# FOOD CHEMISTRY

# 食品化学

主　编　冯凤琴

[illegible]白益　张　辉　刘松柏

ZHEJIANG UNIVERSITY PRESS
浙江大学出版社

# FOOD CHEMISTRY

主　编　冯凤琴
副主编　陆柏益　张　辉　刘松柏

ZHEJIANG UNIVERSITY PRESS
浙江大学出版社

**图书在版编目（CIP）数据**

食品化学：Food Chemistry：英文 / 冯凤琴主编.
—杭州：浙江大学出版社，2013.9
ISBN 978-7-308-12122-4

Ⅰ. ①食… Ⅱ. ①冯… Ⅲ. ①食品化学—英文
Ⅳ. ①TS201.2

中国版本图书馆 CIP 数据核字（2013）第 196150 号

**FOOD CHEMISTRY**
主　编　冯凤琴

---

**责任编辑**　严少洁
**封面设计**　姚燕鸣
**出版发行**　浙江大学出版社
（杭州市天目山路 148 号　邮政编码 310007）
（网址：http://www.zjupress.com）
**排　　版**　杭州中大图文设计有限公司
**印　　刷**　杭州杭新印务有限公司
**开　　本**　787mm×1092mm　1/16
**印　　张**　15.5
**字　　数**　516 千
**版 印 次**　2013 年 9 月第 1 版　2013 年 9 月第 1 次印刷
**书　　号**　ISBN 978-7-308-12122-4
**定　　价**　35.00 元

---

# 前　言

食品化学是食品科学相关专业的重要基础课程之一。食品化学的内容包括:食品及其原材料的组成成分,主要成分的结构及性质,这些成分在食品加工和保藏中的物理、化学及生物学变化,以及食品成分的结构、性质和变化对食品质量、安全及加工性能的影响等。食品科学与工程及相关专业的学生,必须掌握食品化学的基本知识和研究方法,才能在食品相关领域较好地从事教学、科研、生产及管理工作。

在全球化的背景下,越来越多的高等院校开始重视国际化人才培养,国内一些有条件的高等院校食品学院相继开展了食品化学的双语或英语教学,而目前国内还没有针对本科生食品化学教学的双语或英语教学教材。鉴于此,我们尝试编写了本书。本书内容在深度和广度上基本与食品科学与工程专业(本科)食品化学教学大纲相适应,同时也尽可能将食品化学领域的最新进展融入教材相关章节中。因此,本书除了可作为本科教材外,还可以供食品及相关学科的教师和研究生以及从事食品研究、开发和生产的技术人员参考。

参与本书编写的有浙江大学食品科学与营养系冯凤琴(第一、五、八章)、陆柏益(第六、七、九章)、刘松柏(第二、三章)和张辉(第四、十章),全书由冯凤琴主审。

由于编者水平有限,书中难免有错误和不妥之处,敬请读者批评指正。

# CONTENTS

# Chapter 1 Introduction

## 1.1 Definition

### 1.1.1 Food and Food Science

Food is concerned throughout the world, but the aspects of concerns about food differ with location. In underdeveloped regions of the world, the attainment of adequate amounts and kinds of basic nutrients remains an ever-present problem. In developed regions of the world, food is available in abundance, much of it is processed, and the use of chemical additives is common. In these fortunate localities, concerns about food relate mainly to cost, quality, variety, convenience, and the effects of processing and added chemicals on wholesomeness and nutritive value. All of these concerns fall within the realm of food science—a science that deals with the physical, chemical, and biological properties of foods as they relate to stability, cost, quality, processing, safety, nutritive value, wholesomeness, and convenience. Food science is an interdisciplinary subject involving primarily microbiology, chemistry, biology, and engineering.

### 1.1.2 Food Chemistry

Food chemistry, a major aspect of food science, is the application of chemistry principles to the food system. Food chemistry deals with the compositions and properties of foods as well as the chemical changes which undergoes during handling, processing, and storage. Chemistry is found at all levels in the food system; therefore, the scope of food chemistry is broad. This can be showed graphically by drawing lines from "chemistry" to each component of the food system. It is showed that food chemistry extends to agronomy, harvesting, extraction, processing and/or refining, packaging, storage, distribution, and retail (Fig. 1.1). We need to "use" food chemistry to study the behaviors of food ingredients within the whole food system.

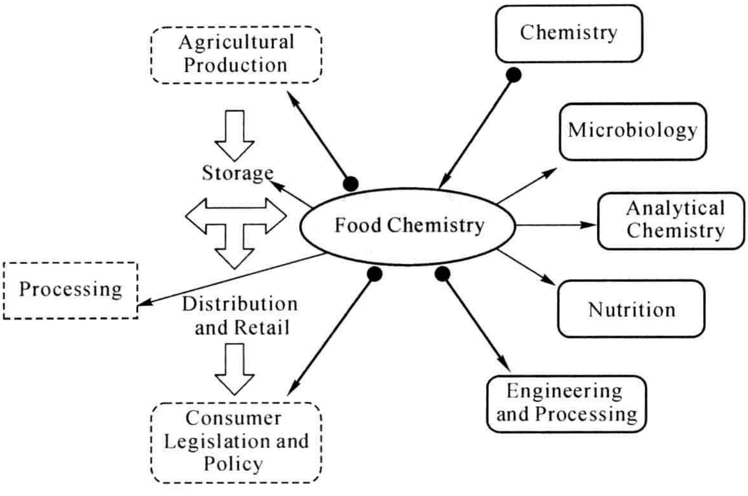


Fig. 1.1 Relating food chemistry with the food system

### 1.1.3 Relationship between Food Chemistry and Other Disciplines

Food chemistry is intimately related to chemistry, biochemistry, physiological chemistry, botany, zoology, and molecular biology. Food chemists rely heavily on knowledge of the aforementioned sciences to effectively study and control biological substances as sources of human food. Knowledge of the innate properties of biological substances and mastery of the means of manipulating them are common interests of both food chemists and biological scientists. The primary interests of biological scientists include reproduction, growth, and changes that biological substances undergo under environmental conditions that are compatible or marginally compatible with life. On the contrary, food chemists are concerned primarily with biological substances that are dead or dying (postharvest physiology of plants and postmortem physiology of muscle) and changes they undergo when exposed to a very wide range of environmental conditions. In addition, food chemists are concerned with the chemical properties of disrupted food tissues (flour, fruit and vegetable juices, isolated and modified constituents, and manufactured foods), single-cell sources of food (eggs and microorganisms), and one major biological fluid, milk. In summary, food chemists have much in common with biological scientists, but they also have interests that are distinctly different and are of the utmost importance to humankind.

## 1.2 Content and Development of Food Chemistry

Food is complicated as for its components. There is an emphasis an food chemistry, including macro-constituents (water, carbohydrates, lipids, and proteins), micro-constituents (for example, flavors, vitamins, minerals, pigments), and their interactions.

Food chemistry emerged as a discipline after World War Ⅱ, and its initial mission was to ensure the supply of food which is nutritious, safe, and affordable. This mission is shared by the other disciplines of food sciences including food microbiology, food processing, food engineering, and food laws. With the fast development and advancement of economy and human society in the past decades, there was a new emphasis on food processing as to make the consumption of food more convenient and the chemical transformations encountered during processing to improve the quality of processed foods. Therefore, advances were made in understanding the maillard reaction, which leads to colored and flavored compounds during processing. The effect of moisture content on food deterioration was also examined leading to a prolonged shelf-life of stored foods. The behaviors of food hydrocolloids, including starch, pectin, bacterial polysaccharides, and protein gelatin, were elucidated. More and more food additives such as sweeteners, antimicrobials, antioxidants, flavorings were developed and applied in food to improve the sensory attributes and to ensure the safety of food. Developments in food analysis enabled the detection of pesticide residues and other toxicants in food.

## 1.3 Approach to the Study of Food Chemistry

It is desirable to establish an analytical approach in food chemistry for food formulation, processing, and storage stability, so that the derived facts from the study of one food or model system can help us to resolve the problems appeared in other food products. There are four components to this approach: (a) to determine what are the properties that are important characteristics of safe, high quality food, namely quality attributes, (b) to determine what are the chemical and biochemical reactions that have important influences on loss of quality and/or wholesomeness of foods, (c) to integrate the aforementioned two points to understand how the key chemical and biochemical reactions influence the quality and safety of foods, and (d) to apply this understanding to various situations encountered during formulation, processing and storage of foods.

### 1.3.1 Quality and Safety Attributes

It is important to reiterate that safety is the first requisite of any food. In a broad sense, safety means a food must be free of any harmful chemical or microbial contaminant at the time of its consumption. In practical operation, this definition takes on a more applied form. For example, in the canning industry, "commercial" sterility as applied to low acid food means the absence of viable spores of *Clostridium botulinum*. This in turn can be translated into a specific set of heating conditions for a specific product in a specific package. Given these heating requirements, one can select specific time-temperature conditions that will optimize retention of quality attributes. Similarly, for peanut butter, operational safety can be regarded primarily as the absence of aflatoxins-a strong carcinogenic substance produced by certain species of molds. Measures taken to prevent growth of the mold may or may not interfere with the retention of some other quality attributes, nevertheless, steps producing a safe product must be employed.

The quality attributes of food including texture, flavor, color, nutritive value and safety and some alterations they may undergo during handling, processing or storage are listed in Table 1. 1. The changes that may occur, with the exception of those involving nutritive value and safety, are readily evident to consumers.

**Table 1. 1 Classification of alterations that may occur on food attributes during handling, processing or storage**

| Attribute | Alteration |
|---|---|
| Texture | Loss of solubility<br>Loss of water-holding capacity<br>Toughening<br>Softening |
| Flavor | Development of:<br>Rancidity (hydrolytic or oxidative)<br>Cooked or caramel flavors<br>Other off-flavors<br>Desirable flavors |
| Color | Darkening<br>Bleaching<br>Development of other off-colors<br>Development of desirable colors (e. g. browing of baked goods) |
| Nutritive value | Loss, degradation or altered bioavailability of proteins, lipids, vitamins, minerals |
| Safety | Generation of toxic substances<br>Development of substances that are protective to health<br>Inactivation of toxic substances |

## 1. 3. 2 Chemical and Biochemical Reactions

Many reactions can alter food quality or safety. Some important classes of these reactions are listed in Table 1. 2. Each type of the reaction may involve different reactants or substrates depending on the specific food and the particular conditions for handling, processing, or storage. They are treated as reaction types because the general nature of the substrates or reactants is similar for all foods. For example, non-enzymatic browning involves reaction of carbonyl compounds, which can arise from existing reducing sugars or from diverse reactions, such as oxidation of ascorbic acid, hydrolysis of starch, or oxidation of lipids. Oxidation may involve lipids, proteins, vitamins, and pigments, and oxidation of lipids may involve triacylglycerols in one food or phospholipids in another. Discussions of these reactions in detail will be carried out in subsequent chapters of this book.

**Table 1.2 Some chemical and biochemical reactions that can lead to alteration of food quality or safety**

| Types of reaction | Examples |
|---|---|
| Non-enzymic browning | Baked goods |
| Enzymic browning | Cut fruits |
| Oxidation | Lipids (off-flavors), vitamin degradtion, pigment decoloration, proteins (loss of nutritive value) |
| Hydrolysis | Lipids, proteins, vitamins, carbohydrates, pigments |
| Metal intereactions | Complexation (anthocyanins), loss of Mg from chlorophyll, catalysis of oxidation |
| Lipid isomerization | Cis→trans, nonconjugated→conjugated |
| Lipid cyclization | Monocyclic fatty acids |
| Lipid polymerization | Foaming during deep fat frying |
| Protein denaturation | Egg white coagulation, enzyme inactivation |
| Protein cross-linking | Loss of nutritive value during alkali processing |
| Polysaccharide synthesis | In plant postharvest |
| Glycolytic changes | Animal tissue postmortem, plant tissue postharvest |

## 1.3.3 Effect of Reactions on the Quality and Safety of Food

The reactions listed in Table 1.3 cause the alterations listed in Table 1.1. Integration of information contained in both tables can lead to an understanding of the causes of food deterioration. Deterioration of food is usually caused by a series of primary events, i.e., physical changes or chemical reactions, followed by secondary events, which, in turn, become evident alteration of quality attributes (Table 1.1) ultimately. Examples of the sequences of this type are shown in Table 1.3. Note particularly that a given quality attribute may be altered as a result of several different primary events.

The sequence in Table 1.3 may be applied in two directions. Operating from left to right, one can design a particular primary, associated secondary events, and get the desirable quality attributes. Alternatively, one can determine the probable cause(s) of an observed quality change (column 3, Table 1.3) by analysing all primarily events that could be involved and then isolating, by appropriate chemical tests, the key primary event. The utility of such constructed sequences is that one can approach the problems of food alteration in an analytical manner.

**Table 1.3 Cause and effect relationship pertaining to food alteration during handling, processing or storage**

| Primary causative event | Secondary event | Attribute influenced(See Table 1.1) |
|---|---|---|
| Hydrolysis of lipids | Free fatty acids react with protein | Texture, flavor, nutritive value |
| Hydrolysis of polysaccharides | Sugars react with proteins | Texture, flavor, color, nutritive value |
| Oxidation of lipids | Oxidation products react with many other constituents | Texture, flavor, color, nutritive value; toxic substances can be generated |
| Bruising of fruit | Cells break, enzymes are released, oxygen accessible | Texture, flavor, color, nutritive value |
| Heating of green vegetables | Cell walls and membranes lose integrity, acids are released, enzymes become inactive | Texure, flavor, color, nutritive value |
| Heating of muscle tissue | Proteins denature and aggregate, enzymes become inactive | Texture, flavor, color, nutritive value |
| Cis → trans con → versions in lipids | Enhanced rate of polymerization during deep fat frying | Excessive foaming during deep fat frying; diminished bioavailability of lipids |

## 1.3.4 Solve Problems by Analyzing and Controlling the Important Variables

Having a description of the attributes of high-quality, safe foods, the significant chemical reactions involved in the deterioration of food and the relationship between the two, we can now begin to consider how to apply these information to the situations encountered during the processing and storage of food, which involves analyzing and controlling the important variables including temperature, time, pH, water activity ($a_w$), light, composition of the product, and composition of the atmosphere and so on.

Temperature is perhaps the most important among these variables because of its broad influences on all types of chemical reactions. Another important factor is time. During storage of a food product, one is interested in time which is respected to the integral of chemical and/or microbiological changes that occur during a specified storage period, and these changes combine together to determine a specified storage life for the product. During processing, one is often interested in the time it takes to reach an ideal sterilization effect or in how long it takes for a reaction to proceed to a specified extent.

Another variable, pH, influences the rates of many chemical and enzymatic reactions. Extreme pH values are usually required for severe inhibition of microbial growth or enzymatic processes, and these conditions may accelerate the acid or base catalyzed reactions. In contrast, even a relatively small pH change may cause profound changes in the quality of some foods, for example, muscle.

Another important compositional determinant of reaction rates in foods is water activity ($a_w$). Numerous investigators have shown $a_w$ strongly influences the rate of enzyme-catalyzed reactions, lipid oxidation, non-enzymatic browning, sucrose hydrolysis, chlorophyll degradation, anthocyanin degradation, and others.

Recently, it has become apparent that the glass transition temperature ($T_g$) of food and the corresponding water content ($W_g$) of the food at $T_g$ are causatively related to rates of diffusion-limited events in food. Thus $T_g$ and $W_g$ have relevance to the physical properties of frozen and dried foods, to conditions appropriate for freeze drying, to physical changes involving crystallization, recrystallization, gelalinization, and starch retrogradation, and to those chemical reactions that are diffusion-limited.

For some products, exposure to light can cause detrimentation, and it is then appropriate to package the products in light-proof material or to control the intensity and wavelengths of light, if possible.

Composition of the product is important since this determines the reactants available for chemical transformation. In some processed foods, the composition can be controlled by adding approved chemicals (food additives), such as acidulants, chelating agents, flavors, or antioxidants, or by removing undesirable reactants, for example, removing glucose from dehydrated egg albumen.

Composition of the atmosphere is important mainly with respect to relative humidity and oxygen content, although ethylene and $CO_2$ are also important during storage of living plant foods. The detrimental consequences of a small amount of residual oxygen sometimes become apparent during storage of food product.

Food chemists must integrate the information about quality attributes of foods, deteriorative reactions to which foods are susceptible, and the factors governing kinds and rates of these deteriorative reactions, in order to solve problems related to food formulation, processing, and storage stability.

# Glossary

| | |
|---|---|
| aflatoxins | 黄曲霉毒素 |
| albumen | 清蛋白 |
| anthocyanin | 花青素 |
| antioxidant | 抗氧化剂 |
| ascorbic acid | 抗坏血酸,维生素 C |
| botany | 植物学 |
| carbohydrate | 糖类 |
| carcinogenic | 致癌的 |