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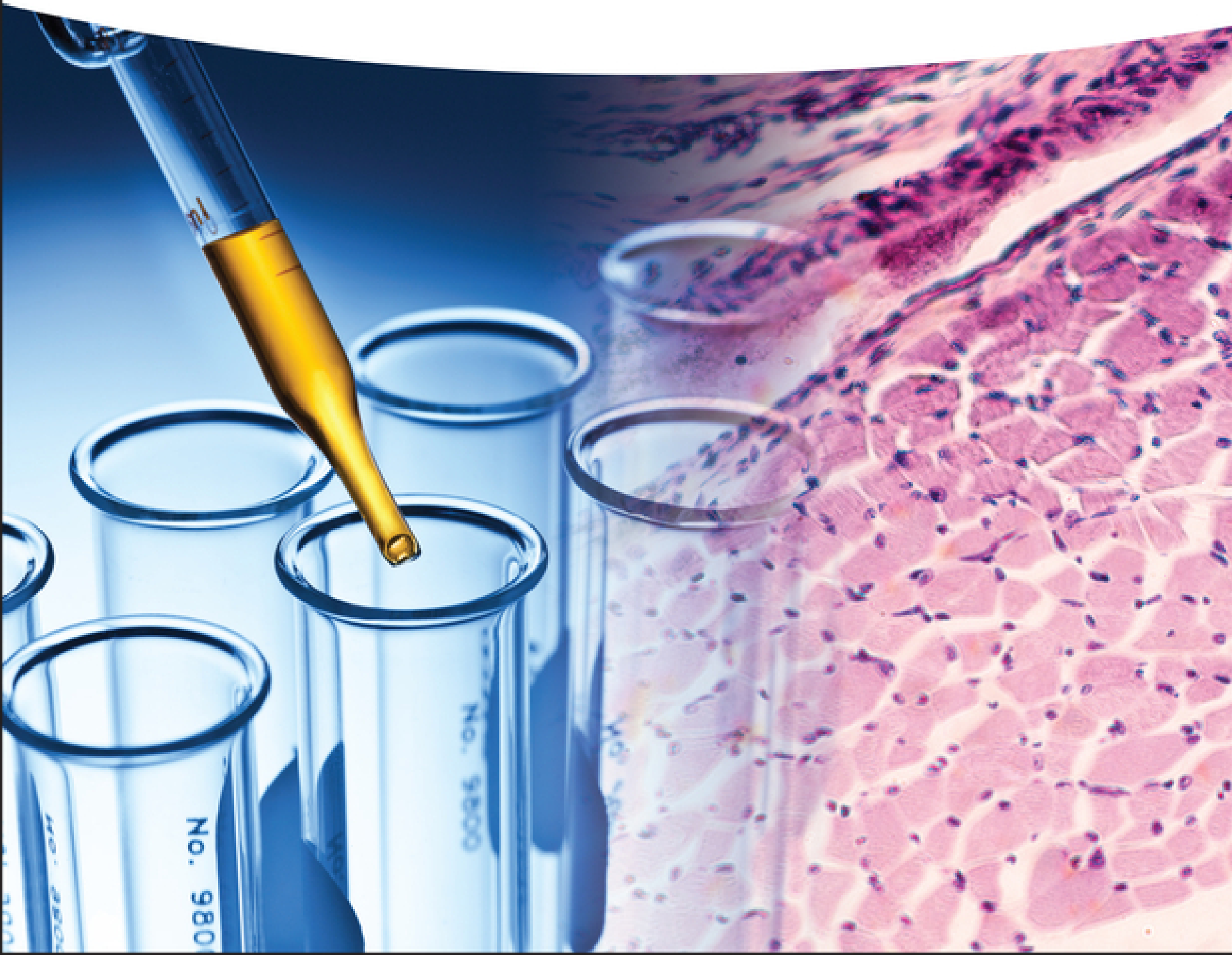

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Volume 1

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Preface

Biopolymers in Pharmaceutical and Food Applications is a new reference book on industrially important, or potentially important, biopolymers, their process technology, and applications. The individual biopolymers focus on major application areas of biopolymers in pharmaceutical, biomedical engineering, and food technology applications.

The reference book is composed of Volume 1 and Volume 2.

This reference book explores the various aspects of biopolymers in pharmaceutical and food applications. This book focuses on current research trends on important biopolymers and biopolymer-based formulations in drug delivery and biomedical applications. This book comprehensively summarizes fabrication technology, characterization, drug delivery, cosmetics, and food technology applications.

The book is an important resource for academics, pharmaceutical, material science, chemical science, life science, and biotechnology scientists, as well as food technologists, who are working in the field of polymers/materials for drug delivery and food science, in addition to medical and other health care professionals in these fields.

We acknowledge that this book would not have been possible without the support and contributions of all the authors and their respective teams.

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Part I

Food Applications

1

Starch in Food Applications

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1.1 Introduction

Starch is a branched homopolysaccharide consisting of D-glucose units as its building blocks. Moreover, starch consists of two polyglucans: amylose and amylopectin. In amylose, D-glucose units are connected to each other by α-1, 4 glycosidic linkages, while amylopectin is a highly branched polymer of D-glucose comprising α-1, 4 glycosidic linkages at the linear chains and α-1, 6 glycosidic linkages at the branching points [1, p. 7011]. Generally, starches constitute 20–30% amylose and 70–80% amylopectin in their structure. The branched chain length varies depending on the type of starch. The structural components of starch, i.e. amylose and amylopectin, are deposited in distinct granules in amyloplasts of plants' storage organs. These granules could be of various sizes and forms, like it could be disk or spherical, as in case of Triticeae family's starch granules [2, pp. 1003–1017]. According to their size, starch granules are categorized as A, B, and C type.

Starch-based foods are an abundant source of energy and are frequently used as the main diet by people all over the communities due to their widespread availability and low cost [3, pp. 513–523]. Starch is widely used in food industries not only due to its nutritional values [4, p. e0228624] but also to manage the homogeneity, stability, and texture of foods. Moreover, it is used to prevent gel disintegration during processing and to enhance the shelf life of foods [5, pp. 1–26]. Despite of its wide use in food-manufacturing sectors, it showed its promise in diverse fields like health and medicine, textiles, paper, fine chemicals, petroleum engineering, agriculture, and construction engineering [6, p. 13]. Pure starch is a white, tasteless, and odorless powder that is insoluble in cold water or alcohol. Starch can be obtained from various sources like roots, tubers, and seeds of plant. Most readily available starches are now derived from tapioca, potatoes, maize, rice, wheat, and other sources [7]. It is estimated that by 2026, the global starch market will reach 160.3 million metric

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tons. It is due to the rapid development of the food processing industries, along with the increasing demand for starch-based adhesives in commercial settings.

Native form of starch is rarely used in food industries due to its poor cold-water solubility, susceptibility to freeze-thawing, shear pressure, pH change, and proneness to retrogradation, demanding structural modification to overcome these limitations. Modification techniques can significantly improve the properties of native starch by improving its physicochemical attributes and structural aspects, as well as increasing its technical value [8]. Such modifications are generally done by enzymatic, physical, or chemical means. Physical modifications (ultra-high-pressure treatment, heat-moisture treatment [HMT], and freezing) are comparably simple and cost-effective than chemical modifications (esterification, acid treatment, etherification, and cross-linking) used to introduce desired functional groups into the native structure of starch molecules [9, pp. 299–312]. Nowadays, considering more greener approach, enzymatic modification techniques have been employed as an alternative to physical and chemical approaches as they are more eco-friendly and healthier than other techniques [10, pp. 278–321]. In the baking sector of food industries, enzymatic modification has a significant impact, as enzymes could react with carbohydrates to render more desirable derivatives [9, pp. 299–312]. Oxidoreductases, like lipoxygenase and glucose oxidase, and hydrolases like, amylases and proteases, are the most common enzymes employed in bakeries. Therefore, in the present chapter, we discussed about the native starch, different modifications of starches, and their applications in the food industries.

1.2 Natural Starch

Being a calorie-rich food component, starch is used around the globe. Moreover, it offers organoleptic properties by aiding the crispness when used as an ingredient in food products. Broadly starch could be used in its two forms i.e. native and modified form. Native starch could be obtained from abundant natural resources, while modified form is achieved through different modification techniques to meet industrial requirements, which are discussed later in this chapter. The characteristics of the native starch largely depend on the source from where it is extracted. The demand for native starch obtained from natural sources is high due to its easy availability and low production cost. Here, we discussed about some commonly used natural starches, i.e. corn, potato, wheat, and tapioca starch [11, pp. 103–165].

1.2.1 Corn Starch

Corn starch is also commonly known as maize starch. It is observed that around 80% of the world's commercial production of starch is corn or maize starch. This is the most abundantly used starch. Corn or maize starch is isolated from corn kernels. The kernel itself contains about 64% to 80% starch. The isolation of starch from the kernels is done by the wet-milling process. Corn starches are used in various products and have a wide range of applications not only in food industries but also in several other sectors. In corn starch, the protein content is about 0.35%, lipid content is about 0.8%, very less little of ash is present, and two polysaccharides: amylose and amylopectin are present in large amounts (about >98%). All natural starches are found in the form of granules that are insoluble in water at room temperature. It is also observed that natural starch granules obtained vary in size and shape. The size of the starch granules varies from 2 to 30 μm [12, pp. 537–549]. Corn starch is commonly found as a white, tasteless, and odorless powder. Corn starch finds its application in papermaking, food processing, manufacturing of industrial adhesives, and as a lubricant in surgical gloves. It is also used as a component in many cosmetics and oral pharmaceutical products [13, pp. 11–14].

The granular nature of corn starch and the partially crystalline nature of their granules are important. These nature of the corn starch helps in many ways. This nature of the starch granules makes them useful for physical and chemical modifications. It is seen that when corn starch granules are added to aqueous systems, they readily absorb water and become hydrated. If the temperature of the aqueous system, in which the hydrated granules are immersed is increased, significant changes could be observed. The water of hydration first disrupts the hydrogen bonds in the amorphous regions of the granules. This results in swelling of the granules, which ultimately changes their shape and makes them more of a spherical one. If the temperature is continuously increased, it will lead to increased hydration and swelling in the amorphous regions [12, pp. 537–549]. The irreversible disruption of amorphous and crystalline structures in the starch granules is called gelatinization. Some dissolved starch polysaccharide molecules, primarily amylase, leaches from the swollen granules during gelatinization.

A process called pasting is achieved by heating starch granules with some shear in excess water. This process leads to further granule swelling, leaching of polymer molecules (mainly amylose), and granule disruption (since swollen granules are fragile). This results in a hot starch paste. Again, cooling the hot paste results in the formation of a gel [12, pp. 537–549]. It should be noted that inhalation of corn starch can cause lung damage [14, pp. 767–769]. A substitute for talcum powder that contains corn starch powder was found to result in severe pneumonitis among infants [15, pp. 108–110].

1.2.2 Potato Starch

Potato starch comprises 70–85% of the dry matter, providing food and energy for a considerable portion of the world's population. However, potato starch also has a number of useful applications outside of food and nutrition [16, pp. 2588–2612]. Essentially, potato starch is made up of two α-(1,4)-D-glucose monomers: amylose, a polymer with an extremely shallow branching, and amylopectin, a polymer with a very steep branching. Along with polysaccharides, proteins, lipids, and minerals are the other components of potato starch [17, pp. 979–988].

Potato starch and its derivatives have properties, such as low temperature of gelatinization and a high sticky consistency. Potato starch is commonly used in the food industries because of its excellent clarity and neutral flavor. Potato starch also finds its importance in the paper and textile industries. The large granule size of potato starch is preferred as a precoat on filters [18, pp. 511–539]. Potato starch is effectively used in puddings. When cold milk is added to the starch, it quickly dissolves and forms a gel. Potato starch is also used as a thickening agent for pie fillings in food industries. It is also finding its application in jelly type candies. It is also used in the body of caramels and marshmallows. In chewing gum and candy gum, potato starch is used as a dusting agent. Starch is mixed with powdered sugar to exert its effect.

1.2.3 Wheat Starch

Wheat is one of the major cereal crops grown all over the world throughout the year. In wheat grain, starch content is 65–70%. Wheat starch is found as a semi-crystalline granule. These starch granules vary in size and shape [19, pp. 954–967]. Two types of polymers, amylase (a linear molecule of α-1,4-linked glucans) and amylopectin (branching with additional α-1,6-linkages) constitute these starch granules. Amylase constitutes 25–30% of the starch, while amylopectin constitutes 70–75% [20, pp. 989–998]. Wheat starch shares some common rheological properties with corn starch. While, the gel strength and viscosity of wheat starch are not as high as those of corn starch. The application of wheat starch in food industries lies in baking. Wheat starch is often found to replace wheat flour. It increases the volume and makes the cake tender.

1.2.4 Tapioca Starch

The native starch of tapioca forms a clear and cohesive paste when cooked. The above mentioned properties of this starch limit its use in food-manufacturing industries. The texture of the tapioca starch is also found to be undesirable. Although the bland flavor of this starch attracts several food manufacturers, it is used in pastry fillings, baby food products, and flavored puddings. This starch finds its value when some modifications are made to remove the problems associated with its texture. The modified version of tapioca starch attracts some food manufacturers and is used in pie fillings [21].

1.3 Modified Starch

Starch in its native form has been extensively used by food industries for a long time. However, due to its physicochemical properties like low thermal stability, its susceptibility to retrogradation limits its application in certain types of food processing. To overcome these limitations, starch used to be modified by physical, chemical, and enzymatic methods (Figure 1.1). This section discusses about these individual processes of modification.