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This book is dedicated to my beautiful daughters, Jodi Rachael and Staci Michelle. No mother could be prouder of the women you have become. And, with this edition of the book, you both have become mothers. We are so blessed.
Brief Contents

Section I  Food Science Background: Food Systems in Relation to Climate Change, Research, Sensory Evaluation, and the Chemical Composition of Food  1
Chapter 1  Food Science in an Era of Environmental Concern  3
Chapter 2  How Food Science Is Guided by Research  51
Chapter 3  Food Evaluation  97
Chapter 4  Food Composition  133

Section II  Food Safety, Categorized Food and Beverage Groupings, Vegetarianism, Food Preservation, and Packaging  181
Chapter 5  Food Safety  183
Chapter 6  Vegetarianism  237
Chapter 7  Meat and Meat Substitutes  267
Chapter 8  Fish  305
Chapter 9  Poultry  323
Chapter 10  Milk, Cheese, and Dairy  337
Chapter 11  Eggs and Egg Replacements  383
Chapter 12  Fruits and Vegetables  411
Chapter 13  Grains, Cereals, Pasta, Rice, Flour, and Starch Cookery  453
Chapter 14  Yeast Breads, Quick Breads, and Cakes  487
Chapter 15  Fats and Oils  515
Chapter 16  Sugar and Sugar Substitutes  545
Chapter 17  Beverages: Coffee, Tea, Sports and Energy Drinks, and Sugar-Sweetened Beverages  571
Chapter 18  Food Preservation and Packaging  611
Appendix A  Herbs and Health  645
Appendix B  Spices and Health  649
Appendix C  Measurement Conversions and Equivalents  651
Glossary  653
Index  663
Preface  xiv
About the Editor  xxiii
Contributors and Reviewers  xxiv

Section I
Food Science Background: Food Systems in Relation to Climate Change, Research, Sensory Evaluation, and the Chemical Composition of Food  1

Chapter 1
Food Science in an Era of Environmental Concern  3
Irana Hawkins, PhD, MPH, RD

Historical, Cultural, and Ecological Significance of Food Production and Consumption  4
How the Natural Environment Relates to Food Science  4

Special Topic 1.1 Food Insecurity in the United States  5
Lauren Adler
The Current Need for an Ecological Approach  7

Special Topic 1.2 Genetically Modified Organisms and Food  8
Jeannie Houchins, MA, RD

Planetary Health  10

Special Topic 1.3 USDA’s Biobased Product Label  12
Katrina Schroeder
Planetary Boundaries  13
Biodiversity Loss  14

Effects of Climate Change  15

Special Topic 1.4 The Effects of Climate Change on the Earth’s Food Supply  17
Lauren Levandowski
Mitigating Climate Change  19
Effects of Diet on Climate Change  20
Effects of Food Waste on Climate Change  21

Resource Utilization  22
Water Conservation and Drought  22
Opposing Impacts of Two Plant Foods: Palm Oil Versus Lentils  23
Agrichemicals  24
Case in Point: Conventional or Organic Bananas?  24
Plastic Debris  25

Nutrition Transitions  26
Effects of Globalization  26
Antibiotic Resistance  27
National Food Trends  27

Special Topic 1.5 Sustainably Feeding the World  28
Jessica Brie Leonard
The Burden of Diet-Related Chronic Diseases  33

Concern for the Natural Environment Among Health Professionals  34

Putting Theory into Practice  36
Working to Change the Global Food Supply Chain  36
Minimizing Food-Serving Container Waste  36
Creating a Green Kitchen  37

Special Topic 1.6 Mariana Cobos, Organic Banana Farmer  38
Closing the Loop  39

Chapter 2
How Food Science Is Guided by Research  51
Carol E. O’Neill, PhD, MPH, RDN; Theresa A. Nicklas, DrPH; Sari Edelstein, PhD, RDN

Food Science and Research  52

How to Interpret Research: An Evidence-Based Approach  52
Navigating the Peer-Reviewed Literature  52

Qualitative Studies  59
Nutrition Screening  61
Section II
Food Safety, Categorized Food and Beverage Groupings, Vegetarianism, Food Preservation, and Packaging 181

Chapter 5
Food Safety 183
Rebecca Kahn, MA, RDN

Introduction 184
Food Safety Defined 184
Protecting the Food Supply 185
Federal Agencies 185
State and Local Collaboration 188
Food Safety Laws 189
Federal Meat Inspection Act of 1906 190
Federal Food, Drug, and Cosmetic Act of 1938 190
Food Additives Amendment, 1958 190
Color Additives Amendment, 1960 191
Nutrition Labeling and Education Act of 1990 191
Dietary Supplement Health and Education Act of 1994 191
Food Quality Protection Act of 1996 191
Public Health Security and Bioterrorism Preparedness and Response Act of 2002 192
Food Allergen Labeling and Consumer Protection Act, 2004 192
Food, Conservation, and Energy Act of 2008 192
Food Safety Modernization Act of 2011 193
Hazard Analysis and Critical Control Points 193
Good Manufacturing Practices 194
Hazard to Food Safety 194
Biologic Hazards 194
Bacteria 194
Special Topic 5.1 Swine Flu: H1N1 Virus 197
Special Topic 5.2 Avian Influenza: H5N1 Virus 197
Viruses 200
Parasites 201
Prions 201
Special Topic 5.3 Animal Prion Diseases 202
Special Topic 5.4 Bovine Spongiform Encephalopathy 202
Chemical Hazards 202
Physical Hazards 209
Food Safety in the 21st Century 210
Safety of Bioengineered Foods 210
Agroterrorism and Bioterrorism 210

Food as a Target 211
Physical Consequences 211
Psychological Consequences 211
Economic Consequences 212
Political Consequences 213
Public Health Preparedness for Food Biosecurity 213
Potential Agents 214
Foods at Risk 218
Food Biosecurity Triad: Food Systems Security, Public Health Vanguard, and Consumer Engagement 218
Food System Security 218
Public Health Vanguard 221
Consumer Engagement 222
From Awareness to Security 225

Chapter 6
Vegetarianism 237
Tim Radak, DrPH, RD

Introduction 238
Classification 238
History of Vegetarianism 239
Reasons for Choosing a Vegetarian Diet 240
Prevalence of Vegetarianism 241
Impact on Health 242
Vegetarianism Through the Life Stages 242
Special Topic 6.1 Nutrition and Growth for Vegetarian Children 243
Tim Radak, DrPH, RD
Comparing Health Effects of Vegetarian Versus Omnivore Diets 245
Vegetarian Diets in the Treatment of Disease 247
Special Topic 6.2 Vegetarian Diets for Obesity Prevention 248
Tim Radak, DrPH, RD
Nutritional Considerations 249
Nutritional Deficiencies of the Typical American Diet 249
Nutritional Benefits of Switching to a Plant-Based Diet 250
Planning a Successful Vegetarian Diet 251
Special Topic 6.3 Phytonutrients 253
Tim Radak, DrPH, RD
Dietary Planning Resources 255
Going Green with Vegetarianism 257
Nutritional Ecology 257
Air Quality 258
## Chapter 9
**Poultry** 323

_Bonnie L. Gerald, PhD, DTR_

### Historical and Cultural Significance 324

#### Types of Poultry 324
- Chicken 324
- Turkey 324
- Duck 325
- Geese 325
- Guinea Fowl 325
- Pheasant 325
- Quail 325
- Squab and Pigeon 325
- Wild Turkeys 325
- Ratites 326

#### Physical and Chemical Properties 326
- Muscle 326
- Pigments 326
- Protein and Fats 326
- Effect of Heat 327

#### Nutritional Properties 327

#### Cooking Methods 327

#### Special Topic 9.1 Sauces for Chicken and Fish 328
_Maura Grimes_

### Going Green with Poultry 329

Poultry Industry Trends 329

#### Food Technology 330
- Poultry Processing 330
- Packaging 331

#### Food Safety 331
- Pathogens Common to Poultry 331
- Inspection and Grading of Poultry 332
- Farm-to-Fork System 333

---

## Chapter 10
**Milk, Cheese, and Dairy** 337

_Jacqueline Suarez, RDN_

### Historical and Cultural Significance 338

#### Physical and Chemical Properties 339
- Casein and Whey 339
- Pasteurization 340
- Homogenization 340

#### Storage and Cooking 341

#### Milk and Dairy Products 342
- Milk 342
- Cream 342
- Cultured Dairy Products 343
- Butter 345
- Cheese 346
- Ice Cream and Ice Milk 349

#### Special Topic 10.1 Ice Cream and Frozen Dairy Desserts 351
_Mary McAvoy_

#### Impact of Milk and Dairy Products on Health 357
- Weight 357
- Muscle Mass and Recovery After Exercise 358
- Bone Health 358
- Oral Health 359
- Digestive Health 360
- Hypertension and Heart Disease 360

#### Special Topic 10.2 Prebiotics and Probiotics 361
_Colleen Lynch_
- Cancer 364
- Diabetes 364
- Other Health Conditions 365

#### Food Technology 366
- Concentrated Milk Products 366
- Processed Cheese 367
- Dairy Substitutes 367

#### Going Green with Milk Products 369

#### Special Topic 10.3 Bovine Somatotropin in Cow's Milk 369
_Bridget Mahoney_

#### Special Topic 10.4 Antibiotic Resistance 370
_Michelle Boutet_
- Greening the Industry 372

#### Food Safety and Potential Foodborne Illness 373
- Common Pathogens 373
- The Pasteurized Milk Ordinance 373
- Concerns About Raw Milk 373
- Food Regulation and Food Quality 374

#### Lactose Intolerance 375
<table>
<thead>
<tr>
<th>Chapter 13</th>
<th>Grains, Cereals, Pasta, Rice, Flour, and Starch Cookery</th>
<th>453</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diane K. Tidwell, PhD, RD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Historical, Cultural, and Ecological Significance</td>
<td>454</td>
<td></td>
</tr>
<tr>
<td>Wheat</td>
<td>454</td>
<td></td>
</tr>
<tr>
<td>Rice</td>
<td>455</td>
<td></td>
</tr>
<tr>
<td>Corn</td>
<td>455</td>
<td></td>
</tr>
<tr>
<td>Barley</td>
<td>455</td>
<td></td>
</tr>
<tr>
<td>Oats</td>
<td>455</td>
<td></td>
</tr>
<tr>
<td>Rye and Triticale</td>
<td>455</td>
<td></td>
</tr>
<tr>
<td>Sorghum</td>
<td>456</td>
<td></td>
</tr>
<tr>
<td>Millets</td>
<td>456</td>
<td></td>
</tr>
<tr>
<td>Other Plants Used as Grains</td>
<td>457</td>
<td></td>
</tr>
<tr>
<td>Physical and Chemical Properties</td>
<td>458</td>
<td></td>
</tr>
<tr>
<td>Physical Structure of the Cereal Grain</td>
<td>458</td>
<td></td>
</tr>
<tr>
<td>Processing Cereal Grains by Milling</td>
<td>458</td>
<td></td>
</tr>
<tr>
<td>Gluten Chemistry</td>
<td>459</td>
<td></td>
</tr>
<tr>
<td>Special Topic 13.1 Gluten Intolerance: Celiac Disease and Nonceliac Gluten Sensitivity</td>
<td>460</td>
<td></td>
</tr>
<tr>
<td>Lisa S. Brown, PhD, RDN</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Starch</td>
<td>461</td>
<td></td>
</tr>
<tr>
<td>Special Topic 13.2 Food Thickeners and Dysphagia</td>
<td>466</td>
<td></td>
</tr>
<tr>
<td>Leslie Rathon, MS, RDN</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cereal Products</td>
<td>467</td>
<td></td>
</tr>
<tr>
<td>Wheat</td>
<td>467</td>
<td></td>
</tr>
<tr>
<td>Rice</td>
<td>471</td>
<td></td>
</tr>
<tr>
<td>Corn</td>
<td>474</td>
<td></td>
</tr>
<tr>
<td>Barley</td>
<td>475</td>
<td></td>
</tr>
<tr>
<td>Special Topic 13.3 History of Beer Making</td>
<td>476</td>
<td></td>
</tr>
<tr>
<td>Caitlin Portrie</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oats</td>
<td>476</td>
<td></td>
</tr>
<tr>
<td>Rye</td>
<td>477</td>
<td></td>
</tr>
<tr>
<td>Millets</td>
<td>477</td>
<td></td>
</tr>
<tr>
<td>Breakfast Cereals</td>
<td>478</td>
<td></td>
</tr>
<tr>
<td>Other Plants Used as Grains</td>
<td>479</td>
<td></td>
</tr>
<tr>
<td>Nutritional Properties and Impact on Health</td>
<td>480</td>
<td></td>
</tr>
<tr>
<td>Whole Grains</td>
<td>481</td>
<td></td>
</tr>
<tr>
<td>Fortified Grains</td>
<td>481</td>
<td></td>
</tr>
<tr>
<td>Going Green with Grains</td>
<td>481</td>
<td></td>
</tr>
<tr>
<td>Farming Practices</td>
<td>481</td>
<td></td>
</tr>
<tr>
<td>Packaging</td>
<td>481</td>
<td></td>
</tr>
<tr>
<td>Food Safety and Regulations</td>
<td>482</td>
<td></td>
</tr>
<tr>
<td>Storage</td>
<td>482</td>
<td></td>
</tr>
<tr>
<td>Enrichment and Fortification</td>
<td>482</td>
<td></td>
</tr>
</tbody>
</table>

| Chapter 14 | Yeast Breads, Quick Breads, and Cakes | 487 |
| Jeannie Houchins, MA, RDN |
| Historical, Cultural, and Ecological Significance | 488 |
| Physical and Chemical Properties | 491 |
| Yeast Breads | 491 |
| Making Yeast Breads | 493 |
| Quick Breads and Cakes | 496 |
| Bread Selection Criteria | 501 |
| Staling and Spoiling | 501 |
| Sensory Research | 501 |
| Choosing Bread | 502 |
| Special Topic 14.1 Phytonutrients and Spices | 503 |
| Andrea Roche |
| Nutritional Properties and Impact on Health | 504 |
| Food Technology | 505 |
| Going Green with Breads | 506 |
| Wheat | 506 |
| Commercial Breads and Cakes | 506 |
| Food Safety and Foodborne Illness | 506 |
| Bacteria | 507 |
| Mold | 507 |
| Yeasts | 507 |
| Fortification and Enrichment | 507 |

| Chapter 15 | Fats and Oils | 515 |
| Jill Meagher Merrigan, MS, RDN, LDN |
| Historical and Cultural Significance | 516 |
| Physical and Chemical Properties | 517 |
| Natural Fatty Acids | 517 |
| Partially Hydrogenated (Trans) Fatty Acids | 518 |
| Natural Sources of Trans Fats | 519 |
| Nutritional Properties | 519 |
| Omega Fatty Acids | 519 |
| Impact of Fats on Health | 520 |
| Fatty Acids as Functional Foods | 520 |
| Health Risks of Trans Fats | 521 |
| Lessons from the Mediterranean Diet | 522 |
| Food Preparation and Storage Principles | 522 |
| Special Topic 15.1 Nuts and Nut Allergies | 523 |
| Allison Stevens, MS, RD, LD |
| The Most Popular Plant Oils for Cooking | 525 |
Deep Fat Frying  526
Baking with Fats  528
Avoiding Rancidity  529

Improving Fat Intake  530
Menu Planning  530
Grocery Shopping  530
Meal Preparation  531

Food Technology  532
Plant Breeding and Genetic Engineering  532
Modified Hydrogenation  533
Fractionation and Interesterification of Fats  533
Reformulating Food Products to Remove Trans Fats  534
Greening Fats and Oils  534

Fat Substitutes  535
Carbohydrate-Based Substitutes  535
Protein-Based Substitutes  536
Fat-Based Substitutes  536
The Dilemma of Using Fat Substitutes  537

Food Regulations  537

Chapter 16
Sugar and Sugar Substitutes  545

Sugar’s Role in Canning and Freezing  563
Impact on Health  563
Special Topic 16.5  Role of Sugar in Dental Caries  564
Carole Palmer, EdD, RDN, LDN
Current Sugar Consumption Versus Recommendations  565
Special Topic 16.6  The U.S. Obesity Crisis  565
Sung Eun Choi, PhD, RD
Sweeteners and Weight Gain  566

Going Green  566

Chapter 17
Beverages: Coffee, Tea, Sports and Energy Drinks, and Sugar-Sweetened Beverages  571

Coffee  572
Historical, Cultural, and Ecological Significance  572
Coffee Production  573
Menu Planning  577
Nutritional Properties  577
Special Topic 17.1  Distilled Liquors  578
Bekah Angoff
Impact on Health  579
Food Safety and Foodborne Illness  581
Going Green with Coffee  582
Special Topic 17.2  Fair Trade Coffee  582
Veronica Salsberg, BS
Tea  584
Historical, Cultural, and Ecological Significance  584
Tea Production  585
Meal Planning  588
Nutritional Properties  589
Impact on Health  590
Special Topic 17.3  Wine and Winemaking  592
Jordan Tillery
Food Safety  594
Food Technology  594
Going Green with Tea  595

Sports Beverages  596
Historical, Cultural, and Ecological Significance  596
Physical and Chemical Properties  596
Special Topic 17.4  Carbonated Beverages and Soft Drinks  599
Christina Ypsilantis
Food Safety and Regulations  601
CONTENTS

Special Topic 17.5  Ergogenic Aids in Sports Drinks  602
Michelle Palladino

Special Topic 17.6  Phytonutrients in Sports Beverages  602
Rene Reynolds, MS, RDN, LDN
Making Sports Drinks Green  604

Chapter 18  Food Preservation and Packaging 611
Jennifer Lerman Sczerbinski, MPH, RDN, LDN

Food Preservation  612
Water Activity and Osmotic Stress 612
Special Topic 18.1  Sodium Intake and Food Processing  613
Jennifer Lerman Sczerbinski, MPH, RDN, LDN
Acidity 615
Thermal Processing  615
Special Topic 18.2  Thermal Food Processing  616
Aisling Whelan
Refrigeration and Freezing  620
Drying, Smoking, and Freeze-Drying 621
Fermentation  621
Microwaves and Irradiation 622
Effects of Preservation on Nutrient Composition 624
Newer Technologies in Food Preservation  625
Special Topic 18.3  Pesticides in Our Food  627
Jennifer Lerman Sczerbinski, MPH, RDN, LDN

Food Packaging  629
Common Packaging Materials 629
Advances in Food Packaging Technologies  630

Special Topic 18.4  Safety of Packaging Material  631
Jennifer Lerman Sczerbinski, MPH, RDN, LDN
Quality Control  634

Special Topic 18.5  Military Packaging: Technology in Action 635
Jennifer Lerman Sczerbinski, MPH, RDN, LDN

Going Green with Food Processing and Packaging 638
Source Reduction  638
Composting 638
Biodegradable Packaging  639
Recycling 639
Challenges 640

Appendix A  Herbs and Health  645
Kimberly Owen

Appendix B  Spices and Health  649
Abby Calcutt

Appendix C  Measurement Conversions and Equivalents  651

Glossary  653

Index  663
Why the Ecological Approach?

The subject of food science includes the study of plant and animal sources at the cellular level. Different species have evolved based on their environments and genetic changes over time. Ecological changes can have devastating consequences for a plant or animal species. For example, the Irish potato famine that occurred in the 1800s was the result of a virulent fungus (*Phytophthora infestans*) whose spores were spread by wind. Similarly, droughts, such as that seen in 2011 in Somalia, can have a negative effect on animal and plant life in a region. The role of food scientists in these types of scenarios is to potentially find plants that are able to survive in such changing environmental conditions.

Food scientists are being challenged to find and develop plant and animal species that are more tolerant of the Earth’s changing ecology (natural or manmade) in order to provide food that is rich in nutrients (food composition and quality), cost-effective, and available to all people (food technology and delivery systems).

Let us examine some of the environmental changes (natural or manmade) that may affect the world’s food supply in the future:

- **Increases in average temperature.** An increase in the average temperature in a region can (1) lengthen the growing season in regions with a relatively cool spring and fall, (2) adversely affect crops in regions where summer heat already limits production, (3) increase soil evaporation rates, and (4) increase the chance of severe drought.

- **Changes in rainfall amounts and patterns.** Changes in rainfall can affect soil erosion rates and soil moisture, both of which are important for crop yields. In addition, it is predicted that climate change will increase the number of extreme precipitation events.

- **Increases in pollution levels.** Higher levels of ground-level ozone will limit the growth of crops. Because ozone levels in the lower atmosphere are shaped by both emissions and temperature, climate change will most likely increase atmospheric ozone concentrations.

- **Change in climatic variability and extreme events.** Increased frequency and severity of heat waves, drought, floods, and hurricanes are a potential result of climate change.

This text examines food science within the context of the modern world we live in. Although the scientific principles remain the same, they must be viewed through a new lens, one that marries food science with present-day concerns regarding food quality, composition, and availability. Each chapter of this textbook brings to light some of these challenges facing food scientists.

This text approaches food science from an ecological perspective. The science of food remains at the very core of this book, as reflected by the concepts and principles that students are required to master. Section I of *Food Science: An Ecological Approach, Second Edition* presents the introductory concepts students studying food science are required to learn. Using concise language and an engaging writing style, these foundational chapters provide students with the background to understand the relationship between food science and the environment, research methods used by food scientists, and the underlying science and chemistry behind food composition.

Chapter 1, “Food Science in an Era of Environmental Concern,” anchors food science within the natural environment. After reading this chapter, students will be able to conceptualize how environmental conditions affect food composition and sources. Principles such as ecosystems, crop yield, sustainable agriculture, and biodiversity are just some of the important concepts introduced in the chapter.

Chapter 2, “How Food Science Is Guided by Research,” presents the traditional evidence-based research models that students will need to embrace as a part of validating food science facts. Chapter 2 also explores some of the various types of scientific studies, including analytical studies; case-control studies; case reports and case series; cohort studies; cross-sectional surveys; descriptive studies; double-blind, placebo-controlled designs; hypothesis testing; intervention studies; longitudinal surveys; observational studies; population or correlational studies; and randomized designs.
Chapter 3, “Food Evaluation,” discusses the traditional sensory evaluation techniques food scientists use for taste tests. After reading this chapter, students will understand traditional taste panel methods, product and panelist control, sensory tests, and test scaling.

Chapter 4, “Food Composition,” establishes students’ foundational knowledge of the chemical structures and chemical reactions common to food. This foundational knowledge is critical to understanding the later chapters of the text. The chapter presents the chemical building blocks of foods through discussion of carbohydrates, starches, lipids, proteins, vitamins, and minerals.

Section II of Food Science: An Ecological Approach, Second Edition primarily provides a focused discussion of the types of food and the science behind each. Using a consistent presentation, each chapter discusses each food’s historical, cultural, and ecological significance; its physical and chemical properties; preparation techniques and food safety concerns; and its impact on health.

Chapter 5, “Food Safety,” identifies current national food safety issues and the agencies responsible for the safety of the U.S. food supply. It also identifies organisms that may be disseminated by ingestion and the foods most at risk for contamination, and it offers recommended actions that dietitians and other professionals can take to promote food safety preparedness.

Chapter 6, “Vegetarianism,” presents information on the different types of vegetarian diets and the prevalence of vegetarianism in the United States. The chapter compares the health effects of vegetarian, vegan, and omnivorous diets.

Chapter 7, “Meat and Meat Substitutes,” delves into the study of meat and meat substitutes. Content coverage includes muscle structure, meat cuts, and factors affecting the composition of meat.

Chapter 8, “Fish,” explores the structure of fish as well as nutritional and environmental issues with regard to raising fish, endangerment, and consumption.

Chapter 9, “Poultry,” explores the structure of poultry as well as nutritional and environmental issues with regard to poultry safety, free-range farms, and human health.

Chapter 10, “Milk, Cheese, and Dairy,” presents milk and dairy products. Topics include issues pertaining to the production and purchase of milk and dairy products and their uses in recipes.

Chapter 11, “Eggs and Egg Replacements,” examines egg-related food science topics such as egg production, quality, and grading and the use of eggs in cooked foods.

Chapter 12, “Fruits and Vegetables,” presents the classification of fruits and vegetables. It also includes a discussion of the structural parts of fruits and vegetables and the various types of pigments present in plant products. Students will learn about the health benefits of plants as a source of phytonutrients and their use as functional foods.

Chapter 13, “Grains, Cereals, Pasta, Rice, Flour, and Starch Cookery,” presents the food science behind grains, cereals, pastas, and starch cookery. Students will learn about the different types of grains and cereals. The anatomy of grains and cereals and various cooking methods are also discussed. A special feature on the use of starch thickeners for use in dysphagia is also provided.

Chapter 14, “Yeast Breads, Quick Breads, and Cakes,” focuses on yeast breads, quick breads, and cakes. Particular attention is paid to the mixing, kneading, rising, and baking of yeast breads. The preparation of cakes and quick breads is also discussed. Students will learn about the role of various ingredients in the preparation of doughs and batters.

Chapter 15, “Fats and Oils,” discusses the role of fats and oils in food science. Among the topics discussed are saturated fats, monounsaturated fats, and fat substitutes. The effects of heat on fats and oils are explored. The effects of rancidity on foods are also presented.

Chapter 16, “Sugar and Sugar Substitutes,” introduces students to the structure of sugar and sugar replacements, as well as their use in baked goods and other products. Students will become familiar with the different sources of sugar, its chemical properties, and its use in baked goods and candy making. A detailed discussion of the various sugar replacements is also provided.

Chapter 17, “Beverages,” focuses on coffee, tea, and sports drinks, discussing the composition, quality, and nutritional benefits of each. Focused discussions of soda, wine, and liquors are presented individually through Special Topics features within the chapter.

Chapter 18, “Food Preservation and Packaging,” presents the most current information related to food preservation and packaging. Traditional methods of food preservation are discussed, including heat treatments, freezing, drying, and irradiation. New technologies, such as high pressure treatments, pulsed light, and ultrasound technology, and the use of alternative chemicals, are also presented. Different methods and materials for food packaging are also discussed.

New to the Second Edition

Based on feedback collected from instructors who adopted the first edition, a number of large- and small-scale changes have been implemented for the second edition of Food Science: An Ecological Approach.

Most notably, Chapter 5, “Food Safety,” is new to this edition. Among other things, this chapter identifies the safety issues that most threaten our food supply; and it also describes actions that dietitians and other health professionals can take to promote safety. Additionally, the single chapter on poultry and fish in the first edition has been separated into two chapters—Chapter 8, “Fish,” and Chapter 9, “Poultry”—thus providing more well-rounded coverage of each. Finally, a Case Study has been appended to the end of each chapter, providing students with the opportunity for practical application of the content.
The following list highlights specific content areas that have been updated, expanded, or added for the Second Edition:

**Chapter 1: “Food Science in an Era of Environmental Concern”**
- Potential impacts of planetary health, planetary boundaries, and biodiversity loss on food science, and the potential role of diet in protecting our planetary boundaries and mitigating climate change
- Examples of how environmental nutrition and sustainable diets can be applied to reduce human impact on the natural environment
- Description of the Paris Agreement signed in 2016
- The role of vegetarianism and plant-based diets in stabilizing the climate
- The effects of eating locally
- The impact of food waste on climate change
- Resource utilization
- Water conservation and drought
- Opposing impacts of palm oil and lentils
- Agrichemicals
- Plastics debris
- Antibiotic resistance stemming from the food supply
- Concern for the natural environment among health professionals

**Chapter 2: “How Food Science Is Guided by Research”**
- Healthy People 2020 Criteria
- Dietary Guidelines for Americans, 2015–2020
- MyPlate, MyWins

**Chapter 3: “Food Evaluation”**
- New section regarding objective evaluation using both physical tests and chemical tests, with coverage of the following:
  - Principles and approaches
  - Selected devices used to apply such approaches

**Chapter 4: “Food Composition”**
- Water research for cleanliness and composition (e.g., Michigan lead issues)
- Sterols as functional foods
- Research concerning pH in canning food
- Maillard reaction chemical changes
- Chemical structures
- Fortification and enrichment updates
- Retroggradation
- 2018 laws concerning trans fat in food

**Chapter 5: “Food Safety” — Completely new to this edition!**

**Chapter 6: “Vegetarianism”**
- Relevant portions of the Dietary Guidelines for Americans, 2015–2020
- Highlights from new research on the benefits of fiber
- Non-dairy and animal protein replacements
- International/global stats on health and disease
- Organizations supporting a plant-based diet
- Recent research findings on vegetarian diets
- Nutritional deficiencies in the typical American diet, with recent research on low intake of specific vegetables in the United States
- Technology creating meat substitutes
- Vegetarian meal planning
- New research on nutritional ecology
- Government guidelines for greener diets, with new dietary guidelines for China as a significant example

**Chapter 7: “Meat and Meat Substitutes”**
- Beef vaccines
- Beef imports
- Recent beef and other meat consumption statistics
- Swine flu update
- E. coli growth and storage
- Dietary guidelines on fat intake
- Processed meat as carcinogens
- “Food Keeper” app
- Porcine epidemic diarrhea virus

**Chapter 8: “Fish”**
- Fish farming and harvesting
- Ecosystem approach to fishing
- Good agricultural practices
- Good manufacturing practices
- HACCP and fish safety

**Chapter 9: “Poultry”**
- Muscle fibers in poultry
- Poultry as a functional food
- Fat types in poultry
- Nutritional statistics
- Hemichrome (iron) in poultry
- Poultry consumption statistics
- Poultry processing

**Chapter 10: “Milk, Cheese, and Dairy”**
- Pasteurization additions as HTST and ultrapasteurization
- Kefir processing
- Innovation Point on rennin
- Unripened cheese
- Obesity and dairy product research
- Muscle recovery and dairy product research
- Table of calcium content from dairy sources
• Labeling of frozen dairy products
• Yogurt consumption and Type II diabetes prevention
• Oral health, osteoporosis, and hypertension prevention
• Chapter 11: “Eggs and Egg Replacements”
  • Avian flu update
  • Egg cookery in differing cultures
  • Additional Gastronomy Point regarding egg emulsions
  • Nutraceuticals in eggs
  • Move toward cage-free egg use
  • Updates in egg preparation and salmonella outbreak prevention
  • External egg parasites
  • Recent salmonella outbreak statistics
• Chapter 12: “Fruits and Vegetables”
  • Updates in the physical and chemical properties of fruits and vegetables
  • Plant cell structure
  • Effects of boiling on vegetables
  • Healthy bacteria produced in the digestion of produce
  • Hydroponics
• Chapter 13: “Grains, Cereals, Pasta, Rice, Flour, and Starch Cookery”
  • Rice and arsenic
• Chapter 14: “Yeast Breads, Quick Breads, and Cakes”
  • Gluten structure and the results of over- or undermixing
  • Surfactants as bread softeners
  • Enzymes as catalysts
  • Vital wheat gluten
  • Yeast nutrients
  • pH regulators
  • Maillard reaction, carmelization, and acrylamide in baking
  • Baking soda/powder effects on baked goods
• Chapter 15: “Fats and Oils”
  • Inclusion of Dietary Guidelines for Americans, 2015–2020 comments on cholesterol
  • FDA statement on partially hydrogenated oils
  • Coconut oil nutrient content
  • Oxidative rancidity and free radicals
  • Unsaturated fat and oxidation
• Chapter 16: “Sugar and Sugar Substitutes”
  • Gastronomy Point update on prebiotic/probiotic fermentation
  • Chemical structures of sugar substitutes
  • Special Topic added on supertasters and sweet/bitter tastes
  • Digestive issues and FODMAP fermentable oligosaccharides, disaccharides, monosaccharides, and polyols
  • Sugar’s role in canning
• Chapter 17: “Beverages”
  • New research on coffee’s effect on health
• Chapter 18: “Food Preservation and Packaging”
  • Updates from the Dietary Guidelines for Americans, 2015–2020 on sodium intake and processed food
  • New York’s regulation for sodium in restaurant and packaged food
  • Updates in the Food Quality Protection Act
  • FDA update on biphenol A (BPA) in infant bottles

The Complete Learning Package
A full suite of resources are available to instructors using Food Science: An Ecological Approach, Second Edition in their classroom. These include the following:
• Test Bank, containing more than 500 questions
• Slides in PowerPoint format, featuring more than 400 slides
• Image Bank, collecting photographs and illustrations that appear in the text
• Instructor’s Manual, including an array of useful instructor tools:
  • Lecture Outlines
  • Teaching Tips
  • Chapter Review Questions
  • Student Activities
• Answers to the end-of-chapter Case Studies

Additional student resources are available online and include the following:
• Lab Manual featuring recipes correlated to chapter content
• Interactive eBook containing Knowledge Check Questions tied to major headings in the text
• Interactive Flashcards that allow students to test their knowledge of key terms
Special Topic

Careers in Food Science

Jackeline Barreto and Sari Edelstein

A food scientist, or food technologist, looks for better ways to select, preserve, process, package, and distribute food products, including the ingredients that go into them. A food scientist also must have extensive knowledge about the nature, composition, and behavior of food, such as what happens to its flavor, color, or nutritional properties when cooked or placed in storage. Biology, microbiology, chemistry, and engineering are just some of the diverse fields of study that food science draws upon to ensure safe, high-quality consumer products.¹

Food scientists and technologists usually work at universities or food processing facilities. Their main objective is to improve food products by finding a more effective and efficient way to preserve, package, store, or deliver foods. It is the responsibility of the food scientist to analyze and determine the nutritional content of the food with respect to carbohydrates, fats, proteins, sugars, vitamins, minerals, and so on. In addition, food scientists work with government agencies and corporations to make sure food safety, food quality, food waste, and food disposal regulations are being met.

Food scientists may be involved in discovering new food sources; analyzing a food item to determine its vitamin, fat, sugar, or protein content; or searching for substitutes for harmful or undesirable additives, such as nitrates. Other food scientists may engage in applied research, finding ways to improve the content of food or to remove harmful additives. Food scientists are also involved in exploring better ways to process, preserve, package, or store food according to industry and government regulations. Some continue to research improvements in traditional food processing techniques, such as baking, Blanching, canning, drying, evaporation, and pasteurization.²

Because of the wealth of knowledge that food scientists must draw upon, a career in food science requires a bachelor's degree, but a master's or doctorate is often preferred. Some states require that certain food scientists have proper licensure, such as that required for soil scientists. Today, food scientists/dietitians are working in the United States, and job growth for food scientists is greater than average compared to other occupations. It can also be a well-paying career, with a median annual salary of $58,920. Employment in this profession is projected to grow faster than average at 14% between 2016 and 2026.³

References

Features of This Text

*Food Science: An Ecological Approach, Second Edition* incorporates a number of engaging pedagogical features to aid in the student’s understanding and retention of the material.

**Each chapter starts with Chapter Objectives**, which highlight the critical points of each chapter.

**Key Terms** are defined throughout the chapter to enhance comprehension. A glossary is now included at the end of the text.

**Nutrient content claim** Statement that a food company can place on a product label that reflects the product’s nutrient content. For example, a package label may state that the product “Contains 100 calories.” Companies also can state that a particular food is a “good source” of a nutrient or that a food is a “high” source of a nutrient.

At the end of each chapter, a **Chapter Review** summarizes key ideas and helps students remember the different concepts discussed in the chapter and how the concepts interrelate.
Each chapter offers a Learning Portfolio, which features a variety of tools to assist student learning.

A list of Key Terms is provided at the end of the chapter for ease of student review.

For this edition, a Case Study has been added to each chapter, allowing students to apply critical-thinking skills to an issue relevant to the chapter. Instructors can find suggested answers in the Instructor’s Manual.

**Case Study**

Finding Evidence-Based Answers

A number of questions in the nutrition literature have not really been answered using an evidence-based approach. Examples include “Does a low fat intake increase weight in children?” and “Why did the recommendation for intake of added sugars fall from 25% of energy intake in the Dietary Guidelines for Americans, 2010 to 10% of energy intake in the Dietary Guidelines for Americans, 2015?”

**Question**

1. Mining in terns, pick either of these questions or a question you develop with your instructor and use it you come to a definitive answer using an evidence-based approach.

**Study Points**

provide the student with an outline of key points presented in the chapter.

**Issues for Class Discussion**

provides an opportunity for student reflection about the chapter content. Many new issues have been incorporated for this edition due to increasing environmental concerns surrounding our food supply.

**Research Areas for Students**

provide suggestions for further research on the topics covered in the chapter and emphasize the need for peer-reviewed material.

Each Learning Portfolio concludes with a list of updated References.
Green Points provide contextual suggestions for living a sustainable lifestyle.

Phytonutrient Points discuss the health benefits of food components.

Gastronomy Points discuss cooking methodologies as they pertain to the chapter.

A comprehensive and instructional art package includes color photographs and illustrations throughout this text to encourage learning with a unique visual appeal.

Green Point

Rice Packaging  Some rice producers have reduced packaging material by approximately 15% by removing the reusable zippers in their 2-pound rice bags, saving 35,000 pounds of plastic from entering landfills yearly.

Gastronomy Point

Nuts as Snacks  The high amounts of fiber, protein, and healthy fats make nuts a perfect, satisfying snack. Pair a handful of nuts with a piece of fruit or make a portable trail mix using dried fruit, popcorn, cereals, and/or chocolate chips.
Special Topics pay particular attention to singular points featured throughout the chapter.

Innovation Points discuss developments in the field of food science.

Technologies to Minimize Trans Fats: New technologies are being developed to decrease or eliminate trans fats through the production of blends. Blends are mixtures of oils with reduced percentages of trans fatty acids and saturated fatty acids. In some instances, hydrogenated oils are used, but in smaller percentages, along with a tropical oil or nonhydrogenated oil.

Innovation Point

Phytonutrients and Functional Foods
Latitha Sunawel, PhD

Phytonutrients (or phytochemicals) are non-nutritive chemicals derived from plants. Unlike carbohydrates, fats, proteins, vitamins, and minerals, phytonutrients are not essential for life; however, they can promote good health. They are found in vegetables and fruits, whole grains, herbs, teas, and spices. A summary of various phytonutrients and their food sources is presented in Table A.

<table>
<thead>
<tr>
<th>Phytonutrient</th>
<th>Food Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anthocyanins</td>
<td>Berries, cherries, red grapes</td>
</tr>
<tr>
<td>Beta-carotene</td>
<td>Carrots, sweet potatoes</td>
</tr>
<tr>
<td>Garlic, onion</td>
<td>Asparagus, green, citrus fruits, some vegetables</td>
</tr>
<tr>
<td>Beta-carotene</td>
<td>Garlic, onions, leeks, scallions</td>
</tr>
<tr>
<td>Vitamin C</td>
<td>Citrus fruits, tomatoes, broccoli, cabbage, kale, spinach</td>
</tr>
<tr>
<td>Flavonoids</td>
<td>Tea, cocoa, chocolate, apples, grapes</td>
</tr>
<tr>
<td>Ferulic acid</td>
<td>Citrus fruits</td>
</tr>
<tr>
<td>Lutein, zeaxanthin</td>
<td>Kale, collard greens, spinach, corn, citrus fruits</td>
</tr>
<tr>
<td>Lutein, zeaxanthin</td>
<td>Kale, collard greens, spinach, corn, citrus fruits</td>
</tr>
<tr>
<td>Lutein, zeaxanthin</td>
<td>Kale, collard greens, spinach, corn, citrus fruits</td>
</tr>
</tbody>
</table>

Table A: Phytonutrients Found in Different Plant-Based Foods

Sari Edelstein, PhD, RD, is a Retired Professor of Nutrition at Simmons College in Boston, Massachusetts. Dr. Edelstein’s research interests are in the field of dietetics and nutrition, inclusive of systems and process management and food science. Dr. Edelstein came to Simmons College with 30 years of corporate experience, with many positions held in leadership roles. She is a prolific author, having authored more than a dozen textbooks, including *Nutrition in Public Health*, *Life Cycle Nutrition*, *Food and Nutrition at Risk in America*, and *Food, Cuisine, and Cultural Competency for Culinary, Hospitality, and Nutrition Professionals*. Dr. Edelstein taught food service systems and management, food science, and sports nutrition private practice at Simmons College.

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