CHAPTER 5

Matching Starches to Applications

The versatility of starch, particularly modified starch, makes it well suited for a wide variety of foods (Table 5-1). Starch contributes to texture, viscosity, gel formation, adhesion, binding, moisture retention, film formation, and product homogeneity. Certain modified starches are also being increasingly used as fat substitutes in low- and no-fat products.

Commercial starches are obtained from cereals such as corn, wheat, and various rices and from tubers or roots such as potato and cassava (tapioca starch). Starches from different sources vary in taste and viscosifying properties. For example, native potato and tapioca starches have weak intermolecular bonding and gelatinize easily to produce high-viscosity pastes that thin rapidly with moderate shear. Potato starch produces clear, viscous, almost bland pastes, which are used in products such as extruded cereals and dry soup and cake mixes. Tapioca starch produces clear, cohesive pastes that gel slowly over time. Native corn, rice, and wheat starches form opaque, gelled pastes that have a slight cereal flavor. High-amylose corn starches produce opaque, strong gels commonly used in gum candies. Waxy maize starch produces a clear, cohesive paste (1).

Because the pastes and gels produced by native starches are often cohesive (gummy) or rubbery, the functional properties of these starches are improved by modification. Different types of modification produce starches that are better able to withstand the heat,

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TABLE 5-1. Starch Usage by Application Sector[a,b]

Application	Binders	Viscosifiers	Film-Formers	Texturizers
Soups, sauces, and gravies	. . .	X, XS, PX, PXS	. . .	X, XS, PX, PXS
Bakery	PN	X, P, PX, PXS	D, M	P, X, PX, PXS, M
Dairy	N, A, M	X, XS, P, PX, PXS	. . .	X, XS, PXS, A, PX, O, PO, M
Confectionery	PO, O	. . .	O, PO, A	. . .
Snacks	N, P, PN, PO, D	. . .	. . .	. . .
Batters and coatings	X, PX, O	P, PX	D	O, PO, D, M
Meat products	N, X, XS, P	. . .	XS	XS

[a] Adapted from Davies, L., 1995, Starch—Composition, modifications, applications and nutritional value in foodstuffs, Food Technol. Europe, June/July, pp. 44-52.
[b] N = native, X = crosslinked, P = pregelatinized, S = substituted, O = oxidized, A = acid hydrolyzed, D = dextrin, and M = maltodextrin.

shear, and acids associated with various foods and food-processing conditions. Modification can have an effect on starch solubility, viscosity, freeze-thaw stability, paste clarity and sheen, gel formation, film formation, and cohesiveness.

There are numerous factors to consider in the choice of a starch for use in a particular food system. The desired properties of the food (e.g., texture, mouthfeel, and viscosity), the method of processing, and the distribution parameters, especially storage temperatures, must all be examined. An up-front strategy in which the various requirements of the food product are reviewed prior to selection of a starch saves time, frustration, and probably money in the product-development process.

General Considerations

SENSORY CONSIDERATIONS

The goal of the product-development process is to create safe, high-quality foods with optimal sensory properties. Sensory considerations such as texture, appearance, and flavor usually determine consumer acceptability. The desired "look" of a product, which is usually conceptualized prior to the development process, is not always easy to achieve. Ingredients, processing, and distribution all influence final product quality and ultimately dictate success or failure in the marketplace.

Since starch is an ingredient that can affect the texture, body, and appearance of a product, many factors need to be taken into account. Table 5-2 contains terms used in the vernacular of the starch industry that are associated with texture, body, and appearance of starch-containing foods. These terms, although not "scientific," have been used for years to describe the performance of starch, either as a paste or as part of a food product, during or after processing.

TABLE 5-2. Common Terms Used to Describe Starch-Based Food Products

Texture	Body	Appearance
Grainy	Heavy	Dull
Smooth	Thin	Shiny
Cohesive (gummy)	Long	Opaque
Gelled (soft or firm)	Short	Translucent

Texture. Starch can produce various textures, ranging from grainy to smooth and from cohesive (i.e., gummy or slimy) to gelled. Graininess is affected by the particle size of the starch granule itself as well as by the cooking characteristics. The particle size of drum-dried pregelatinized starches, for example, can be controlled by grinding so that various particle sizes are generated. Particle size not only affects texture, but dispersibility and dissolution of the starch as well. Powders of pregelatinized starch that have a fine granulation (i.e., small particle size and therefore a greater surface area) have a tendency to lump during hydration, especially if proper mixing is not achieved during the addition step. This problem is caused by quick hydration and gelling of the starch at the outer surface, thus preventing the interior starch from wetting. The centers of these lumps actually contain dry, pregelatinized starch powder. These characteristic gelled lumps are often referred to as "fish eyes" in the industry. Pregelatinized starches that are coarsely ground and/or agglomerated usually dissolve more easily because of their larger particle size (less surface area) and slower hydration rate. Large particles can sometimes generate a grainy, apple sauce-like texture, depending on how the starch has been modified, the manner in which the starch is pregelatinized, and/or its hydration properties. The amount of cooking that a starch undergoes may also affect texture. For example, cook-up starches that are not sufficiently gelatinized may result in products with a "pasty" or "grainy" mouthfeel. Finally, a pasty texture can also occur if too much starch is used.

Cohesive or gummy textures are most often related to the type of starch used. In particular, cooked pastes from native waxy starches often produce cohesive textures. Chemical modification, however, particularly crosslinking, generally changes a normally cohesive-type starch into one that generates a short, pudding-like texture. Gelling behavior is related primarily to the amylose content of the starch. In general, native starches with high levels of amylose have a greater tendency to form a gel after cooking.

Body. Related to texture is the flow property of a starch paste or final product once a force has been applied. Simply put, how does the product behave after processing, especially after being disturbed, e.g., stirred, spooned, mixed, blended, or poured? Some starches result in a paste and/or final product with a very short, heavy body or consistency (for example, a pudding or salve-like product) while others are considered long and thin, that is, less viscous and more syrup-like. Both the type of starch base and the type of modification influence the final texture and body of the product.

Appearance. Starch can significantly affect the appearance or clarity of the product. Certain foods are expected to be dull, while others may require a surface shine (gloss). Gelling starches, such as that from native dent corn, become opaque after cooking, and others, such as that from native waxy corn, are more translucent. Potato starch yields a clear paste. The chemical modification of starch can also affect paste clarity. For example, chemical substitution such as hydroxypropylation has a tendency to improve paste clarity.

Flavor. Another sensory consideration for the product developer is the flavor of the final product. Here, too, starch and starch-related products can have a dramatic impact. The starch base, the milling process, and the type of chemical modification of the starch can all affect the resultant flavor. Delicately flavored foods, such as cream sauces or lightly flavored puddings, can develop an off-flavor from their ingredients, including starch. Because starches are isolated from plant materials, off-odors associated with the botanical source from which they are milled may be present. Residual protein and/or lipid not extracted during the milling process can influence starch flavor. Cereal-based starches such as corn and wheat starch are sometimes considered to have off-notes described as “cardboard” or “cereal-like.” Root and tuber starches such as tapioca and potato, on the other hand, are usually judged to be cleaner in flavor. The type of starch modification can also influence the flavor. For example, it is believed that acetylated starches can sometimes cause a recognizable off-note in delicately flavored foods. In general, when considering a starch for a specific application, one needs to keep in mind the desired flavor profile and understand the impact the chosen starch will have on that flavor.

pH CONSIDERATIONS

Another property of the food product that needs to be considered is pH. The pH of a product not only influences ingredient functionality, but is an important parameter in dictating food-preservation processes. For example, pH is a critical factor in determining the type of thermal process that is required for “commercial sterility” (as related to microbial growth and food safety). The thermal process requirements for high-acid foods (pH < 3.7), acid foods (pH 3.7–4.5), and low-acid foods (pH > 4.5) differ from one another and must meet strict guidelines (2).

Acidic conditions can have a dramatic impact on paste viscosity, texture, and stability. Native (unmodified) starches are typically unstable under acidic conditions. They are susceptible to viscosity breakdown during processing and may also result in the development of poor texture. Stability in an acidic environment is one of the primary reasons that starches are chemically modified. In general, the higher the degree of crosslinking, the more acid-tolerant the starch. Although neutral pH is less detrimental to starch viscosity, the thermal process that is usually required to preserve low-acid foods is quite severe. For this reason, modified starches are also required for low-acid products that require a more stringent thermal process.

FORMULA-RELATED CONSIDERATIONS

The food technologist also needs to be cognizant of other ingredients that could influence starch performance. Product composition should be kept in mind when determining the proper starch for a system. For example, the amount of moisture present to hydrate the starch, the presence of fats and oils, and the level of solids such as salts and sugars can all influence starch behavior. In general, ingredients that have a tendency to “complex” with starch and/or to compete directly with starch for water negatively impact starch performance, particularly during gelatinization and pasting. The effects of sugar content on starch gelatinization temperature and viscosity development are shown in Figure 5-1.

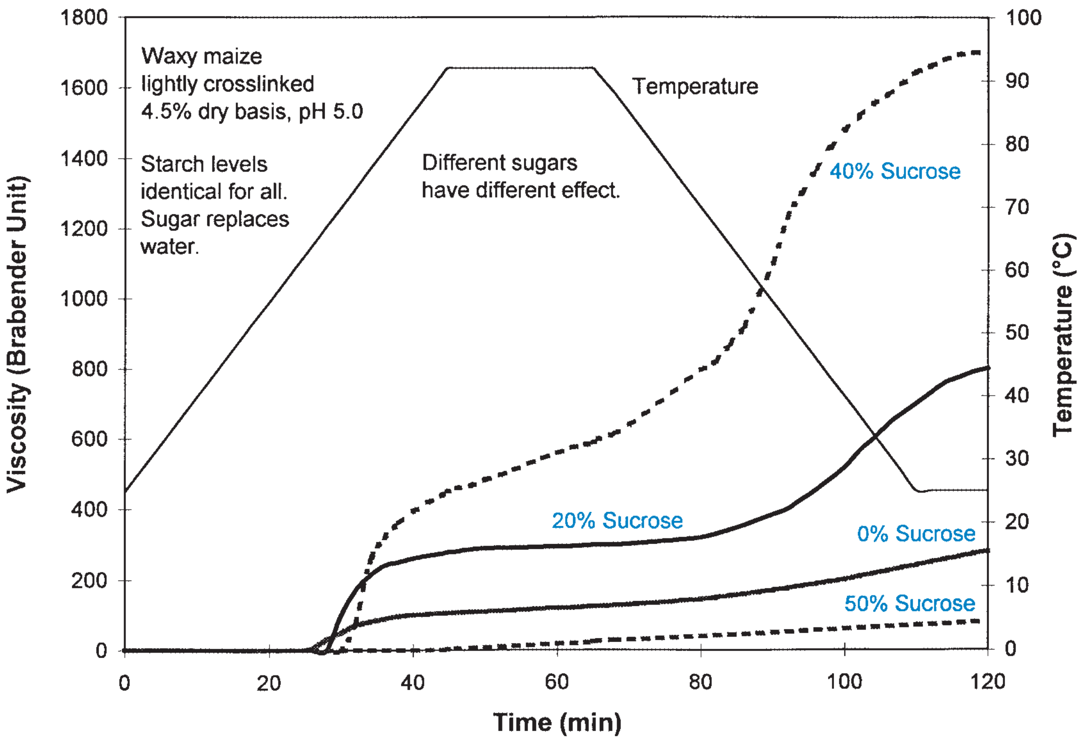

Fig. 5-1. Effects of sugar concentration on the gelatinization profile of waxy corn starch. Note that at the 50% sucrose level, almost no gelatinization takes place because little water is available. (Courtesy Cerestar USA)

PROCESSING CONSIDERATIONS

Although the selection of a starch that is compatible with a particular process is one of the most critical aspects of achieving proper starch performance (e.g., viscosity, gel formation, and water binding) and the desired product quality (e.g., texture and mouthfeel), it is perhaps the least understood. Starches are chemically modified not only for functionality in the product, but also for process tolerance.

Starches have been designed to perform in, or at least withstand, the usually hostile environment associated with various food-manufacturing processes. A key concern is the direct physical impact of the process. For example, processes that employ high shear, high heat, and/or high pressure are considered detrimental to starch performance. Thus, the type of processing equipment needs to be taken into consideration. High-shear pumps, mixers, homogenizers, colloid mills, and jet cookers can destroy starch integrity and significantly reduce paste viscosity. Therefore, in order to achieve proper functionality, it is critical to select a modified starch that can withstand such processes. In general, the higher the degree of modification, particularly crosslinking, the more resilient the starch and the better the chance that it will tolerate severe processing conditions.

TABLE 5-3. Conditions Created by Common Food-Processing Equipment[a]

Equipment	Processing Conditions
Pumps	Low to high shear
Steam-jacketed kettles	Low shear, long cooking times
Swept-surface cookers and coolers	Medium to high shear, medium cooking time
Steam-injection cookers	Medium to high shear, short cooking times
Jet cookers	High shear, high heat, short cooking times
Retorts	Low shear, high heat, high pressure, long cooking times
Extruder cookers	High shear, high heat, high pressure, short cooking times
Colloid mill	Very high shear
Homogenizers	Very high shear

[a] Adapted from (3).

Table 5-3 lists typical food-processing equipment and the conditions each creates for the food system (3).

DISTRIBUTION AND END-USE CONSIDERATIONS

The storage and distribution of the food product after processing must also be considered when selecting a starch. Probably the most critical factor is the temperature during distribution. Of particular concern are those products that are stored either refrigerated or frozen, especially if temperatures fluctuate during storage.

Without digressing into lengthy reviews on freezing curves, moisture migration, ice crystal growth, the effect of solutes, and types of cold-temperature storage equipment, it can be said that the primary requirement for starch in a refrigerated or frozen product is that it be chemically modified (see Chapter 4). Substituted starch contains chemical "blocking" groups linked to the starch polymers and is especially important for chilled or frozen applications. It is this blocking action that prevents retrogradation of amylose and amylopectin. Compared with native starch, substituted starch can better withstand moderate temperature cycling or protracted storage at refrigeration temperatures. Modified starches, particularly substituted starches, have what is commonly referred to as *freeze-thaw (F-T) stability*. The F-T stability of a food product is often tested by allowing the frozen product to reach ambient temperature and then refreezing it. This process is usually repeated through numerous cycles in order to ascertain changes in product quality through each cycle. Product quality usually refers to textural changes and/or a loss of water from the product, i.e., syneresis. If there is no appreciable loss in product quality, the system is said to be F-T stable.

Freeze-thaw (F-T) stability—Ability of a product to withstand cold temperature cycling and/or prolonged storage at reduced temperatures.

The end-use, i.e., how the product will be prepared by the consumer, must also be considered. For example, the choice of a starch will depend on whether the product will be microwaved or baked, reconstituted with hot water, or refrigerated or frozen after final preparation.

Starch-Selection Guides

In order to make starch selection easier for the food technologist, starch manufacturers have various types of booklets, pamphlets, and selection charts or tables available. The specific starch recommendations within these guidelines are usually functions of the food application (e.g., product texture and pH requirements), processing conditions (e.g., type of thermal process and amount of shear), and distribution requirements (e.g., storage temperature).

Given the multifunctional characteristics of starch, particularly certain types of chemically modified starch, one starch product may work adequately in a variety of foods. On the other hand, certain starches are specifically designed for a particular application. Just because a starch is "recommended" for a particular application, however, does not necessarily mean that it will always work appropriately. Unexpected variability, usually related to product formulation, processing, and/or storage conditions, can sometimes affect starch behavior. By using creative formulation and processing, it is sometimes possible to "force fit" a starch product into a particular food application for which it may have not been originally intended. Hence, selection information should be considered a best estimate of the proper starch and usage level and should not be considered absolute.

References

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