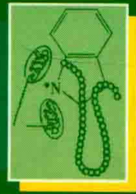
Chemical and Functional Properties
of Food Components Series



Chemical and Functional Properties of Food Components

Second Edition

EDITED BY Zdzisław E. Sikorski

CRC PRESS

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Chemical and Functional Properties of Food Components

Second Edition

Chemical and Functional Properties of Food Components Series

SERIES EDITOR
Zdzisław E. Sikorski

Chemical and Functional Properties of Food Proteins
Edited by Zdzisław E. Sikorski

Chemical and Functional Properties of Food Components, Second Edition
Edited by Zdzisław E. Sikorski

Chemical and Functional Properties of Food Lipids
Edited by Zdzisław E. Sikorski and Anna Kolakowska

Dedication

I am honored to dedicate this volume
to Professor Owen R. Fennema.

Preface

Water, saccharides, lipids, proteins, and minerals — the main components — form the structure of and are responsible for the sensory and nutritional properties of foods. Other constituents, present in lower quantities, especially colorants, flavor compounds, vitamins, probiotics, and additives, also contribute to different aspects of food quality. The catabolysis that takes place in raw materials postharvest, as well as chemical and biochemical changes and interactions of components during storage and processing, affect all aspects of food quality. These processes can be effectively controlled by the food processor who knows food chemistry.

The contents of this book go beyond that of a standard food chemistry text. This volume contains a concise, yet well-documented presentation of the current state of knowledge on the content, structure, chemical and biochemical reactivity, functional properties, and biological role of the components most important to food quality. The first two chapters describe in general terms the contents and role of different constituents in food quality and structure. The main components are presented in Chapters 3–7, while Chapter 8 deals with their impact on the rheological properties of foods. Chapters 9 and 10 discuss the effects of different constituents on the color and flavor of foods, while Chapters 11–14 are concerned primarily with the biological value and safety aspects of the constituents.

Most chapters have the character of monographs prepared by specialists in the respective areas. They are based on the personal research and teaching experience of the contributors, as well as on critical evaluation of the present state of knowledge as reflected in the current world literature. The large lists of references in the chapters include both English papers and papers published in other languages. This volume is addressed to food scientists in industry and academia, food science graduate students, nutritionists, and all persons interested in the role and attributes of various food components.

I am honored to dedicate this volume to Professor Owen R. Fennema, University of Wisconsin – Madison, whom I met in person during three IUFoST congresses. Fennema's books, especially the excellent *Food Chemistry,* have been an invaluable source of information and inspiration to me, my students, and probably most food professionals in the world.

Zdzisław E. Sikorski

Acknowledgment

As the editor, I have had the privilege to work with colleagues from universities and research institutions in Australia, The Netherlands, Poland, Taiwan, and the United States, who have contributed to this volume, sharing their knowledge and experience. Their acceptance of my conception of the book and of the editorial suggestions is highly appreciated. Special thanks are due to those contributors who prepared their chapters ahead of the deadline. It was possible to publish the book without delay only because of the understanding of Dr. Eleanor Riemer and Sara Kreisman of CRC Press, who agreed to accept several chapters even after the deadline.

I also want to thank several of my coworkers in the department of food chemistry and technology of the Gdańsk University of Technology, Poland, who willingly helped me in different ways, especially in handling the computer. Last but not least my gratitude goes to my wife, Krystyna, who generously tolerated a husband heavily involved for the past 40 years in writing and editing food science books.

Zdzisław E. Sikorski
Gdańsk University of Technology

Editor

Zdzisław E. Sikorski received his B.S., M.S., Ph.D., and D.Sc. degrees from the Gdańsk University of Technology (GUT) and his doctor *honoris causa* from the Agricultural University in Szczecin, Poland. He served as head of the department of food chemistry and technology and dean of the faculty of chemistry at GUT and was visiting researcher and professor at the Ohio State University, Columbus, Ohio; CSIRO, Hobart, Australia; DSIR, in Auckland, New Zealand; and National Taiwan Ocean University, Keelung. He is currently professor at GUT and, since 1996, chairman of the Committee of Food Technology and Chemistry of the Polish Academy of Sciences. He has published 200 journal articles, 11 books (in Polish, English, Russian, and Spanish), and 8 book chapters in marine food science and food chemistry. He holds seven patents.

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1 Food Components and Their Role in Food Quality

Zdzisław E. Sikorski

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1.1 MAIN FOOD COMPONENTS

1.1.1 INTRODUCTION

Foods are derived from plant material, carcasses of animals, and single-cell organisms. They are composed mainly of water, saccharides, proteins, lipids, and minerals (Table 1.1). These main components serve as nutrients by supplying the human body with the necessary building materials and source of energy, as well as elements and compounds indispensable for the metabolism. Some plant polysaccharides are only partly utilized for energy. However, as dietary fiber, they affect various processes in the gastrointestinal tract in different ways (Kritchevsky and Bonfield, 1995). Foods also contain a host of other constituents present in smaller quantities, especially nonprotein nitrogenous compounds, vitamins, colorants, flavor compounds, and functional additives. Many of the minor components originally present in foods are nutritionally essential, e.g., vitamins (some can be utilized by the body) and amino acids. Numerous groups, including tocopherols, ubiquinone, carotenoids, ascorbic acid, thiols, amines, and several other nonprotein

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TABLE 1.1
Main Components in Typical Foods

Water	Saccharides	Proteins	Lipids	Minerals	Vitamins
Juices	Saccharose	Soybean	Oils	Vegetables	Vegetables
Fruits	Honey	Beans	Lard	Fruits	Fruits
Milk	Cereals	Meat	Butter	Meat	Fish liver
Vegetables	Chocolate	Fish	Chocolate	Fish products	Meat
Jellies	Potato	Wheat	Nuts	Dairy products	Cereals
Lean fish	Cassava	Cheese	Egg yolk	Cereals	Milk
Lean meat	Fruits	Eggs	Pork	Nuts	Yeast

nitrogenous compounds, serve as endogenous muscle antioxidants, playing an essential role in postmortem changes in meat (Decker et al., 2000). Other minor components are useless or even harmful if present in excessive amounts. Most food raw materials are infected with different microorganisms — putrefactive and often pathogenic — and some contain parasites. A variety of compounds are added intentionally during processing to serve as preservatives, antioxidants, colorants, flavorings, sweeteners, and emulsifying agents and to fulfill different other technological purposes. The chemical nature and role of functional food additives are presented in detail in Chapter 12.

1.1.2 Contents and Role in Food Raw Materials

Polysaccharides, proteins, and lipids are involved in different structures of the plant and animal tissues used for food. The structures built from these materials are responsible for the form and tensile strength of the tissues and create the necessary conditions for the metabolic processes to occur. Compartmentation resulting from these structures plays a crucial biological role in the organisms. Some other saccharides, proteins, and lipids are stored for reserve purposes. Other constituents are either bound to different cell structures or distributed in soluble form in the tissue fluids.

The content of water in various foods ranges from a few percent in dried commodities, e.g., milk powder, through about 15% in grains, 16–18% in butter, 20% in honey, 35% in bread, 65% in manioc, and 75% in meat — to about 90% in many fruits and vegetables. Most of the water is immobilized in the plant and animal tissues by the structural elements and various solutes, contributes to buttressing the conformation of the polymers, and interacts in metabolic processes.

Saccharides are present in food raw materials in quantities ranging from about 1% in meats and fish, to about 4.5% in milk, 18% in potatoes, and 15–20% in sugar beets, to about 70% in cereal grains. Polysaccharides participate in the formation of structures in plants. They are also stored in plants as starch and in muscles as glycogen. Other saccharides are dissolved in tissue fluids or perform different biological functions: in free nucleotides, as components of nucleic acids, or bound to proteins and lipids.

The protein content in foods is given mainly as crude protein, i.e., as N × 6.25. The 6.25 nitrogen-to-protein (N:P) conversion factor has been recommended for most plant and animal food products under the assumption that the N content in their proteins is 16% and they do not contain nonprotein N. The N content in the proteins in various foods, however, is different, since it depends on the amino acid composition. Furthermore, the total N consists of protein N and of N contained in numerous nonprotein compounds, e.g., free peptides and amino acids, nucleic acids and their degradation products, amines, betains, urea, vitamins, and alkaloids. In some foods the nonprotein N may constitute up to 30% of total N. In many of these compounds the C:N ratio is similar to the average in amino acids. However, the N content in urea (47%) is exceptionally high. Most of the nonprotein nitrogen compounds can be utilized by the organism as a source of nitrogen.

The average conversion factor for estimation of true protein, based on the ratios of total amino acid residues to amino acid N, determined for 23 various food products is 5.68 and for different classes of foods, 5.14–6.61 (Table 1.2). The N:P factor of 4.39, based on analysis of 20 different vegetables, has been proposed by Fujihara et al. (2001) for estimating the true protein content in vegetables. A common N:P factor of 5.70 for blended foods or diets has been recommended by Sosulski and Imafidon (1990).

Proteins make up about 1% of the weight of fruits, 2% of potatoes, 3.2% of bovine milk, 12% of eggs, 12–22% of wheat grain, about 20% of meat, and 25–40% of different beans. They serve as the building material of muscles and other animal tissues and, in plants and animals, play crucial metabolic roles as enzymes and enzyme inhibitors, participate in the transport and binding of oxygen and metal ions, and perform immunological functions. During their development cereal grain and legume seeds deposit large quantities of storage proteins in granules known also as protein bodies. In soybeans these proteins constitute 60–70% of the total protein content, and the granules in 80% are made of proteins.

Lipids constitute below 1% of the weight of fruits, vegetables, and lean fish; 3.5% of milk; 6% of beef; 32% of egg yolk; and 85% of butter. The lipids contained in the food raw materials in low quantities serve mainly as components of protein-phospholipid membranes and perform metabolic functions. In fatty commodities the majority of the lipids are stored as depot fat in the form of triacylglycerols. The lipids of numerous food fishes, such as orange roughy, mullets, codfish, and sharks,

TABLE 1.2
N:P Conversion Factors in Foods

Product	Factor	Product	Factor
Dairy products	6.02–6.15	Potato	5.18
Egg	5.73	Leafy vegetables	5.14–5.30
Meat and fish	5.72–5.82	Fruits	5.18
Cereals and legumes	5.40–5.93	Microbial biomass	5.78–6.61

Source: From Sosulski, F.W. and Imafidon, G.I., *J. Agric. Food Chem.*, 38, 1351, 1990.

as well as some crustaceans and mollusks, also comprise wax esters. Some shark oils are very rich in hydrocarbons, particularly in squalene (Sikorski et al., 1990). Furthermore, the lipid fraction of food raw materials harbors different sterols, vitamins, and pigments that are crucial for metabolism.

1.1.3 Factors Affecting Food Composition

The content of different components in food raw materials depends on the species and variety of the animal and plant crop, the conditions of cultivation and harvesting of the plants, the feeding and age of the farm animals or the season in which fish and marine invertebrates are caught, and postharvest changes taking place in the crop during storage. The food industry, by establishing quality requirements for raw materials, can encourage producers to control within limits the contents of the main components in their crops, e.g., saccharose in sugar beets, starch in potatoes, fat in various meat cuts, pigments in fruits and vegetables and in the flesh of fish from aquaculture, or protein in wheat and barley, as well as the fatty acid composition of lipids in oilseeds and meats. The contents of desirable minor components such as natural antioxidants can also be effectively controlled to retard the oxidation of pigments and lipids in beef meat (Matsumoto, 2000). Contamination of the raw material with organic and inorganic pollutants can be controlled by observing recommended agricultural procedures in using fertilizers, herbicides, and insecticides and by restricting certain fishing areas seasonally to avoid marine toxins. The size of predatory fish like swordfish, tuna, or sharks that are fished commercially can be limited to reduce the risk of too high a content of mercury and arsenic in the flesh.

The composition of processed foods depends on the applied recipe and on changes taking place due to processing and storage. These changes are mainly brought about by endogenous and microbial enzymes, active forms of oxygen, heating, chemical treatment, and processing at low or high pH (Haard, 2001). Examples of such changes are:

- Leaching of soluble components, e.g., vitamins and minerals during washing, blanching, and cooking
- Drip formation after thawing or due to cooking
- Loss of moisture and volatiles due to evaporation and sublimation
- Absorption of desirable or harmful compounds during salting, pickling, or smoking
- Formation of desirable or harmful compounds due to enzyme activity, e.g., development of a typical flavor in cheese or decarboxylation of amino acids in fish marinades
- Generation of desirable or objectionable products due to interactions of reactive groups induced by heating or chemical treatment, e.g., flavors or carcinogenic compounds in roasted meats or *trans* fatty acids in hydrogenated fats
- Formation of different products of oxidation of food components, mainly of lipids, pigments, and vitamins
- Loss of nutrients and deterioration of dried fish due to the attack by flies, mites, and beetles