
- 5.2. Rheology and Texture
- 6. Properties of Food Powders
 - 6.1. Primary Properties
 - 6.2. Secondary Properties
- 7. Role of Food Microstructure in Engineering Properties
 - 7.1. Structural Characterization of Foods
 - 7.2. Practical Implications

Thermal Properties of Foods

70

Jorge E. Lozano, *Plapiqui (UNS-CONICET), Camino La Carrindanga, Km. 7 (8000) Bahía Blanca, Argentina*

- 1. Introduction
 - 1.1. Food Properties during Freezing
 - 1.2. Water Content
- 2. Experimental Data and Prediction Models
- 3. Density
 - 3.1. Definition and Units
 - 3.2. Porosity
 - 3.3. Density Measurement
 - 3.4. Bulk Density of Selected Foods
 - 3.5. Theoretical Density Models
- 4. Specific Heat
 - 4.1. Definition and Units
 - 4.2. Measurement Methods
 - 4.3. Specific Heat of Selected Foods
 - 4.4. Prediction Models
 - 4.5. Empirical Equations
- 5. Thermal Conductivity
 - 5.1. Definition
 - 5.2. Measurement Methods
 - 5.3. Selected Values
 - 5.4. Prediction Models
 - 5.5. Empirical Equations
- 6. Thermal Diffusivity
 - 6.1. Definition
 - 6.2. Measurement Techniques
 - 6.3. Thermal Diffusivity of Selected Foods
 - 6.4. Empirical Equations
- 7. Boiling Point Rise and Freezing Depression
 - 7.1. Definitions
 - 7.2. Measurement Methods
- 8. Viscosity
 - 8.1. Definition
- 9. Conclusions

Electrical Properties of Foods

110

Howard Zhang, *Food Safety Intervention Technologies Research Unit, USDA Eastern Regional Research Center, USA*

- 1. Electrical Conductivity
- 2. Electric Permittivity

Optical Properties of Foods

120

Luis Duran, *IATA-CSIC, Valencia, Spain*C. Calvo, *IATA-CSIC, Valencia, Spain*

1. Introduction
2. Nature of Light
3. Physical Phenomena
 - 3.1. Refraction-absorption-transmission
 - 3.2. Reflection
 - 3.3. Scattering
4. Optical Properties of Materials
 - 4.1. Chromophores
 - 4.2. Colorants
5. The Vision Process
6. Visual Appearance
 - 6.1. Color
 - 6.1.1. Optical Color
 - 6.1.2. Sensory Attributes of Color
 - 6.1.3. Color and Its Attributes in the Spectrum
 - 6.1.4. Tristimulus Nature of Color
 - 6.1.5. C.I.E. Chromaticity Coordinates
 - 6.1.6. Munsell Color System
 - 6.1.7. Hunter Color System
 - 6.1.8. Practical Measurement of Color
 - 6.2. Gloss
 - 6.3. Translucency

Mechanical Properties of Foods

143

M. Shafiur Rahman, *Department of Food Science and Nutrition, Sultan Qaboos University, Muscat, Sultanate of Oman*

1. Introduction
2. Classification of Mechanical Properties
3. Density
 - 3.1. Terminology
 - 3.2. Measurement Techniques
 - 3.2.1. Apparent Density
 - 3.2.2. Material Density
 - 3.2.3. Particle Density
 - 3.2.4. Bulk Density
 - 3.3. Predictions of Density
 - 3.3.1. Gases and Vapors
 - 3.3.2. Liquid and Solid Foods
4. Shrinkage and Expansion
 - 4.1. Terminology
 - 4.2. Measurement Techniques of Shrinkage
 - 4.3. Predictions of Shrinkage
 - 4.3.1. Kilpatric Model
 - 4.3.2. Model Based on Thermal Analogy
 - 4.3.3. Suzuki Model
 - 4.3.4. Empirical and Theoretical Models
 - 4.4. Mechanism of Shrinkage or Collapse
5. Porosity
 - 5.1. Terminology
 - 5.2. Measurement Techniques of Porosity
 - 5.2.1. Direct Method
 - 5.2.2. Microscopic Method

- 5.2.3. Density Method
- 5.3. Predictions of Porosity
- 6. Volume and Surface Area
 - 6.1. Euclidian Geometry
 - 6.2. Non-Euclidian or Irregular Geometry
 - 6.2.1. Methods to Estimate Fractal Dimension
 - 6.3. Measurement Techniques of Surface Area
 - 6.3.1. Boundary Surface Area
 - 6.3.2. Pores Surface Area
- 7. Morphological Properties
 - 7.1. Mean Particle Diameter
 - 7.2. Roundness
 - 7.3. Sphericity
- 8. Applications of Density, Shrinkage, Porosity, and Surface Area
 - 8.1. Process Design
 - 8.2. Estimating Other Properties
 - 8.3. Food Characterization and Quality Determination
 - 8.4. Future Needs

Physical Properties of Food Powders

177

Micha Peleg, *Department of Food Science, Chenoweth Laboratory, University of Massachusetts, USA*

- 1. Introduction
- 2. Bulk Density and Compressibility
 - 2.1. Bulk Density Determination
 - 2.2. Bulk Density and Cohesion
 - 2.3. Mechanical Compressibility
 - 2.4. Compressibility under Vibration, Tapping, and Drop
- 3. Angle of Repose
- 4. Flowability
- 5. Caking
 - 5.1. Anticaking Agents
 - 5.2. Other Effects
- 6. Mixtures and Segregation
 - 6.1. Types of Mixtures
 - 6.2. Segregation
 - 6.3. Segregation Indices
- 7. Disintegration and Attrition
 - 7.1. Breakage Mechanisms
 - 7.2. An Erosion Index

Particle Size Distribution in Food Powders

199

Gustavo V. Barbosa-Canovas, *Department of Biological Systems Engineering, Washington State University, USA*

Federico Harte, *Department of Biological Systems Engineering, Washington State University, USA*

Hong Helen Yan, *Department of Food Science and Technology, University of California, Davis, USA*

- 1. Introduction
- 2. Methods for Particle Size Measurement
 - 2.1. Size Characterization Methods
 - 2.1.1. Direct Methods
 - 2.1.2. Indirect Methods
 - 2.1.3. Scanning Methods
 - 2.2. Size Ranges
- 3. Particle Size Distribution
 - 3.1. Particle Size Distribution Functions

- 3.2. Measures of Central Tendency
4. Applications in Food Powder Field
 - 4.1. Attrition Evaluation
 - 4.2. Mathematical Treatment of Distribution Functions for Further Information
 - 4.3. Evaluation of Grain Hardness
5. Conclusion

Food Microstructure

223

Jose M. Aguilera, *Department of Chemical and Bioprocessing Engineering, Universidad Católica de Chile, Chile*

1. Introduction
2. Structure-Property Relationships in Foods
3. Examining Food Microstructure
 - 3.1. Light Microscopy
 - 3.2. Fluorescence Microscopy
 - 3.3. Confocal Microscopy
 - 3.4. Transmission and Scanning Electron Microscopy
 - 3.5. Scanning Probe and Atomic Force Microscopy
 - 3.6. X-ray Analysis
 - 3.7. Immunolabeling Techniques
4. Food Preservation and Microstructure
 - 4.1. Food Freezing
 - 4.2. Ice Cream
 - 4.3. Extrusion of Foods
 - 4.4. Spreadable Fat Products
5. Perspectives

Thermodynamics in Food Engineering

240

Jorge Welte-Chanes, *Departamento de Ingeniería Química y Alimentos, Universidad de las Américas, Puebla, México*

H. Mujica-Paz, *Facultad de Ciencias Químicas, Universidad Autónoma de Chihuahua, México*

Aurora Valdez-Fragoso, *Facultad de Ciencias Químicas, Universidad Autónoma de Chihuahua, México*

Fidel T. Vergara-Balderas, *Departamento de Ingeniería Química y Alimentos, Universidad de las Américas, Puebla, México*

Luis Gabriel Rios, *Departamento de Ingeniería Química y Alimentos, Universidad de las Américas, Puebla, México*

1. Introduction
2. Thermophysics
 - 2.1. Thermodynamic Concepts
 - 2.1.1. System
 - 2.1.2. System Variables
 - 2.1.3. State Equations for Ideal Gases
 - 2.1.4. Thermodynamic Variables
 - 2.1.5. Thermodynamic Transformations
 - 2.2. Zero Law of Thermodynamics
 - 2.3. Thermodynamic Equilibrium
 - 2.4. First Law of Thermodynamics
 - 2.5. Enthalpy
 - 2.6. Heat Capacity
 - 2.6.1. Heat Capacity at Constant Volume
 - 2.6.2. Specific Heat at Constant Pressure
 - 2.6.3. Specific Heat Relationships of Gases
 - 2.6.4. P-V-T Relationships for Ideal Gases, in Thermodynamic Processes
 - 2.7. Entropy and the Second Law of Thermodynamics

- 2.8. Third Law of Thermodynamics
 - 2.8.1. Dependence of Entropy on Temperature
 - 2.8.2. Dependence of Entropy on Pressure
- 3. Chemical Thermodynamics
 - 3.1. Helmholtz Free Energy
 - 3.2. Gibbs Free Energy
 - 3.2.1. Dependence of Free Energy on Pressure
 - 3.2.2. Dependence of Free Energy on Temperature
 - 3.3. Phase Equilibrium
 - 3.3.1. Clapeyron Equation
 - 3.3.2. Clausius-Clapeyron Equation
 - 3.3.3. Thermodynamic Equilibrium, Chemical Potential and Activity Coefficients

Colligative Properties of Foods

274

Jorge Welti-Chanes, *Department of Chemistry and Biology and Department of Chemical and Food Engineering, Universidad de las Américas, Puebla, México*

M.S. Tapia, *Instituto de Ciencia y Tecnología de Alimentos, Universidad Central de Venezuela, Venezuela*

Stella M. Alzamora, *Departamento de Industrias, Facultad de Ciencias Exactas y Naturales, Argentina*

Enrique Palou, *Departamento de Ingeniería Química y Alimentos, Universidad de las Américas, Puebla, Mexico*

Aurelio Lopez-Malo, *Departamento de Ingeniería Química y Alimentos, Universidad de las Américas, Puebla, Mexico*

Fidel T. Vergara-Balderas, *Departamento de Ingeniería Química y Alimentos, Universidad de las Américas, Puebla, Mexico*

- 1. Introduction
- 2. Ideal Solutions
 - 2.1. Thermodynamic Properties of Truly Ideal Solutions
 - 2.2. Ideal Solid-liquid Solutions
- 3. Colligative Properties
 - 3.1. Depression of the Freezing Point
 - 3.1.1. Basic Concepts
 - 3.1.2. Applications to Foods
 - 3.2. Elevation of the Boiling Point
 - 3.2.1. Basic Concepts
 - 3.2.2. Applications to Foods
 - 3.3. Osmotic Pressure
 - 3.3.1. Basic Concepts
 - 3.3.2. Applications to Foods

Phase Transitions

299

Yrjo H. Roos, *Department of Food and Nutritional Sciences, University College, Cork, Ireland.*

- 1. Introduction
- 2. Phase and State Transitions
 - 2.1. The Equilibrium State
 - 2.2. Types of Transitions
 - 2.3. Measurement of Transitions
 - 2.4. Transitions and Water
 - 2.4.1. Phase Behavior of Water
 - 2.4.2. Amorphous Water
 - 2.4.3. Water in Foods
 - 2.4.4. Water Sorption
 - 2.4.5. Water Plasticization
- 3. Phase and State Transitions in Foods

- 3.1. Melting and Crystallization
 - 3.1.1. Sugars
 - 3.1.2. Starch Gelatinization and Retrogradation
 - 3.1.3. Lipids
- 3.2. Protein Denaturation
- 3.3. Glass Transition
4. Phase Transitions and Food Structure
 - 4.1. Stickiness, Caking, and Collapse
 - 4.2. Crispness
 - 4.3. Crystallization and Recrystallization
5. Transitions and Food Processing
 - 5.1. Dehydration and Powder Handling
 - 5.1.1. Quality Control in Dehydration
 - 5.1.2. Encapsulation
 - 5.1.3. Agglomeration
 - 5.2. Confectionery and Extrusion
 - 5.3. Food Freezing
6. Reaction Kinetics and Food Stability
 - 6.1. Low-Water Foods
 - 6.2. Frozen Foods
7. Conclusions

Surface Phenomena**322**

Ganesan Narsimhan, *Biochemical and Food Process Engineering, Department of Agricultural and Biological Engineering, Purdue University, USA*

1. Introduction
2. Colloidal Forces Between Particles
 - 2.1. Van der Waals Interaction
 - 2.2. Electrostatic Interactions
 - 2.3. Steric Interaction
 - 2.3.1. Forces Due to Adsorbed Macromolecules
 - 2.3.2. Forces Due to Free Macromolecules
 - 2.4. Combination of Forces
3. Flocculation
 - 3.1. Brownian Flocculation
 - 3.2. Gravity-Induced Flocculation
 - 3.3. Coalescence
4. Food Emulsifiers
 - 4.1. Small Molecular Weight Surfactants
 - 4.2. Hydrophile-Lipophile Balance
 - 4.3. Proteins
 - 4.4. Adsorption Isotherm
 - 4.5. Kinetics of Adsorption
5. Competitive Adsorption in Mixed Emulsifier Systems
6. Interfacial Rheological Properties of Adsorbed Layer

Kinetics of Chemical Reactions in Foods**361**

R.P. Cavalieri, *Department of Biological Systems Engineering, Washington State University, USA*
 Jose I. Reyes De Corcuera, *Department of Biological Systems Engineering, Washington State University, USA*

1. Introduction
2. Fundamental Concepts
 - 2.1. Rate of Reaction
 - 2.2. Order of Reaction

- 2.3. Effect of Temperature
- 2.4. Activation Energy and Frequency Factor
3. Simple Reactions
 - 3.1. Noncatalytic Reactions
 - 3.2. Autocatalytic Reactions
4. Complex Chemical Reactions
 - 4.1. Mechanisms
 - 4.1.1. Parallel Reactions
 - 4.1.2. Consecutive Reactions
 - 4.2. Mathematical Approximations
 - 4.2.1. Rate-Determining Step
 - 4.2.2. Steady-State Approximation
 - 4.3. Chain Reactions
 - 4.3.1. Free Radicals
 - 4.3.2. Polymerization
 - 4.4. Homogeneous Catalysis
5. Chemical Kinetics in Food Processing and Preservation
 - 5.1. Lipid Autoxidation
 - 5.2. Non-Enzymatic Browning
 - 5.2.1. Mechanism
 - 5.2.2. Effect of Type of Amino Acid
 - 5.2.3. Effect of Type of Sugar
 - 5.2.4. Effect of Sugar-Amine Ratio
 - 5.2.5. Effect of pH
 - 5.2.6. Effect of Water Activity
 - 5.2.7. Effect of Temperature
 - 5.2.8. Ascorbic Acid Browning
 - 5.3. Chemical Reactions with Proteins
 - 5.4. Chemical Reactions with Carbohydrates
 - 5.5. Chemical Reactions with Lipids
 - 5.6. Empirical Kinetics
6. Enzyme Kinetics
 - 6.1. Enzymes as Catalysts
 - 6.2. Enzyme Mechanisms and Reaction Rates
 - 6.2.1. Michaelis-Menten Approach
 - 6.2.2. Determination of Kinetic Parameters
 - 6.2.3. Effect of Temperature
 - 6.2.4. Effect of pH
 - 6.2.5. Effect of Ionic Strength
 - 6.2.6. Effect of Inhibitors
 - 6.3. Enzyme Kinetics in Food Processing and Preservation
7. Conclusions and Future Trends

Cycles and Refrigeration

405

Gustavo V. Barbosa-Canovas, *Biological Systems Engineering, Washington State University, USA*
 Federico Harte, *Biological Systems Engineering, Washington State University, USA*
 Fernanda San Martin, *Biological Systems Engineering, Washington State University, USA*

1. Introduction
2. Vapor Compression Cycles
 - 2.1. Coefficient of Performance
3. Multistage Compression Cycle
4. Absorption Refrigeration Cycle
5. Components of Refrigeration System
 - 5.1. Compressors
 - 5.2. Evaporators
 - 5.3. Condenser

- 5.4. Expansion Valve
- 6. Other Refrigeration Systems
 - 6.1. Thermoelectric Refrigeration
 - 6.2. Pulse Tube Refrigeration
 - 6.3. Thermoacoustic Refrigeration
 - 6.4. Magnetic Refrigeration
- 7. Refrigerants
- 8. Applications in the Food Industry

Index **425**

About EOLSS **431**

VOLUME II

Food Rheology and Texture **1**
 M. Anandha Rao, *Department of Food Science and Technology, Cornell University, Geneva, NY, USA*

- 1. Introduction
- 2. Measurement

Newtonian and Non-Newtonian Flow **11**

Albert Ibarz, *Departament de Tecnologia d'Aliments (Universitat de Lleida), Spain*
 Elena Castell-Perez, *Department of Biological and Agricultural Engineering, Texas A&M University, USA*
 Barbosa-Canovas, *Biological Systems Engineering Department, Washington State University, Pullman, USA*

- 1. Introduction
- 2. Stress and Deformation
- 3. Elastic Solids and Newtonian Fluids
- 4. Viscometric Functions
- 5. Rheological Classification of Fluids
- 6. Newtonian Flow
- 7. Non-Newtonian Flow
 - 7.1. Time-Independent Flow
 - 7.2. Time Dependent Flow
- 8. Viscoelasticity
- 9. Temperature Dependency
- 10. Effect of Concentration on the Viscosity
 - 10.1. Structural Theories of Viscosity
 - 10.2. Viscosity of Solutions
 - 10.3. Combined Effect of Changes in Temperature and Concentration
- 11. Rheological Measurements in Semi-Liquids Food Products
 - 11.1. Fundamentals Methods
 - 11.2. Empirical Methods
 - 11.3. Imitative Methods
- 12. Determination of Yield Stress
- 13. Typical Applications
 - 13.1. Chocolate
 - 13.2. Beverages
 - 13.3. Ketchup
- 14. Final Remarks

Viscoelasticity**59**

Alberto Tecante, *Departamento de Alimentos y Biotecnología, Facultad de Química “E” – UNAM, Cd. Universitaria, México, D.F., 04510, México*

1. Introduction
2. The Foundations of Viscoelasticity
 - 2.1. Hooke’s Postulate and Linear Elasticity
 - 2.1.1. Stress
 - 2.1.2. Deformation and Strain
 - 2.1.3. Elastic Moduli
 - 2.2. Newton’s Postulate and Viscosity
 - 2.3. Early Evidence of Deviation from Linear Behavior
 - 2.4. Rheology: the Science of Materials
3. Liquids, Solids, and Viscoelastic Materials
 - 3.1. The Deborah Number
4. Linear Viscoelasticity
 - 4.1. Ideal Elastic and Viscous Behaviors
 - 4.2. Some Simple Models of Linear Viscoelasticity
 - 4.2.1. The Kelvin Model
 - 4.2.2. The Maxwell Model
 - 4.2.3. Other Models
5. Experimental Methods of Measurement of Linear Viscoelastic Functions
 - 5.1. Static Methods
 - 5.1.1. Creep
 - 5.1.2. Relaxation Tests
 - 5.2. Dynamic Methods
 - 5.2.1. Harmonic Oscillatory Motion
 - 5.2.2. Other Dynamic Techniques
6. Viscoelastic Properties of Food Biopolymers
 - 6.1. Types, Sources, and Uses of Food Biopolymers
 - 6.2. Characterization of the Viscoelastic Behavior of Biopolymer Systems
 - 6.2.1. Solutions
 - 6.2.2. Gels

Squeezing and Elongational Flow**91**

Carlos M. Corvalan, *School of Bioengineering, University of Entre Rios, Argentina*

Oswaldo H. Campanella, *Agricultural and Biological Engineering Department, Purdue University, USA*

1. Squeezing and Elongational Flow in Fluid Foods
2. Foundations of Squeezing Flow Viscometry
 - 2.1. Elongational Flow: Lubricated Squeezing Flow Kinematics
 - 2.2. Shear Flow: Non-lubricated Squeezing Flow Kinematics
3. Parallel Plates Viscometer
 - 3.1. Lubricated Squeezing Flow
 - 3.2. Non-lubricated Squeezing Flow
 - 3.3. Applications
 - 3.4. Shortcomings
 - 3.5. Other Configurations
4. Concluding Remarks and Perspectives

Food Suspensions**122**

Laura Patricia Martinez-Padilla, *Laboratory of Rheology and Functional Properties of Foods, Engineering and Technology Department, Universidad Nacional Autónoma de México, México*

1. Introduction
2. Rheological Behavior

3. Forces Acting on Particles
4. Measurement Techniques
 - 4.1. Large Gap Separation
 - 4.1.1. Parallel Plates
 - 4.1.2. Tube Viscometer
 - 4.2. Large Rheometers
 - 4.3. Modification of Conventional Geometries
 - 4.4. Mixers
 - 4.4.1. Helical Ribbon
 - 4.4.2. Vane
5. Factors Affecting Viscous Behavior
6. Predictions of Rheological Properties Based on Structure
 - 6.1. Newtonian Continuous Phase
 - 6.2. Non Newtonian Continuous Phase
 - 6.3. Viscoelastic Properties
7. Flow Behavior of Solid/Liquid Mixtures
 - 7.1. Pressure Drops
 - 7.2. Particle Velocity
8. Future Trends

Food Emulsions

150

Amparo Chiralt, *Department of Food Technology, Universidad Politécnica de Valencia, Spain*

1. Introduction
2. Structure of Food Emulsions
 - 2.1. Oil-water Interface
3. Emulsion Stability. Destabilization Mechanisms
 - 3.1. Creaming
 - 3.2. Flocculation
 - 3.3. Coalescence
 - 3.4. Ostwald Ripening
 - 3.5. Phase Inversion
4. Interaction Forces Between Droplets
 - 4.1. Van der Waals Forces
 - 4.2. Electrostatic Double-layer Forces
 - 4.3. Interaction with Polymers
 - 4.3.1. Adsorbing Polymers
 - 4.3.2. Non-adsorbing Polymers
 - 4.4. Repulsive Hydration Forces
5. Emulsion Formation
6. Food Emulsion Rheology
7. Conclusions

Constitutive Models for Food Systems

176

Jozef L. Kokini, *Department of Food Science, Rutgers University, New Brunswick, New Jersey, USA*
 Muthukumar Dhanasekharan, *Department of Food Science, Rutgers University, New Brunswick, New Jersey, USA*

1. Introduction
2. Linear Viscoelasticity
3. Dilute Solution Theories
4. Concentrated Dispersion Theories
5. Concentrated Solution/Melt Theories
6. K-BKZ Type Models
7. Differential Constitutive Models
 - 7.1. Upper Convected Maxwell Model

- 7.2. Giesekus Model
- 7.3. White-Metzner Model
- 7.4. Phan Thien-Tanner Model
- 8. Solid-Like Constitutive Models
- 9. Conclusion

Solid Foods **203**

Gipsy Tabilo-Munizaga, *Food Engineering Department Universidad del Bío Bío, Chile*
 Barbosa-Canovas, Gustavo V., *Department of Biological Systems Engineering Department, Washington State University, Pullman, USA*
 Juan J. Fernandez-Molina, *Ezequiel Zamora University, Venezuela*

- 1. Introduction
- 2. Rheological Properties of Solid Foods
- 3. The Deformability Modulus
- 4. Viscoelastic Properties of Solid Food
 - 4.1. Stress Relaxation Behavior
 - 4.2. Creep Behavior
 - 4.3. Dynamic Testing
 - 4.4. Failure in Solid Foods
- 5. Final Remarks

Texture in Solid and Semisolid Foods **224**

Malcolm Bourne, *New York State Agricultural Experiment Station and Institute of Food Science, Cornell University, Geneva, NY, USA*

- 1. Introduction
- 2. Food Processing Affects Texture
- 3. Desirable and Undesirable Textures
- 4. Time of Day Affects Texture Preferences
- 5. Non-Destructive Test
- 6. How the Body Processes Food
- 7. Correlating Instruments with Sensory Evaluation of Texture
- 8. History of Development of Texture Measuring Instruments

Food Texture: Sensory Evaluation **238**

Elvira Costell, *IATA-CSIC, Valencia, Spain*
 Luis Duran, *IATA-CSIC, Valencia, Spain*

- 1. Introduction
- 2. Physiological Perception
- 3. Elaboration and Interpretation of Sensation
- 4. Communication of the Sensation: Sensory Analysis
 - 4.1. Discriminatory Tests
 - 4.2. Descriptive Tests
 - 4.2.1. Texture Descriptors
 - 4.2.2. Texture Profile
 - 4.2.3. Free Choice Profile
 - 4.3. Affective Tests
 - 4.3.1. Influence of Texture on Acceptability
 - 4.3.2. Quantitative Tests

Index **257**

VOLUME III

Food Process Engineering 1

Romeo T. Toledo, *University of Georgia, USA*

1. Food Process Engineering Overview
2. Scope of Food Process Engineering
3. Raw Material Preparation
4. Prevention of Food Spoilage
5. Food Preservation by Canning
6. Aseptic Packaging
7. Non-Thermal Processes for Food Preservation
 - 7.1. Food Preservation by Dehydration
 - 7.2. Combined Dehydration and Solute Infusion
 - 7.3. Concentration of Liquid Foods
8. Low-Temperature Food Preservation
9. Frying of Foods
10. Physical Separation of Food Components
11. Shaping and Textural Modification of Foods
12. Optimization of Processes for Food Preservation

Conventional Thermal Processing (Canning) 19

Art A. Teixeira, *Agricultural and Biological Engineering Department, University of Florida, USA*

1. Introduction
2. Historical Perspective
3. Current Technology
 - 3.1. In-Can Sterilization
 - 3.2. In-Can Pasteurization
4. Scientific Principles
 - 4.1. Interrelating Bodies of Knowledge
 - 4.2. Microbiological Considerations
 - 4.3. Process Lethality (F-value)
 - 4.4. Heat Transfer Considerations
 - 4.5. Process Calculations
5. Future Trends and Perspectives
 - 5.1. Packaging Systems
 - 5.2. On-Line Computer Control

Ohmic Heating 37

Sudhir K. Sastry, *Ohio State University, USA*

1. Introduction
2. Microbial Death Kinetics
3. Electrolytic Effects
4. Applications
 - 4.1. Sterilization
 - 4.2. Fouling by Proteinaceous Materials
 - 4.3. Seafood Processing
 - 4.4. Pretreatments for Water Removal
 - 4.5. Ohmic Heating for Detection of Starch Gelatinization
 - 4.6. Extraction Enhancement
5. Conclusions/Opportunities

Food Freezing**53**

R. Paul Singh, *Department of Biological and Agricultural Engineering, University of California, Davis, USA*

1. History and Origin
2. Food Quality and the Freezing Process
 - 2.1. Handling Prior to Freezing
 - 2.2. Freezing Conditions
 - 2.3. During Frozen Storage
3. The Freezing Process
 - 3.1. Freezing Rate
 - 3.2. Freezing Diagram
 - 3.3. Freezing Time
4. Freezing Systems
 - 4.1. Air Blast Freezing
 - 4.1.1. Tunnel Freezer
 - 4.1.2. Belt Freezer
 - 4.2. Fluidized-Bed Freezing
 - 4.3. Cryogenic Freezing
 - 4.4. Plate Freezing

Concentration of Liquid Foods**69**

Ernesto Hernandez, *OmegaPure Technology and Innovation Center, Houston, Texas, USA*

1. Introduction
2. Physical Properties of Liquid Foods
3. Concentration by Evaporation
 - 3.1. Evaporator Types and Applications
 - 3.2. Design of Evaporators
 - 3.2.1. Multiple-Effect Evaporators
 - 3.3. Fouling
 - 3.4. Food Applications
4. Concentration with Membranes
 - 4.1. Concentration by Reverse Osmosis
 - 4.2. Design Considerations
 - 4.3. Construction Materials
 - 4.4. Membrane Configurations
 - 4.5. Concentration by Direct Osmosis
 - 4.6. Concentration by Membrane Distillation
 - 4.7. Concentration by Osmotic Distillation
5. Combined Technologies in the Concentration of Liquid Foods
6. Freeze Concentration

Food Dehydration**93**

Pascual E. Viollaz, *Department of Industry, University of Buenos Aires, Argentine*
 Stella M. Alzamora, *Department of Industry, University of Buenos Aires, Argentine*

1. Introduction
2. Basic Concepts Associated with Drying
 - 2.1. State of Water in Foods
 - 2.1.1. Water Activity and Molecular Mobility
 - 2.1.2. Moisture Sorption Isotherms
 - 2.1.3. Food Stability
 - 2.2. Internal Mechanisms of Moisture Transport
3. Drying Rate
 - 3.1. Constant Rate Period

- 3.2. Falling Rate Period(s)
4. Heat and Mass Transfer Controlling Resistances during Drying
 - 4.1. External vs. Internal Control
 - 4.2. Heat vs. Mass Transport Control
5. Dehydration Techniques
6. Future Directions

Food Frying**122**

R. Paul Singh, *Department of Biological and Agricultural Engineering, University of California, Davis, California, USA*

1. Introduction
2. Physicochemical Changes in Foods during Frying
3. Edible Oils Used in Frying Foods
 - 3.1. Physicochemical Changes in Oil during Frying
 - 3.2. Oil Migration into Foods during Frying
4. Heat Transfer during Frying
5. Frying Systems
 - 5.1. Batch Frying
 - 5.2. Continuous Frying Equipment
6. Future Studies

Separation**136**

Humberto Vega-Mercado, *Bio Sterile Validation, Merck & Co., Inc., West Point, Pennsylvania, USA*

1. Liquid-Liquid Extraction
 - 1.1. Introduction
 - 1.2. Theoretical Aspects
 - 1.2.1. Triangular Coordinates and Equilibrium Data
 - 1.3. Selection of Solvent
 - 1.4. Thermodynamic Aspects of Liquid-Liquid Equilibria
 - 1.4.1. Single Stage Equilibrium Extraction
 - 1.4.2. Multistage Crosscurrent Extraction
 - 1.4.3. Countercurrent Multistage Extraction
 - 1.5. Equipment for Liquid-Liquid Extraction
 - 1.5.1. Stagewise Systems
 - 1.5.2. Continuous Contact Equipment – Differential Contactors
 - 1.5.3. Selection of Liquid-Liquid Extraction Equipment
2. Solid Liquid Separation
 - 2.1. Introduction
 - 2.2. Theoretical Aspects
 - 2.3. Types of Processes (Unit Operations)
3. Mechanical Separation
 - 3.1. Introduction
 - 3.2. General Principles for Centrifuges and Cyclones
 - 3.3. Equipment
4. Membrane Processing
 - 4.1. Introduction
 - 4.2. Physical Chemistry of Membrane Processes
 - 4.3. Membrane Types and Configurations
 - 4.3.1. Hollow Fibers
 - 4.3.2. Dead-End Membranes or Screen Filters
 - 4.3.3. Depth Filters
 - 4.3.4. Plate Units
5. Column Chromatography
 - 5.1. Introduction

- 5.2. Equipment and Commercial Resins
 - 5.2.1. Ion Exchange Chromatography
 - 5.2.2. Size Exclusion or Gel Filtration Chromatography
 - 5.2.3. Affinity Chromatography
 - 5.2.4. Hydrophobic Interaction Chromatography
 - 5.2.5. Reversed Phase Chromatography
 - 5.2.6. Hydroxyapatite Chromatography
- 6. Distillation
 - 6.1. Interphase Mass Transfer Separation Processes
 - 6.2. Thermodynamic Aspects of Vapor-Liquid Equilibrium
 - 6.3. Bubble and Dew Points
 - 6.4. Distillation Methods
 - 6.4.1. Flash Distillation
 - 6.4.2. Differential Distillation
 - 6.4.3. Simple Steam Distillation
 - 6.4.4. Continuous Distillation of Binary Systems
 - 6.4.5. McCabe-Thiele Method
 - 6.5. Recent Advances in Distillation

Supercritical Extraction**210**Thierry M. Jonin, *Nestle, Switzerland*Laurent P. Adjadj, *Laboratorium für Technische Chemie/LTC, Switzerland*Syed S. H. Rizvi, *Food Science Department, Cornell University, USA*

- 1. Introduction
- 2. Concepts of Supercritical Fluids
- 3. Solubility Measurement Techniques
 - 3.1. Dynamic Systems for the Determination of Solubility in Supercritical Fluids
 - 3.2. Static Systems for the Determination of Solubility in Supercritical Fluids
 - 3.3. Dynamic Systems vs. Static Systems
- 4. Solubility Measurements
- 5. Applications of Supercritical Fluid Extraction
 - 5.1. Decaffeination
 - 5.1.1. Decaffeination of Coffee
 - 5.1.2. Cocoa Bean Extraction
 - 5.2. Hop Extraction
 - 5.3. Spice Extraction
 - 5.4. Fractionation
 - 5.5. Analysis of Wine Aroma
- 6. Other Applications of Supercritical Fluids
 - 6.1. Supercritical Fluid Extrusion (SCFX)
 - 6.2. Supercritical Water Oxidation

Food Extrusion**227**Mukund V. Karwe, *Cook College, Rutgers University, New Jersey, USA*

- 1. Introduction
- 2. Extruded Products
 - 2.1. Products for Human Consumption
 - 2.2. Pet Food and Animal Feed Products
- 3. Extrusion Equipment
 - 3.1. Single-Screw Extruders
 - 3.2. Twin-Screw Extruders
 - 3.3. Extrusion Equipment Size
- 4. Extrusion Variables and Process Parameters
- 5. Process Modeling and Scaling

- 5.1. Process Modeling
 - 5.1.1. Fully Deterministic Modeling
 - 5.1.2. Empirical Modeling
 - 5.1.3. Artificial Neural Networks (ANN)
6. Scale-Up
7. Physico-Chemical Changes During Extrusion
 - 7.1. Changes in Starches
 - 7.2. Changes in Proteins
 - 7.3. Changes in Lipids
8. Flavor Formation and Loss during Extrusion
9. Effect of Extrusion on Nutritional Quality
10. Other Applications of Extrusion Processing

Crystallization**257**Richard W. Hartel, *Department of Food Science, University of Wisconsin, USA*

1. Introduction
2. Crystallization Principles
 - 2.1. Phase/State Behavior
 - 2.2. Nucleation
 - 2.3. Crystal Growth
 - 2.4. Recrystallization
3. Controlling Crystallization in Foods
 - 3.1. Control for Product Quality
 - 3.2. Control for Separation
 - 3.3. Control to Prevent Crystallization
4. Factors Affecting Control of Crystallization
 - 4.1. Heat and Mass Transfer Rates
 - 4.1.1. Rate of Cooling
 - 4.1.2. Crystallization Temperature
 - 4.1.3. Agitation
 - 4.1.4. Drying
 - 4.2. Product Formulation

Nonthermal Processing of Foods and Emerging Technologies**281**Gustavo V. Barbosa-Canovas, *Department of Biological Systems Engineering, Washington State University, USA*M. Marcela Gongora-Nieto, *Department of Biological Systems Engineering, Washington State University, USA*J.J. Rodriguez, *Department of Biological Systems Engineering, Washington State University, USA*B.G. Swanson, *Department of Food Science and Human Nutrition, Washington State University, USA*

1. High Hydrostatic Pressure
 - 1.1. Introduction
 - 1.2. Engineering Principles
 - 1.3. Biological Effects
 - 1.4. Future Trends
2. Ultrasound
 - 2.1. Introduction
 - 2.2. Engineering Principles
 - 2.3. Biological Effects
 - 2.4. Future Trends
3. Food Irradiation
 - 3.1. Introduction
 - 3.2. Engineering Principles
 - 3.3. Biological Effects

- 3.4. Future Trends
4. Light Pulses
 - 4.1. Introduction
 - 4.2. Engineering Principles
 - 4.3. Biological Effects
 - 4.4. Future Trends
5. Pulsed Electric Fields
 - 5.1. Introduction
 - 5.2. Engineering Principles
 - 5.3. Biological Effects
 - 5.4. Future Trends
6. Oscillating Magnetic Fields
 - 6.1. Introduction
 - 6.2. Engineering Principles
 - 6.3. Biological Effects
 - 6.4. Future Trends
7. Nonthermal Methods as Hurdles
8. Final Remarks

Hurdle Technology**311**Lothar Leistner, *Federal Centre for Meat Research, Germany*

1. Introduction
2. Principles of Hurdle Technology
 - 2.1. Hurdle Effect
 - 2.2. Hurdle Technology
 - 2.3. Total Quality
3. Basic Aspects of Hurdle Technology
 - 3.1. Homeostasis
 - 3.2. Metabolic Exhaustion
 - 3.3. Stress Reactions
 - 3.4. Multi-target Preservation
4. Applications of Hurdle Technology
 - 4.1. Industrialized Countries
 - 4.1.1. Minimally Processed Foods
 - 4.1.2. Refrigerated Foods
 - 4.1.3. Healthful and Functional Foods
 - 4.1.4. Packaging of Foods
 - 4.1.5. Nonthermal Preservation of Foods
 - 4.2. Developing Countries
 - 4.2.1. Fruit Products in Latin America
 - 4.2.2. Meat Products of China and Taiwan
 - 4.2.3. Dairy Products of India
5. Food Design by Hurdle Technology
6. Conclusions and Perspectives

Food Fermentation**329**Pedro Wesche-Ebeling, *Department of Chemistry and Biology Universidad de las Américas - Puebla, Ex Hda. Sta. Catarina Mártir, Puebla, México*Jorge Welti-Chanes, *Department of Chemical and Food Engineering, Universidad de las Américas - Puebla, Ex Hda. Sta. Catarina Mártir, Puebla, México*

1. Introduction
2. Definitions
3. Microbial Ecology
 - 3.1. The Fermenting Microorganisms

- 3.2. Prokaryots and Eukaryots
- 3.3. Metabolism
 - 3.3.1. Phototrophs, Chemotrophs, Lithotrophs, Autotrophs and Heterotrophs
 - 3.3.2. Catabolism and Anabolism
 - 3.3.3. Aerobic and Anaerobic Respiration
 - 3.3.4. Central Metabolisms: Pentose Phosphate Pathway, Glycolysis and Citric Acid Cycle
- 3.4. Fermentation
4. Groups of Fermenting Organisms
 - 4.1. Prokaryota - Kingdom Eubacteria
 - 4.1.1. Homoacetogenic Bacteria (product: acetate)
 - 4.1.2. Acetic Acid Bacteria (acetate, aldonic acids, ascorbic acid)
 - 4.1.3. Gram Negative, Facultative Aerobic Bacilli (CO₂ and ethanol)
 - 4.1.4. Enteric Bacteria (lactate, succinate, ethanol/acetate, 2,3-butanediol)
 - 4.1.5. Lactic Acid Bacteria (lactate, ethanol, acetoin, diacetyl, dextran, levan)
 - 4.1.6. Butyric Acid Clostridia (butyrate, acetate, caproate, butanol, ethanol, isopropanol)
 - 4.1.7. Amino Acid Fermenting Clostridia (acetate, butyrate)
 - 4.1.8. Propionic Acid Bacteria (propionate, acetate, butyrate, succinate, formate)
 - 4.1.9. Mycoplasma (acetate, lactate, formate, ethanol)
 - 4.2. Eukaryota - Kingdoms Protoctista and Chromista (Sagenista)
 - 4.3. Eukaryota - Kingdom Fungi
 - 4.3.1. Phyla Chytridiomycota and Basidiomycota (Non-fermenting)
 - 4.3.2. Phylum Zygomycota
 - 4.3.3. Phylum Deuteromycota
 - 4.3.4. Phylum Ascomycota
5. Fermented Products
 - 5.1. Alcoholic Beverages
 - 5.1.1. Beer
 - 5.1.2. Wine
 - 5.1.3. Distilled Beverages
 - 5.1.4. Other Alcoholic Beverages
 - 5.2. Fermented Vegetable Products
 - 5.3. Fermented Cereal Products – Bread
 - 5.4. Fermented Dairy Products
 - 5.4.1. Fermented Milk (functional milk/probiotics)
 - 5.4.2. Cheese
 - 5.5. Fermented Sausage
 - 5.6. Cacao, Coffee, Tea, Vanilla
 - 5.7. Other Fermented Food Products
6. Fermentation as a Source of Chemical Compounds for Foods
7. Industrial Fermentation
 - 7.1. Screening for Metabolites
 - 7.2. Strain Development and Preservation
 - 7.3. Substrates for Fermentation
 - 7.4. Methods of Fermentation
 - 7.5. Product Recovery or Downstream Processing

Food Powder Processing

363

Enrique Ortega-Rivas, *Graduate Program in Food Science and Technology, University of Chihuahua, Mexico*

1. Introduction: Applied Powder Technology to Food Materials
2. Comminution
 - 2.1. Principles of Size Reduction; Properties of Comminuted Products
 - 2.2. Energy Requirements: Comminution Laws
 - 2.3. Size Reduction Equipment: Features and Operation
 - 2.4. Criteria for Selection of Comminution Processes
3. Attrition

- 3.1. Mechanisms of Attrition
- 3.2. Kinetics of the Attrition Process
- 3.3. Compaction Characteristics and the Fractal Approach
4. Mixing
 - 4.1. Introduction: Statistical Approach to Solids Mixing
 - 4.2. Mixing Mechanisms–Segregation
 - 4.3. Assessment of Mixing Processes: Mixing Index
 - 4.4. Powder Mixers
5. Separation and Classification
 - 5.1. Sieving and Screening
 - 5.2. Dedusting Technology: Cyclones and Filters
 - 5.3. Air Classification
6. Agglomeration and Growth
 - 6.1. Introduction: Size Enlargement Processes
 - 6.2. Aggregation Fundamentals: Strength of Agglomerates
 - 6.3. Agglomeration Methods
7. Drying and Reconstitution
 - 7.1. Powder Dryers: Fluidized Bed Dryers and Spray Dryers
 - 7.2. Reconstitutability of Dried Powders
8. Conclusion and Future Trends

Food Mixing**414**K. Niranjana, *Department of Food Science and Technology, University of Reading, United Kingdom*

1. Introduction
2. Special Features of Food Mixing
3. Assessment of Mixedness
 - 3.1. Scale of Scrutiny
 - 3.2. Intensity and Scale of Segregation
 - 3.3. Mixedness in Particulates
 - 3.4. Mixedness in Dough
 - 3.5. Mixedness in Liquids
4. Types of Food Mixers
 - 4.1. Mixers Used for Particulates and Powders
 - 4.2. Mixers for Doughs, Pastes, and Batters
 - 4.3. Mixers for Dissolving and Dispersing into Liquids
5. Concluding Remarks

Food Packaging**428**Ramon Catala, *Packaging Laboratory, Instituto de Agroquímica y Tecnología de Alimentos. CSIC. Paterna, Valencia, Spain*Rafael Gavara, *Packaging Laboratory, Instituto de Agroquímica y Tecnología de Alimentos. CSIC. Paterna, Valencia, Spain*

1. Introduction
2. Metal Containers
 - 2.1. Tinplate
 - 2.2. Electrolytic Chromium-Coated Steel
 - 2.3. Aluminum
 - 2.4. Protective Coatings: Lacquers and Lithography
 - 2.5. Metal Container Manufacturing
 - 2.5.1. Three-piece Cans
 - 2.5.2. Two-piece Cans
 - 2.6. Corrosion in Metal Containers
3. Glass Containers
 - 3.1. Glass Composition and Structure

- 3.2. Glass Container Manufacturing
- 3.3. Glass Properties
- 4. Paper and Paperboard Packages
 - 4.1. Paper
 - 4.2. Paperboard
 - 4.3. Corrugated Board
- 5. Plastic Containers
 - 5.1. General Characteristics of Plastics
 - 5.2. Properties of Plastic Packages
 - 5.2.1. Mechanical Behavior
 - 5.2.2. Thermal Behavior
 - 5.2.3. Optical Properties
 - 5.2.4. Barrier Properties
 - 5.3. Polymeric Materials with Packaging Applications
 - 5.3.1. Polyolefins
 - 5.3.2. Polystyrene (PS)
 - 5.3.3. Polyvinyl Chloride (PVC)
 - 5.3.4. Polyesters (PET) and Polyamides (PA)
 - 5.3.5. High-barrier Polymers
 - 5.4. Plastic Container Manufacturing Technologies
 - 5.4.1. Flexible Containers
 - 5.4.2. Rigid Containers
 - 5.5. Interactions in Environment/Plastic Package/food Systems
 - 5.5.1. Permeation, Sorption, and Migration

Index **453**

About EOLSS **461**

VOLUME IV

Food Plant Design	1
<i>J. Peter Clark, Oak Park, IL 60302, USA</i>	

- 1. Introduction
- 2. Principles
 - 2.1. Material Flow
 - 2.2. Sanitary Design
 - 2.3. Site Location
 - 2.4. Design for People
- 3. Critical Issues
 - 3.1. Minimize Capital and Operating Costs
 - 3.2. Satisfy Food Safety Regulations and Quality Expectations
 - 3.3. Perform the Intended Function
 - 3.4. Meet the Agreed Upon Schedule and Budget
- 4. Project Execution
 - 4.1. Feasibility Study
 - 4.1.1. Develop Process Parameters
 - 4.1.2. Develop Utility Requirements
 - 4.1.3. Develop Site Parameters
 - 4.1.4. Cost Estimate and Schedule
 - 4.2. Engineering and Architectural Design
 - 4.2.1. Process Specification and Engineering
 - 4.2.2. Utility Specifications and Engineering
 - 4.2.3. Site and Facility Specifications and Engineering

- 4.2.4. Cost Estimate and Financial Analysis
- 4.3. Project and Construction Management
 - 4.3.1. Bidding
 - 4.3.2. Site Management
 - 4.3.3. Start Up and Commissioning

Food Process Design**24**J. Peter Clark, *Oak Park, IL 60302, USA*

1. Introduction
2. A General Approach to Food Process Design
 - 2.1. Develop a Process Flow Diagram
 - 2.2. Perform Material and Energy Balances
 - 2.3. Select Equipment Types and Sizes for Unit Operations and Transfers
 - 2.4. Develop Process Layout under Ideal Circumstances
 - 2.5. Develop Process Layout under Realistic Conditions
 - 2.6. Develop Cost Estimate
3. Categories of Food Processes
 - 3.1. Fabrication and Disassembly
 - 3.2. Thermal Preservation
 - 3.3. Cooking and Forming
 - 3.4. Size Modification
 - 3.5. Mixing and Formulating
 - 3.6. Separation
 - 3.7. Unconventional Preservation Processes
4. Future Directions in Food Process Design

Food Process Modeling**40**Ashim K. Datta, *Department of Agricultural and Biological Engineering, Cornell University, USA*Jeff Rattray, *Department of Food Science, Purdue University, USA*

1. Modeling and Its Various Uses
2. Types of Process Modeling
 - 2.1. Analytical Models
 - 2.2. Numerical or Computational Models
 - 2.3. Observational (Empirical) Models
3. Other Models Used in Food Plant Design and Operation
4. Computational or Numerical Models
 - 4.1. Computer-based Engineering as a Design Tool
 - 4.2. Typical Characteristics of Physical Processes in Food Processing
 - 4.3. Typical steps in Numerical Modeling
 - 4.3.1. Governing Equations and Boundary Conditions
 - 4.3.2. Mesh Generation
 - 4.3.3. Material Property Data
 - 4.3.4. Solution Technique
 - 4.3.5. Post-Processing
 - 4.3.6. Trusting Computational Results
 - 4.4. Application Examples
 - 4.4.1. Computational Electromagnetics: Microwave Heating
 - 4.4.2. Computational Mechanics: Thermal Cracking during Freezing
 - 4.4.3. Computational Heat and Moisture Transfer: Combined Microwave and Infrared Heating
 - 4.4.4. Other Processes
 - 4.5. Future Needs and Developments in Computational Modeling for Food Processing
 - 4.5.1. Linkages between Commercial Software
 - 4.5.2. Customized Software for Food Processing
 - 4.5.3. Inclusion of Appropriate Physics

- 4.6. Resource Needs for Numerical Modeling for Design Purposes
- 4.7. A Cautionary Statement
- 5. Observational (Empirical) Models
 - 5.1. Introduction
 - 5.1.1. Biological Neurons
 - 5.1.2. Artificial Neurons
 - 5.2. Learning
 - 5.3. Training
 - 5.3.1. Initialization
 - 5.3.2. Performance Tracking
 - 5.4. Other Issues
 - 5.5. Examples

Process Instrumentation and Control

62

Rosana G. Moreira, *Department of Agricultural Engineering, Texas A&M University, USA*

- 1. Introduction
- 2. Background
 - 2.1. Variables in a Control System
- 3. The Control Problem
 - 3.1. Feedback Controller
 - 3.2. Open-loop and Feedforward Control Systems
- 4. Instrumentation
 - 4.1. Measurement Transducer
 - 4.2. Measurement Devices or Sensors
 - 4.3. Final Control Elements and Regulators
 - 4.4. Transmission Lines
- 5. Computer-Controlled Systems
 - 5.1. Digital Control Hardware
 - 5.2. Programming Language
 - 5.3. Programmable Logic Controllers
- 6. Future Trends
- 7. Future Directions

Software for Food Engineering Applications

85

Jose Bon Corbin, *Department of Food Technology, Polytechnic University of Valencia, Spain*

- 1. Introduction
- 2. Software Sources
- 3. Software Tools
 - 3.1. General Software
 - 3.2. Food Physical Properties
 - 3.3. Process Simulation And Design
 - 3.4. Control
 - 3.5. Other
 - 3.6. On-Line Executable Software
- 4. Conclusions

Automation of Food Processing

102

Sundaram Gunasekaran, *Department of Biological Systems Engineering, University of Wisconsin-Madison, USA*

- 1. Introduction
- 2. Why Automate?
 - 2.1. Improved Productivity

- 2.2. Improved Product Quality
- 2.3. Improved Profitability
- 3. Uniqueness of the Food Industry
- 4. Tools of Automation
 - 4.1. Computer Vision Systems
 - 4.2. On-line Sensors
 - 4.3. Expert Systems
 - 4.3.1. Neural Networks
 - 4.3.2. Fuzzy Logic
 - 4.4. Robot Technology
 - 4.5. Computer Integrated Manufacturing
 - 4.6. Flexible Manufacturing Systems
 - 4.7. Systems Engineering
 - 4.7.1. Examination of Existing Equipment
 - 4.7.2. Review of Available Automation Methods
 - 4.7.3. Operation Selection
 - 4.7.4. Prediction of Potential Advantages and Disadvantages
 - 4.7.5. New System Design
 - 4.7.6. Equipment Selection and Staff Planning
 - 4.7.7. Post-Introduction Evaluation

The Sanitary Design and Construction of Food Production Facilities

123

John A. Troller, John A. Troller Consulting Inc., Cincinnati, Ohio, USA

- 1. Introduction
- 2. Programs
 - 2.1. ISO 9000
 - 2.2. HACCP
 - 2.2.1. Establishment and Facilitation of HACCP Programs
 - 2.3. Good Manufacturing Practices (GMPs)
- 3. The Product
- 4. Site Selection and Plant Design
- 5. Plant Layouts
 - 5.1. Lighting
 - 5.2. Process Equipment: Placement and Installation
 - 5.3. Walls
 - 5.4. Floors
 - 5.5. Ceilings and Roofs
 - 5.6. Doors and Windows
 - 5.7. Cafeterias
 - 5.8. Restrooms, Locker Rooms, and Shower Facilities
- 6. Equipment
- 7. The "Enemy": Bio-Films
- 8. Placement of Equipment
- 9. Valves
- 10. Pumps and Piping
- 11. Thermal Processing Equipment
- 12. Conveying Systems
 - 12.1. Screw Conveyors
 - 12.2. Belt Conveyors
 - 12.3. Air and Water Conveying
- 13. Containment Vessels
- 14. A Perspective

Food Waste	148
Shulin Chen, <i>Department of Biological Systems Engineering, Washington State University, Pullman, WA, USA</i>	

1. Introduction
2. Wastewater Parameters
 - 2.1. Temperature
 - 2.2. Solids
 - 2.3. pH
 - 2.4. Dissolved Oxygen
 - 2.5. Biochemical Oxygen Demand
 - 2.6. Chemical Oxygen Demand
 - 2.7. Oil and Grease
 - 2.8. Nitrogen
 - 2.9. Phosphorous (P)
 - 2.10. Sulfur
3. Characteristics of Food Processing Wastewater
 - 3.1. Waste Generation and Waste Load
4. Regulatory Issues
5. Management and Treatment Processes
 - 5.1. Waste Reduction Strategies
 - 5.2. Utilization
 - 5.3. Wastewater Treatment
 - 5.3.1. Pretreatment
 - 5.3.2. Primary Treatment
 - 5.3.3. Secondary Treatment
 - 5.4. Treatment and Disposal of Sludge

Index	169
About EOLSS	173