Applied Food Protein Chemistry
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The intent of this book is to provide an updated applied reference book for those who work with or do research on food proteins. This book is also intended to provide an updated text on applied food protein chemistry for upper-level students or graduate students in Food Science programs.

The information in the book is grouped into three sections: (1) overview of food proteins, (2) plant proteins, and (3) animal proteins. The first section on the overview of food proteins covers amino acid, peptide, and protein chemistry, reviews physical and chemical properties of food proteins, their chemical, physical, and enzymatic modification. Functional properties, nutritional aspects of proteins as well as biologically active and antioxidant peptides are also covered in separate chapters. The focus of the remaining two sections is to cover in depth use of both plant proteins (soy, canola, wheat, rice, sorghum, millet) and animal proteins (muscle, dairy, egg, seafood). Each chapter discusses global production, distribution, utilization, physicochemical properties, their functional properties, and food applications. The authors for each of the chapters have been carefully selected from those actively working in the topic area and have a reputation of being an expert in the field. All chapters are peer-reviewed. The book is designed to augment the related books currently in the market.

I am indebted to the contributing authors of this book and the scientific review panel for their hard work, contributions, and high level of professionalism. I hope that readers of this book will find it useful, and will direct their comments, and any unavoidable errors that they detect to my attention.

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Protein Properties
The word protein was coined by Jons J. Berzelius in 1838, and is derived from the Greek word *proteios* which refers to being “of the first rank.” Over the past 100 years proteins were studied extensively and food proteins have been of much interest not only because of their importance nutritionally and for their functionality in foods, but also for their detrimental effects. Food proteins include proteins from milk, meats (including fish and poultry), eggs, cereals, legumes, and oilseeds. Although these have been the traditional sources of protein in the human diet, potentially any proteins from a biological source could serve as a food protein. However, a food protein must be nontoxic, nutritionally adequate, digestible, have functionality desirable in foods, be readily available, and agriculturally sustainable.

The primary role of proteins in the diet is to provide the building materials for synthesis of muscle and other tissues. Proteins play a critical role in many biological processes. For example, proteins such as myoglobin and ferritin are involved in the transport of important biological molecules; oxygen and iron, respectively. Proteins are also major components of muscle and skin, and are essential for providing mechanical support in the body. Antibodies are highly specific proteins, important in immune defenses. Nerve cell responses to specific stimuli are mediated by protein receptors. Growth and differentiation of cells are also controlled by growth factors that are often proteins. Enzymes are proteins with catalytic activity which stimulate many chemical reactions in biological systems. Recently, there has been much interest in proteins due to the satiety they provide, as well as the bioactive peptides derived from them because of their potential as nutraceuticals. Proteins and bioactive peptides have the potential to improve health and reduce risk of various diseases.
The nutritional value of a protein is determined by its amino acid composition. A protein containing all of the essential amino acids in life and growth sustaining proportions is considered a complete protein and will have a high biological value. Many animal proteins generally have high biological value, whereas plant proteins generally are not as high in biological value due to their deficiency in some of the essential amino acids. However, incomplete proteins can be supplemented with the missing essential amino acids. This has been an important practice in improving world’s food sources. The body’s daily protein requirements vary by person, with typical demand being greatest during growth, pregnancy, and lactation. Protein malnutrition can be reversed by proper diet. However, when protein intake is inadequate for too long the recovery may not be complete and the damage is irreversible, possibly leading to mental retardation.

Food proteins are responsible for texture, color, and flavor. Today they are extracted, modified, and incorporated into processed foods to impart specific functional properties. For example, proteins can function as buffering agents, emulsifiers, and fat mimetics in foods. Certain proteins can also form gels and foams. Because proteins contain both hydrophilic and hydrophobic characteristics they can orient themselves at the oil–water interface and can stabilize emulsions, which is important for the stability of foods such as salad dressings, sauces and mayonnaise. Foams are colloidal dispersion of gas in liquid. The protein orients itself at the air–water interface to trap air, similarly as emulsions. Foams are important in foods such as dessert toppings and ice creams. Egg and milk proteins are good foaming agents. Proteins can also form a well-ordered protein matrix or a gel which then traps water, fat, and other food components. Food products like yogurt, tofu, and gelatin dessert rely on the gelation properties of proteins.

Enzymes in food can be desirable or undesirable. Enzymes may serve as processing aids in food processing. For example, lactose-free (or lactose-reduced) milk and lactose-free dairy products are produced from milk where lactose has been hydrolyzed through a controlled enzymatic process. Enzymes also have undesirable aspects including their involvement in deteriorative reactions in foods. For example, polyphenoloxidase catalyzes browning reactions in fruits like apples in the presence of oxygen, and lipoxygenase is involved in lipid oxidation of polyunsaturated oils.

Food proteins can also have adverse effects in the diet. Food proteins can be powerful allergens for some people. Peanut, various tree nuts (such as walnuts, pecans, almonds, and cashews), soybean, wheat, milk, egg, crustacean, and fish proteins have been demonstrated to induce immunoglobulin E (IgE)-mediated food allergies. These eight foods account for approximately 90% of the food allergy reactions in the United States and are sometimes referred to as the “big eight.” There are also some proteins that have antinutritional properties. Trypsin inhibitors (which reduce digestibility of protein) and avidin (which binds biotin, a B vitamin) are common examples. There are also proteins, or amino acids that may react to form toxins. For example, acrylamide in fried potatoes is formed from the reaction of amino acid asparagine with a reducing sugar.

It is important to note that food processing can alter the nutritional value and functional properties of proteins, along with enzyme activity.

This book will review the properties of food proteins, and provide in-depth information on important plant and animal proteins consumed around the world.
2

Overview of Food Proteins

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2.1 Overview of food proteins

This book, *Applied Food Protein Chemistry*, is divided into three main sections. The first section reviews amino acid, peptide, and protein chemistry. It covers the properties of proteins important in foods. The second section provides an in-depth review of the chemistry, properties, and application of food proteins derived from plant sources. The third and last section is on the chemistry, properties and application of food proteins from animal sources.

2.1.1 Section I. Protein properties

Food proteins are essential source of amino acids in the diet which are necessary for normal growth and maintenance of the body. Chapter 3 provides a review of amino acid, peptide, and protein chemistry. Many of our food proteins are denatured and/or altered at the time of their consumption. Thus Chapter 4 is dedicated to protein denaturation, chemical modification of proteins, as well as processing-induced changes. The effects of these changes on specific food proteins are further discussed in the specific chapter dedicated to that protein. Protein denaturation may or may not be desirable, and the nutritional value of a particular protein may be dependent on the extent of denaturation; this is addressed in several of the chapters.

Proteins are essential in the human diet, therefore it is critical to accurately define protein quality and the amount of protein required to meet nutritional needs of different populations. Since the optimum balance between the amino acid supply (provided by dietary proteins) and the dietary needs is important for the health and well-being of
human populations, dietary applications for proteins are determined by the nutritional value of the protein and the human requirements for protein and amino acids. Chapter 8 provides a critical review of the most relevant method for evaluation of food protein quality, the relevance of the pig as a model for assessment of protein quality, and the most recent development in amino acid requirement estimates for humans.

Food proteins also encode a series of bioactive peptides within their structure. Bioactive peptides, once ingested and absorbed, can play a key biological role as regulators of the immune system, blood pressure, or as signalling molecules. Bioactive peptides derived from food proteins are reviewed in detail in Chapter 6.

In addition to their importance nutritionally, food proteins are used as ingredients in foods because of their functional properties and are important in providing structure to the food matrix. Chapter 4 reviews functional properties of food proteins. However, as the authors indicate, this chapter is not a comprehensive review of food protein functionality, rather it highlights some of the novel aspects and recent advances in the methodologies used to study protein functionality. Understanding protein structure provides insight into different aspects of protein functionality; food texture may be manipulated by manipulating the structure and aggregation of proteins. This may be accomplished through processing, by altering environmental conditions, or the interaction of protein with other components in foods. It is important to emphasize that food matrices are complex. The presence of other food components and phases in food provide for additional complexity to studying these systems. Food proteins’ ability to form colloidal structures is also discussed in Chapter 4 as these are important in the processing and nutritional properties of the food matrix they form.

Proteins or peptides derived from food proteins also offer potential as natural antioxidants. They can serve as food preservatives, against lipid oxidation. Lipid oxidation is the primary way lipids and lipid-containing foods deteriorate. Lipid oxidation can lead to loss of nutrients and color, and produce off-flavors and off-aromas. Lipid oxidation can also impact texture and functionality because of its effect on protein structure. Chapter 7 provides an overview of lipid oxidation mechanisms in foods and offers an insight into natural antioxidant options derived from proteins and peptides, among the variety of existing natural antioxidants, to manage lipid oxidation in food and beverage systems. Allergenicity of proteins of course is a concern when using proteins as ingredients/additives. Hydrolyzed pea protein currently looks most promising in food applications. A section in this chapter is dedicated to pea proteins.

2.1.2 Section II. Plant proteins

Proteins from soybeans, canola, corn, wheat, rice, sorghum, and millet are the most significant sources of plant proteins around the world. The nutrient composition of plants and thus proteins are influenced by cultivar, breeding, growth conditions, processing, and refinement.

Soy proteins is one of the most widely consumed oilseed protein in the world. They have been of interest due to their low cost and data accumulating on their health benefits. Soy protein products have experienced significant increase in sales in the United States.
Their application in foods range from functional ingredients to biopolymers, biofilms, and nanocomposite. Particularly popular are energy bars, soy beverages, flavored soy nuts texturized meat substitutes. Changes in their physicochemical properties can further extend their applications in food formulations by improving on their functional, sensory, rheological, and nutritional properties. Chapter 9 reviews chemical composition and principal physicochemical modifications of soybean proteins, and their application in foods.

Canola is a variety of rapeseed that was developed in Canada. It is characterized by its low erucic acid and glucosinolate content in the oil and the meal. Canola is a major oilseed crop. Canola proteins are found in the meal that results as a by-product of oil extraction. The nutritional profile and functional properties of canola proteins make them good candidates as ingredients for use in the food and beverage industries. However, a number of antinutritional components such as glucosinolates, phenolics, phytates, tannins, sinapine, and high fiber in the canola meal have limited their food use. These components also contribute to the inferior physicochemical properties of canola proteins, their digestibility, color, and taste. Over the years research has focused on removing or reducing the amount of these undesirable components, which has provided canola proteins with desirable functional properties with potential use in foods. Chapter 10 discusses the characteristics of canola and low erucic acid rapeseed proteins as well as their functional and health-related properties.

Among cereals grains, wheat, rice, and maize make up approximately 87% of the world production. Wheat is one of the oldest cereal grains to be domesticated. Today it is grown in almost all continents. Among cereal grains wheat has the highest protein content. Wheat proteins are storage proteins whose primary application are bakery products. When the grain is milled and mixed with water, the water-insoluble storage proteins form an elastic dough, due to the unique rheological properties of the gluten proteins. This dough has the ability to retain gas bubbles. Wheat flour is well suited for making the many wheat-based food products that are an important part of the diet for millions around the world. These products included bread in many different forms, noodle and pasta products, pastries, and other baked goods. Gluten was one of the first proteins to be purified and identified as contributing to wheat’s unique dough-forming properties. Today, great complexity of wheat grain proteins is well known. Chapter 11 provides an in-depth review of wheat proteins. Growing interest and expanding markets for “gluten-free” products are also covered in this chapter.

After wheat, maize (or corn) contains the highest amount of protein among cereal grains. Maize is one of the top three cereal crops in terms of world consumption and economic importance. It is the main source of calories and protein for majority of the population in about 20 of the developing countries in Central and South America, Asia, and Africa. It is also used as a weaning food for babies in these countries. Much research has been conducted on improving the nutritional value of maize. There are several excellent books dedicated to maize and maize proteins, therefore, maize is not covered in this book.

Rice is a cereal grain also consumed as a staple food in parts of the world particularly Asia and parts of Central and South America, and to a lesser extent Africa. Rice is a tropical cereal, typically grown in paddies. Rice has one of the lowest protein contents
among cereals. Proteins are present in rice hull, bran, and endosperm but the highest protein content is found in the bran. The best sources of rice proteins are the bran and broken rice because these by-products of rice processing are undervalued and with limited applications. Contrary to other cereal proteins which tend to be deficient in lysine, rice has a good amount of lysine. Recently rice proteins have been of interest due to their hypoallergenicity. The functional properties of protein hydrolysates from rice bran and rice endosperm and their various food applications are described in Chapter 12.

Chapter 13 is dedicated to sorghum and pearl millet which rank fifth and sixth worldwide in production among the cereal grains. They serve as the major source of energy and protein for a large segment of the population in parts of Africa and Asia in the semi-arid tropics. Sorghum is generally a tropical or a subtropical crop, and is considered drought resistant. Millets are a group of variable plants that adapt to low moisture and hot climates. Pearl millet is the most popular among millets. Both sorghum and millets are ground into flour for production of various foods. White sorghum recently has been of interest as a source of gluten-free flour and meal.

2.1.3 Section III. Animal proteins

Animal proteins, meat, poultry, fish, milk, and eggs are nutritionally more complete compared to proteins from plant sources. However, traditionally they have not been consumed to the same extent particularly in the developing countries due to their higher cost.

Meat has been consumed as a food and protein source all throughout history. Chapter 14 is dedicated to meat proteins and it covers key factors affecting raw meat production, structure and functionality of skeletal muscle, muscle protein utilization, protein quality control, and value-added processing of meat.

Surimi is stabilized myofibrillar proteins extracted from mechanically deboned fish meat that is washed with water and blended with cryoprotectants. Surimi is the common seafood protein that is commercially used as raw material; surimi seafood is the finished product. Surimi, forms thermo-irreversible gels upon heating, thus, makes it useful as a food ingredient. Surimi serves as an intermediate product in a variety of products such as kamaboko products of Japan, or surimi seafood products including crabstick. Chapter 15 covers world production, distribution, and utilization of surimi. It reviews the chemistry and rheology of proteins involved in surimi gelation, as well as the biochemical and immunochemical assays used for proteins, differentiation of fish species, and allergen identification.

Milk is a biological fluid produced by mammals; its intent in nature is to nourish the newborn. Although, cow’s milk is most widely used around the world for the production of dairy foods, milk from other species are also utilized. Milk proteins contribute approximately 25% of the daily protein intake of the US diet and are an important source of protein in the diet around the world. Milk proteins include caseins, whey proteins, milk fat globule membrane proteins, and enzymes that naturally occur in milk. Chapter 16 provides an in-depth review of cow’s milk proteins, their structure, and their functional properties.
Eggs from avian species have also been recognized as a good source of proteins for humans. Eggs have high nutritional value and unique functional properties. They are commonly used as ingredients in the food industry. Chapter 17 provides a detailed review of egg proteins, their chemistry, and functional properties. Better understanding of egg protein chemistry and functional properties is important for the application of eggs in food products, improving existing products, as well as in developing novel food products.

2.2 Projected needs for the future

In an in-depth review of food proteins, their chemical properties, and importance in our food and diet—some key issues facing the future became apparent. These include but are not limited to population growth, food availability, and energy. The world population is estimated to reach 9.5 billion by 2075. Currently, majority of the population growth is in the developing world. The challenge ahead is to provide food security and adequate nutrition to the growing world population. Traditional plant breeding methods and advances in agricultural biotechnology has provided for production of higher yields with less use of agrochemicals. Various other tools including biotechnology for modifications in plant and animal foods that can benefit society are available. Clearly, as with any new scientific advancement, the risk versus benefit to society as a whole needs to be evaluated. Public knowledge and consumer attitudes also need to be considered.

In assessing need for the future however, a more urgent issue at hand is global food waste. Approximately one-third of the food produced for human use is lost or wasted globally (Gustaffson et al., 2011). This waste occurs at various stages; at the initial stages of food production as well as in the household at the consumption stage. For example, cereal grains are harvested at certain times during the year. Losses during storage due to insects, molds, and rodent infestation can be as high as 50% in hot climates. With animal products again losses can be significant due to lack of proper processing, storage, and refrigeration. In the low-income countries losses are during the early stages of food production and less food is wasted in the household at the consumer level. In the medium- and high-income countries the waste tends to be at the consumption stage. When compared on the per capita basis, overall, more food is wasted in the industrial world than in developing countries (Gustaffson et al., 2011). So efforts and resources dedicated to food production are in vain. Research on preventing global food waste is urgent. Proper preservation and storage is a key area for improvement and essential for the future of food security.

Reference
