tryptophan, most cereals contain the essential amino acids required by humans, as well as vitamins and minerals. When they are consumed with other foods that can supplement the nutritional elements that are low in cereals, the minimum dietary requirements may be met. Research in cereal genetics may be expected to produce hybrid cereals that will be complete or nearly complete foods, containing more of the nutritional elements required by humans. A composite proximate analysis for cereal grains indicates that they have a protein content of about 11%, fat about 3%, moisture about 12%, carbohydrate about 68%, and fiber about 6%.

On a worldwide basis, rice is the most important cereal, being produced for human food in the largest amount, while in the United States, corn is produced in the largest amount, although it is used for animal food and other products as well as for human food. The grain grown in the largest quantity for human food use in the United States is wheat.

For most food uses in cereals, the bran and the germ are removed: the bran, because it is indigestible by humans and because of its adverse effect on the appearance and on some functional properties of flour, and the germ, because of its high oil content, which may subsequently become rancid. The germ is used to produce oil (e.g., corn oil). The bran goes mainly to feed animals. However, with dietary guidelines recommending more fiber, a growing amount of bran is being used in the production of breakfast cereals, bakery products, and other human foods.

The first ready-to-eat cereals were produced just before the turn of the twentieth century, with flaked and puffed cereals following within a decade. Ready-to-eat cereals, made from the endosperm of wheat, corn, rice, and oats, are convenient, nutritious, and they come in a very large variety of forms, textures, and tastes. The processing of cereals into breakfast commodities was started in the United States and is still largely carried out in the United States, with considerable quantities being exported throughout the world. The most popular of the breakfast cereals are those that are ready to eat. These are formed or puffed and oven-baked.

In the United States, grain is usually sold by the growers to operators of storage elevators, near the farms, where the grain is cleaned and stored. It is then sold directly to processors or to operators of storage elevators (near processors). They may sell directly to the processors or to their brokers.

A brief description of the handling, processing, and use of the more important cereal grains in the United States is found in this chapter.

WHEAT

Whole wheat, consisting of about 13% protein, can contribute considerably to the diet. The flour made from the whole wheat is higher in biological value than white flour (made from the endosperm only). Table 18.1 gives some examples of the higher nutritional value of whole wheat flour over white flour.

Wheat is the most popular cereal grain for the production of bread and cakes and other pastries. Wheat produces a white flour. In addition, the unique properties of wheat protein alone can produce bread doughs of the strength and elasticity required to produce low-density bread and pastries of desirable texture and flavor.

There are many varieties of wheat. They may be classified as hard red winter wheats, hard spring wheats, soft red winter wheats, white wheats, and durum wheats. Winter wheats are planted in the fall and harvested in the late spring or early summer. Spring

Table 18.1. Comparison of Some Nutrients in Whole Wheat and White Flours

Nutrient	Whole Wheat Flour[a]	White Flour[a]
Protein	13%	11%
Thiamin	2.3 mg/lb	0.3 mg/lb
Riboflavin	0.6 mg/lb	0.2 mg/lb
Niacin	26.0 mg/lb	3.5 mg/lb
Pyridoxine	2.0 mg/lb	1.0 mg/lb

[a]1 lb = 454g

wheats are planted in the spring and harvested in the late summer. Hard wheats are higher in protein content and produce more elastic doughs than soft wheats. Therefore, hard wheats are used for breads, and soft wheats are used for cakes. Durum wheats are used most for alimentary pastes (spaghetti, macaroni, etc.) and for the thickening of canned soups.

Wheat is harvested by combines that cut the stalk, remove and collect the seed, and either return the straw to the soil, to be plowed under with the stubble and thus provide humus, or compress and bale it for future uses such as for litter or ensilage.

Wheat may be bagged in jute sacks and stored in warehouses, or it may be stored in bulk in elevators. The latter method provides the best protection against rodent and insect infestation. The moisture content of bulk-stored wheat should not be higher than 14.5% and that of sack-stored wheat not higher than 16%. Otherwise, microorganisms may grow and cause heating and spoilage. When it is necessary to lower the moisture content of wheat, it may be dried in bins by blowing hot air (not higher in temperature than 175°F (79.4°C) across the bins.

In preparing wheat for milling, the wheat is blown into hopper scales that record the quantity of uncleaned wheat. Some of the coarser impurities are removed by this process. The grain then passes over a series of coarse and fine sieves that further remove contaminating materials, including chaff and straw. With the wheat still in the dry state, stones may be removed by passing wheat over short openings that allow the heavier stones to fall out of the mass and be trapped. The wheat is next passed over discs or cylinders containing indented surfaces that remove seeds shorter or longer than wheat, following a pass through a magnetic separator to remove any metals present. The next cleaning process is dry scouring to remove adhering dirt. The wheat is then washed in water, a process that both removes dirt and adds 2% to 3% water to the grain. The added water is necessary to provide desirable conditions for milling. A stone trap is included in the washer. Excess water is removed by centrifugation. A second wet cleaning with a light brushing action is ordinarily used, followed by aspiration (blowing air through the grain), which is the final cleaning operation. The grain is then carried into a bin from which it is fed to the milling operation. This bin is located on the top floor of the flour mill, the grain having been elevated to this position during the various cleaning operations.

In milling, grain is fed automatically through scale hoppers that regulate the flow of the seeds at rates corresponding to those of the following operations: milling may be carried out by passing the grain through a series of corrugated rolls rotating toward each other, which remove chunks of the endosperm from the bran. After each passage

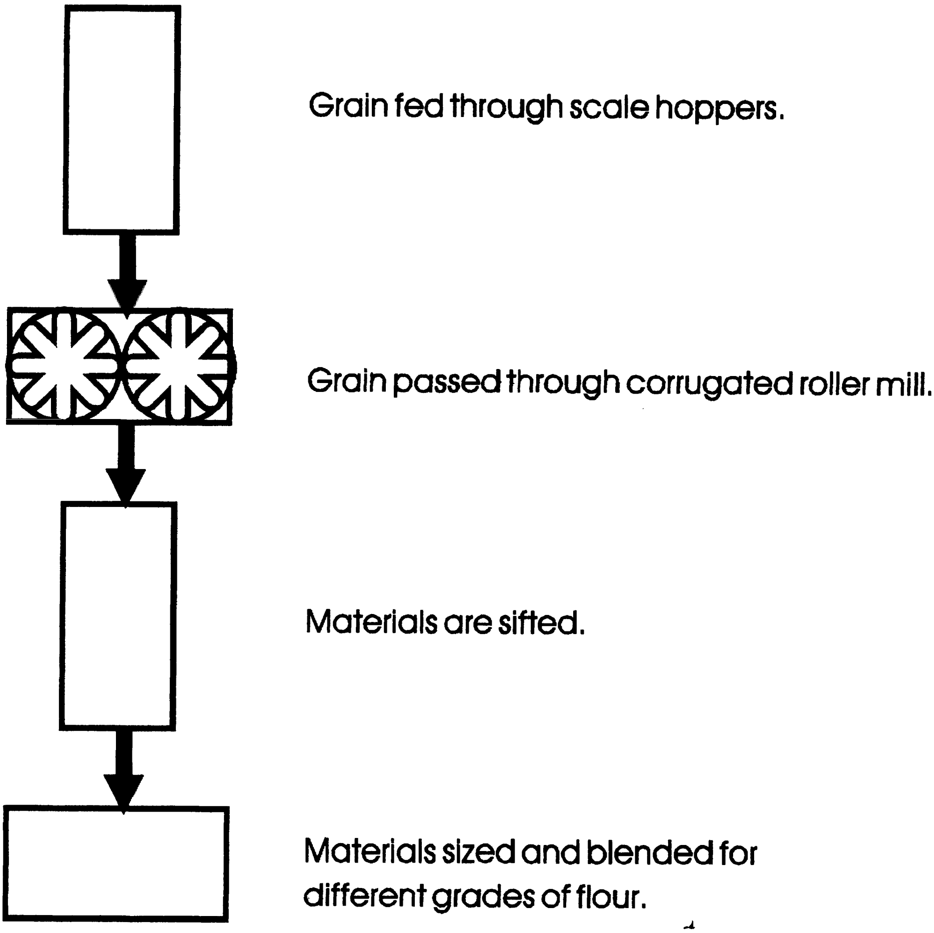


Figure 18.2. General procedure for milling of grain.

through the break rolls, the material is sifted through cloth, or wire sieves, and separated according to particle size. The various streams of different-sized flour particles are finally blended to provide the different grades of flour. The more finely ground flour is nearer to white but less nutritious than the coarser ground flour. This results from the more effective removal of bran and germ from finely ground flour (see Fig. 18.2). Impact milling is now used in some operations. With this method, the seed is broken open by impact in a machine called an Entoleter, first developed to control insect infestation. Flour particles of different sizes are separated by air classification or by centrifugation.

High-protein flour is desirable for some types of baked products; flour of moderate protein content for others; and high-starch, low-protein flour is desirable for still other baked goods. The smaller flour particles are higher in proteins; the larger flour particles are higher in starch. Through air classification in a turbomill it is possible to separate flour particles into various sizes, which can be blended to provide whatever protein or starch content is required by the baker or other users of flour. Turbomilling, developed in the late 1950s, was considered to be a significant milling innovation, because through this process, the variety of flour blends for different products is possible.

In the United States, wheat flour may be enriched with the minerals iron (as a salt such as ferrous sulfate) and calcium (also in the form of salts). Wheat flour is also enriched by the addition of small amounts of the vitamins thiamin, riboflavin, and niacin.

Wheat flour is used to make leavened products, such as bread, cakes, pastries, and doughnuts, and unleavened products, such as alimentary pastes (macaroni, spaghetti, noodles, etc.). Cake mixes are also prepared with flour, and flour is used for thickening canned and homemade stews, soups, gravies, and white sauces.

Various breakfast cereal products are made from wheat. Generally, in these products, the wheat is precooked and passed through heated rolls to form flakes or it may be shredded. An interesting technique also may be used to produce the "puffed" cereals which give a different appearance and texture. Either a grain or its composite dough can be used. The material is cooked to gelatinize the starch and then partially dried (see methods in Chapter 11). Then it is dropped into a pressure chamber that builds up to 100 to 200 lb/in.^{2} and a temperature of 500 to 800°F (260 to 427°C). The material is then ejected by the opening of a valve releasing the high pressure inside, thus "puffing" the dough or grain through water vapor expansion and escape. The result is a light, dry fragment. A similar texture can be achieved in "oven puffing" by cooking the grain and rolling it into a flat, thick flake. This is quickly toasted and the blistering lightens the texture. This method is usually used with rice.

Wheat bran may also be produced as flakes. High-protein cereals may be produced from wheat together with added wheat starch, sugar, malt, minerals (such as phosphates), vitamins, and other ingredients. Some wheat flakes are coated with very thin layers of sugar, honey, fruit, or other flavored syrups.

CORN

Many types of corn are grown in the United States. Sweet corn is produced as a vegetable and eaten fresh, canned, or frozen. Popcorn is also used as a food. However, the type of corn most utilized in the United States and considered as a grain rather than a vegetable is field corn. There are a number of varieties of corn usually classified as starchy or waxy, depending on the characteristics of the carbohydrate present. The development of hybrid strains has improved the yields of field corn. This corn is lower in protein than wheat, and, like all vegetable proteins, including wheat, is deficient in some amino acids and so does not provide a complete protein for humans. Corn is especially deficient in the amino acid lysine, but a variety of high-lysine corn has been developed that may eventually have a great impact on human nutrition in some parts of the world.

Ears of field corn are harvested by a machine that strips the matured ears from the stalks. If harvested in wet weather, corn may have to dried before it is stored. Usually, it is allowed to dry on the stalk in the field, is harvested, and is stored in small roofed bins or silos with metal or wire mesh walls. Much of the corn storage is done on the farm, as most of the corn crop is used as feed for animals. Stalks and leaves may be harvested, chopped, and placed in piles or in silos to form ensilage for animal feed. Stalks and leaves may also be chopped and returned to the soil for humus.

Corn milled for flour (corn meal) is cleaned, as is wheat, then moistened to a water content of 21%. The germ is removed mechanically. The endosperm is then dried to a moisture content of 15%, passed through crushing rolls, and sifted to remove the bran.

With use of sieves, milled corn is separated into grits (largest-sized particles) and meals and flours (smallest-sized particles).

Most of the corn crop is used for animal feed, but considerable amounts are used to produce cornstarch, corn syrup, high-fructose corn syrup, and other various sugar derivatives. The production of corn starch, modified starch, and uses of these is discussed further in Chapter 21.

Various types of sweeteners are made from cornstarch, as starch consists of a long straight or branched chain of glucose molecules that may be broken down to short chains of glucose molecules (dextrins), to maltose (two molecules of glucose), or to glucose (dextrose). The production of some of these products is also discussed in Chapter 21.

Corn is also used to produce popcorn. The variety used is a specific one. When the dried kernels are heated, internal moisture creates a vapor pressure owing to the rise in temperature, and when the pressure is sufficient, the hard outer shell is burst and the pressurized grain is expanded. Essentially, popcorn is puffed cereal.

OATS

Oats, one of the popular nutritious present-day cereals, was once regarded as useful for feeding only cattle. Oats can grow in colder and wetter climates than can wheat. Oats are harvested much in the same manner as is wheat. The moisture content at the time of harvest should not be higher than 13%.

Milling of oat kernels requires that they first be washed and cleaned and then dried in a rotary kiln or pan drier to a moisture content of about 12%. They are then hulled by impact, the seeds being thrown from a rotating disc against a rubber ring that splits off the hull and leaves the groat mostly intact. After the hulls are removed by passing the product through sieves, the oats are steam heated and passed between rollers to produce rolled oats, or they are cut into pieces about one-third of the original size and then steamed and rolled to produce quick-cooking rolled oats. Small amounts of oatmeal may be produced by grinding the steamed oats. Steaming facilitates cooking and inactivates enzymes that, if not inactivated, may cause bitter flavors to develop. Oat flour may be produced for use as an ingredient of bread or a thickener for soups. If made from unheated oats, lipolytic enzymes may remain and there may be a problem with the development of rancidity.

Oat bran has become a very popular item and much of this is due to the research that links its water-soluble fiber with reduction of blood cholesterol. Many articles have been published such as those by James Anderson of the University of Kentucky in the American Journal of Clinical Nutrition (1981) and by Jeremiah Stamler of Northwestern University School of Medicine in the Journal of the American Dietetic Association (1986) which show that consumption of oat bran can lower blood cholesterol (Anderson said that those who ate 100 g of oat bran a day lowered their cholesterol by 13% and Stamler said it dropped 3% if 35 to 40 g of oat bran was consumed daily). Frank Sacks of Harvard Medical School in the New England Journal of Medicine (1990) found that oat bran didn't lower the cholesterol level any more than refined wheat flour with a low bran content. He suggested here than just the replacement of foods with high levels of saturated fat and cholesterol with those low in these components will lower the blood cholesterol.

It is agreed by the vast majority that this replacement of fatty foods with lower fat varieties is beneficial. The American Dietetic Association and American Heart Association have recommended a decrease of fat to less than 30% of calories consumed and an increase of fiber in the diet. The Institute of Food Technologists (IFT) in 1989 cautioned against the overuse of such fibers. If fiber is greatly increased in a low-fat diet, consumers may not retain and adequately use numerous minerals required by the body. The IFT report said: "Recommendations for stepping up fiber in the diet—fiber supplements, oat or other types of fiber—should take into account a person's mineral intake and all other nutrient consequences for the best outcome."

BARLEY

Barley products do not bake as well as wheat products; thus, barley, containing little or no gluten, is not as popular as wheat when there is an option. However, barley has the advantage of growing in climates too cold and in soils too poor to grow wheat, and, in addition to being a hardy grain, its growth requires a shorter time than does that of wheat.

Some barley is produced in the United States. Spring and winter varieties are planted as in the case of wheat. In the United States, barley is used as feed for cattle and poultry, for the production of malt used in brewing, and as an ingredient of soups. Small amounts of barley flour are also produced.

For producing malt, the grain is soaked in water for several days or until the moisture content reaches approximately 50%. It is then removed from the steep tank and placed in containers where air at 65 to 70°F (18.3 to 21.1°C) can be drawn through it over a period of approximately 1 week. This allows the barley to germinate or sprout. The sprouted barley is then kiln dried over a period of 24 hours. Drying is begun at a low temperature that is gradually raised as drying proceeds. The purpose of malting barley is to produce enzymes that will hydrolyze starch to maltose, a sugar that can be utilized by yeasts to produce ethyl alcohol and carbon dioxide. Nondiastatic malt (will not hydrolyze starch) may be produced for its flavor components. Therefore, in drying the sprouted barley, the temperature must not be raised to the point where the starch-splitting enzymes, produced during sprouting, will be inactivated. It would appear, however, that temperatures are raised to the point where some of the sugars present in the sprouted barley are caramelized, hence the dark brown color of malt. Malt is used in the brewing industry for converting the starches present in barley, rye, rice, corn, or other grains to maltose, which can be utilized by yeasts.

Producing beer is an interesting process. The science of fermentation or zymurgy is utilized here. First, as mentioned previously, the barley is allowed to germinate to accumulate starch-digesting enzymes (amylases). Next, the partially germinated kernels of barley malt are dried to stop enzyme activity (but not to permanently inactivate them) and to develop color and some flavor. In this process, called mashing, the malt is mashed in warm water and another grain such as corn, rye, or rice may be added and the enzymes are reactivated by the gentle temperature and moisture and act to reduce the long-chained carbohydrates to sugars (glucose). The resulting sweet liquid produced by this enzymatic action is called wort. With beer and related beverages, hops are added here for flavor. This process, called brewing, takes place in the brew kettle at elevated temperatures and the enzymes are now permanently inactivated.

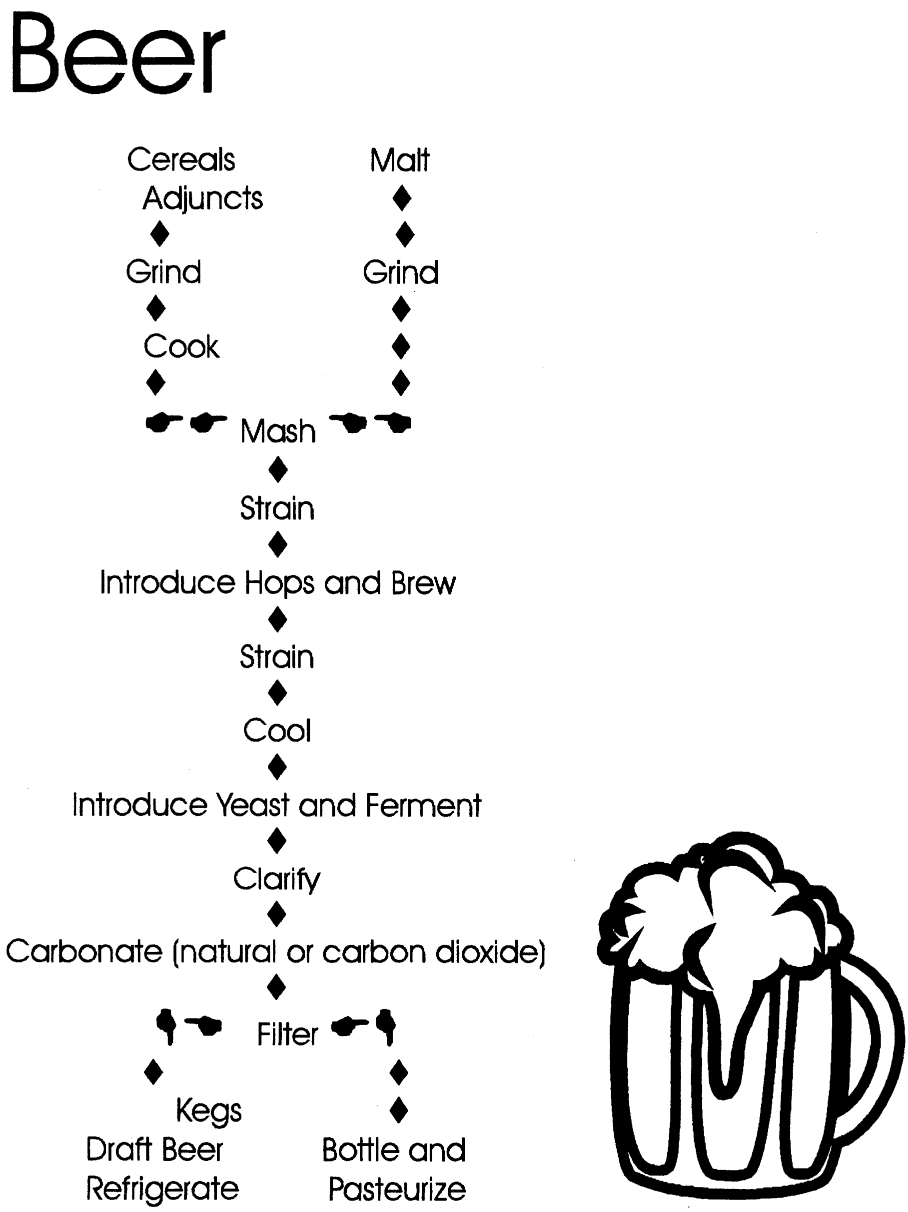


Figure 18.3. Method of domestic beer production in the United States.

The hops are now strained out and the bittersweet liquid remaining (hopped wort) can now be fermented by yeast to produce ethyl alcohol and carbon dioxide. Beer is then filtered through diatomaceous earth filters that remove almost all of the yeast. It is then clarified and bottled or packaged in kegs. Draft beer must be refrigerated whereas bottled beer is pasteurized in the bottle and then cooled. Some beer is "cold pasteurized," a process in which it is sent through fine filters to remove all of the yeast before it is bottled. Beer may be carbonated naturally in a secondary fermentation before packaging called kraeusening or carbon dioxide may be pumped in prior to packaging.

Malt may also be used in bread baking for much the same reason as in beer production, although in this case, the purpose is to have the yeast produce carbon dioxide for leavening (raising the dough), the alcohol produced being largely dissipated during the heating involved in baking.

Some quick-cooking rice is produced by precooking the kernels and redrying. This process provides for the preparation of rice for human consumption by merely bringing the water used for rehydration to the boiling point and allowing the mixture to stand for short periods.

Some puffed rice cereal is produced by heating the rice to a temperature above the boiling point of water in closed containers and suddenly releasing the pressure, which causes the kernel to increase in size, as the water vaporizes, allowing it to escape from the interior to the outside.

About one-third of the rice produced in the United States is used by the coffee brewing industry. This consists mostly of broken kernels, but some whole grain rice is also used for this purpose.

Rice flour is produced, and most of this is used by those who are allergic to wheat flour. Rice flour may be used, too, for the preparation of white sauces, especially for prepared frozen-food products, as certain types of rice flour produce sauces that do not curdle and weep (separation of liquid from the sauce) when frozen and defrosted.

Rice bran has been used for cereal and baked goods and its water-soluble fiber is said to have cholesterol-lowering effects similar to those suggested with oat bran.

Rice kernels may be enriched, as is wheat flour, by mixing with powder containing vitamins and minerals. This powder sticks to the surface of the kernels. The enrichment materials may then be coated with a waterproof, edible film to protect them from being washed off.

The protein of rice is comparable to that of wheat in composition, although rice is lower in total protein content than wheat. Neither of these grains contain a complete protein, that is, the proteins do not contain sufficient amounts of certain amino acids to provide for the requirements of the human, although the biological value of rice protein is reportedly equal to or superior to that of wheat protein.

OTHER CEREAL GRAINS

Sorghum

Sorghums, comprising four general classes (sweet sorghum, broom corn, grass sorghum, and grain sorghum), are grown in southern sections of the Great Plains and in parts of the Southwest. Some varieties of the grain sorghum class yield glutinous starch, similar to that of corn. During World War II, sorghum was used as a substitute for tapioca, because the importation of tapioca was impeded by the war situation. The deterrent to the use of grain sorghum for the production of starch is the pigmentation of the grain's pericarp, which complicates the production of a white starch. However, enough progress has been made in the development of desirable sorghums to warrant the consideration of sorghum for the production of starch in the future.

Buckwheat

Buckwheat is not a true cereal grain. All the cereal grains belong to the botanical family Gramineae, whereas buckwheat belongs to the family Polygonaceae. However, from a use standpoint, it is considered to be a cereal food. Although it is a minor crop in the United States, only the Soviet Union and France produce more buckwheat than the United States. It is grown mainly in New York, Pennsylvania, Michigan, Maine, and Ohio. Of the few varieties used, the Silverhull is used mainly for producing flour because of the higher yield of the endosperm. Buckwheat is dried to about 12% moisture, cleaned, graded by size, and milled similarly to wheat. Most of the flour is used for making pancakes.

Cottonseeds, Soybeans, and Peanuts

Although cottonseeds come from plants of the family Malvaceae, and soybeans and peanuts from plants belonging to the family Leguminosae, it should be mentioned that they have been used to produce edible flours and other food ingredients.

Cottonseeds are used the least in flour production because they contain the toxic pigment gossypol ($C_{30}H_{30}O_8$). The pigment glands that contain gossypol can be removed by a process that involves disintegration of the seeds in hexane and separation of the glands by centrifugation. Heating also destroys the toxin and when heat is applied, the flavor of the seed is improved.

Soybeans have been studied extensively and many soy byproducts have been produced. These include soy "meats" from the dehulled bran, oil, soy flour, and grits (about 50% protein). The grits can be washed at a pH of 4.5 and dried to produce soybean concentrate (70% protein). Grits can also be dissolved in alkali, filtered, and have acid added to a pH of 4.5. This can now be concentrated further to a simple protein isolate (90% to 95% protein). The flour can also be wet, extruded, and dried to textured vegetable protein (50% to 55% protein). The simple protein isolate can be modified further into a range of isolates, spun protein, or structured protein isolates.

Some of the extruded, dried soy protein doughs, on rehydration and cooking, have a very similar texture to that of meat and are being used in combination with meats in mixtures. They add protein, little fat, and are less costly than meat. Dried, flavored textured protein produced such as imitation bacon bits are quite popular also.

A problem exists with soybean in that the raw beans contain a trypsin inhibitor. This interferes with normal growth of animals and humans but it can be inactivated by the heat of cooking or by heat in processing.

Peanuts can also be processed into flour, protein concentrates, and protein isolates but their use in human foods is limited. Peanuts have lower amounts of lysine than do soybeans. Most of the world's peanuts are used for oil (about 67%). In the United States, however, about one-half of the crop is made into peanut butter. Peanuts have a high moisture content at harvest and are susceptible to mold spoilage. If the molds grow, they may produce aflatoxins as metabolites. Strict government controls govern peanuts and if levels of aflatoxins reach 15 parts per billion (ppb) in the raw peanut or 20 ppb in the finished product they must be rejected. This could be devastating economically to the peanut growers, so peanuts are stored under conditions to control mold growth and they are carefully inspected.

Millet

Millet is used for food in Asia and, to some extent, in Europe. In many parts of Europe, it is used for hay, as it is used in the United States. Some varieties are used as food seeds for caged birds and poultry.

Triticale

Triticale, a hybrid of wheat and rye, first produced in the late 1800s, combines the high total protein content of wheat with the high lysine content of rye. It is also more adaptable to unfavorable growth conditions and seems to resist wheat rust (a disease caused by molds). The improvement of this hybrid is continuing and can lead to more beneficial genetic changes. This cereal is now being grown in more than 52 different countries.

9

Carbohydrates in Foods

Carbohydrates are one of the three main energy-providing nutrients, the other two are proteins and fats.

We get most of our energy from carbohydrate foods, which form a large proportion of the total dry weight of plant tissues. The carbohydrate foods, give the highest yields of energy per unit land cultivated, are easy to store and transport. Hence carbohydrates are the cheapest and most abundant source of energy for human beings.

All green plants synthesis carbohydrates by the process of **photosynthesis. Sunlight provides the** energy needed to transform the carbon dioxide and water into carbohydrates. Hence, photosynthesis cannot occur in the dark. Animals are unable to synthesize carbohydrates and are dependent on plants for their supply of carbohydrates.

Carbohydrates occur in plant—

- In the sap (sugar)
- In fruits (sugar)
- In storage reserve (starch) in seeds, roots and tubers, and as parts of the structural tissues (celluloses, hemicelluloses, pectins and gums)

In the animals, carbohydrates are found in milk of mammals (lactose) and as a storage reserve (glycogen) to some extent.

The literal meaning of the word 'carbohydrate' is hydrated carbon, that is carbon and water. Carbohydrates are composed of the elements carbon, hydrogen and oxygen.

Simple sugars and all substances, which on hydrolysis yield simple sugars, comprise the principal carbohydrates.

The following simple equation illustrates carbohydrate synthesis in plants.

$$6\ CO_2 + 12\ H_2O \underset{\text{Sunlight}}{\rightarrow} C_6H_{12}O_6 + 6\ O_2 + 6\ H_2O$$

The solar energy used in photosynthesis is stored as chemical energy in the plant. Animals, which eat plants are able to utilize the chemical energy stored in the carbohydrate molecule to meet major part of their energy needs.

Plants can synthesise a variety of carbohydrates by photosynthesis. The sugars, glucose, sucrose and the polysaccharides, starch and cellulose are important examples of carbohydrates produced by photosynthesis.

Carbohydrates have the general formula $C_x(H_2O)_y$ where *x* and *y* are whole numbers.

Naturally occurring carbohydrates are of interest in food chemistry; especially those which have six or multiples of six carbon atoms.

Familiar examples are glucose $C_6H_{12}O_6$ and sucrose $C_{12}H_{22}O_{11}$ and starch represented by $(C_6H_{10}O_5)_n$

Classification

Carbohydrates are classified on the basis of their molecular size into

Monosaccharides,

Disaccharides and

Polysaccharides

Monosaccharides as their name indicates, (mono meaning one and saccharide meaning sugar) are the simplest of carbohydrates because they consist of a single sugar unit. More complex carbohydrates are built from the units of monosaccharides.

Three monosaccharides that are of importance in food preparation are glucose (dextrose), fructose (levulose) and galactose.

Disaccharides ('di', meaning two) contain two units of sugar, which may be alike or different. Two monosaccharides unite with the loss of a molecule of water to form a disaccharide. Likewise, disaccharides can be hydrolysed by boiling with dilute acid or by enzymes, to produce the sugars from which they are made.

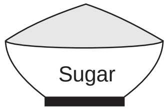
Sucrose, lactose and maltose are the most familiar examples of disaccharides.

Polysaccharides, as their name indicates, ('poly' meaning many) consist of many units of sugar. When polysaccharides are linked together to form one molecule, they may be linked together in straight long chains, or may be branched. Starch, glycogen, celluloses, hemicelluloses, gums and pectic substances are some of the polysaccharides found in plants and animals.

Monosaccharides

D-Glucose, Dextrose or Grape-sugar are all names for the sugar found in grapes and other sweet fruits. Honey contains 35 per cent glucose. During digestion, starch and other carbohydrates are hydrolyzed to glucose.

Glucose $C_6H_{12}O_6$ is a white solid. It is less sweet than sucrose and fructose. There is an aldehyde group in the glucose molecule, hence it behaves like an aldehyde. As the aldehyde gets easily oxidized to its corresponding acid, it acts as a reducing sugar, with even mild oxidizing agents. This reducing action forms the basis of many tests used for glucose and other reducing sugars.



Glucose structure as given originally with numbered carbon atoms is given below:

1. CHO
2. CHOH
3. CHOH
4. CHOH
5. CHOH
6. CH_2OH

Carbon atoms 2, 3, 4 and 5 are asymmetric, hence glucose is optically active. Ordinary glucose is dextrorotatory, which is written as *D* (+) glucose and using the projection formula it is represented thus:

CHO
H – C – OH
HO – C – H
H – C – OH
H – C – OH
CH_2OH

D-Fructose, Levulose or Fruit Sugar is a laevoratotory sugar, found in juices of sweet fruits and honey with glucose. When sucrose is hydrolysed, fructose and glucose are formed. It is sweeter than glucose and sucrose.

Galactose is obtained by the hydrolysis of lactose, the milk sugar. It does not occur in the free state in nature. Isotope experiments have shown that galactose is synthesized from blood glucose by mammals. The galactose thus formed combines with glucose to form lactose, which is secreted by mammals in the milk to sustain their young.

Galactose, a component of lactose, has unique nutritional properties. The sugar level in the milk tends to vary directly with the weight of the adult brain. Of all the animals, man has the largest brain, in proportion to body weight, and human milk has 7.4% lactose, the highest percentage of milk sugar. In contrast, cow's milk, which is used to prepare infant milk formulas, has only 4.4% lactose.

The high percentage of lactose in human milk may be related to glycolipids of the brain, which usually contain galactose. Moreover, glucose is the only fuel normally used by the brain in its activities and it is conceivable that during brain formation (first year of life), the more stable galactose is more suitable as a building material. Hence, galactose is sometimes referred to as 'brain food'. Infants, being less able to synthesize galactose than adults, it is nature's provision that they get it in milk, their primary food.

Diasaccharides

In nature, disaccharides are formed by the combination of two monosaccharides, a molecule of water is released in the process

$$C_6H_{12}O_6 + HO(C_6H_{11}O_5) \rightarrow (C_6H_{11}O_5) - O - (C_6H_{11}O_5) + H_2O$$

Disaccharides are the most abundant and familiar of natural sugars. The sugar, we use to sweeten our cup of tea is sucrose. It is one of the few pure manufactured foods used in food preparation. It is extracted from sugarcane in the tropics and sugar beet in the temperate region. The sugar found in mammalian milk is lactose. The sugar found in malted grains is maltose. Sucrose, lactose and maltose are the most familiar examples of disaccharides.

Maltose or Malt Sugar is got from starchy materials by the action of the enzyme *diastase*. The maltose is hydrolysed to glucose by the action of the enzyme maltase or by heating with dilute acid.

Maltose contains two combined units of glucose, which are released as D-glucose by hydrolysis. Maltose is a reducing sugar, but only one of the aldehyde groups of glucose is free, the other is used up to unite the two glucose units:

Lactose or Milk Sugar is a crystalline, gritty solid. It is found in the milk of all mammals. Human milk contains 6 to 8 per cent and cow's milk contains 4 to 5 per cent of lactose. Lactose can he hydrolysed by the enzyme *lactase* or by boiling with dilute acid to yield the constituent monosaccharides D-glucose and D-galactose.

Sucrose, Cane or Beet Sugar is a white crystalline solid and is the ordinary sugar we use everyday as a sweetener in beverages and sweetmeats. It is widely distributed in the vegetable kingdom in many fruits, grasses, stems and roots. It is also present in the sap of some trees. Since it is produced economically in large quantities, it is the main sugar used in the diet. In India, its main source is cane and over 1 tons of sugarcanes are produced annually.

Sucrose, when hydrolysed with dilute acids or the enzyme *sucrase*, yields equals amounts of glucose and fructose, indicating that it is a combination of one unit of glucose with one unit of fructose. It is not a reducing sugar as the reducing groups in the two monosaccharides are involved in the link joining them. Please note from the structure of sucrose given above that the fructose unit in sucrose is a five membered ring. Sucrose is readily hydrolyzed to glucose and fructose and the solution is laevorotatory, as fructose is more strongly laevorotatory than glucose is dextrorotatory. This in known as *inversion*, as there is a change in the direction of rotation. The mixture of glucose and fructose formed is called *invert sugar*. Invert sugar is found in honey, Acidic foods tend to hydrolyze the sucrose added to these in preparation. Fruit drinks, jams and fruit *sherbets* also contain invert sugar.

Sugars

Monosaccharides and disaccharides are crystalline, water-soluble and sweet compounds. In food preparation, they are referred to as *sugars*.

Sources and Properties of Sugars

When we talk of sugars, we usually imply the monosaccharides, fructose and glucose, and the disaccharides sucrose (the sugar we use daily), lactose and maltose.

The important sugars found in foods and their natural sources are given in Table 6.1.

TABLE 9.1 Sugars—Natural Sources and their Components

Sugar	Natural sources	Components
Glucose or Dextrose	Honey, fruit and plant juices Is a part of cane and beet	–
Fructose or Fruit sugar	Honey, fruit juices Is a part of cane or beet sugar	–
Galactose	Does not occur in the free form in nature Occurs as a part of lactose	–
Sucrose	Sugar cane Sugar beet Sugar palm Sugar maple In fruit and plant juices	Glucose and Fructose
Lactose	Milk	Glucose and Galactose
Maltose	Germinated or malted grains Formed by hydrolysis of corn starch	Glucose and Glucose

Sugar occurs in solution in nature. When the solution is concentrated, the sugar crystallizes. This principle is used in the manufacture of sugar.

Sugars crystallize out of solution with ease when concentrated. This property is used in preparation of confectioneries.

When sugar is heated to a temperature above the melting point, it decomposes and forms a brown mass, which is known as *caramel*. Caramel has a bitter taste. In some products sugar is partially caramelized to enhance the colour and flavour of the product.

Manufacture of Sugar from Sugar Cane

Sugar cane is a tall giant grass and looks like a bamboo. The sugar is present in the cell sap and is extracted by crushing the cane and dissolving he sugar in the water sprayed on it. The solution is purified by boiling and adding lime to precipitate impurities. Some impurities float on the top. After removing the impurities, the sugar solution is concentrated by evaporation under reduced pressure. Crystals formed are separated by spinning the mixture in large perforated drums. Molasses, separated in the process are used to manufacture industrial alcohol.

Sugar is refined by precipitating the impurities with lime solution and removing these. The concentrated sugar solution is passed through a bed of bone charcoal to get a clear liquor, which is concentrated by evaporating the water under reduced pressure, to get fine, clean, white, uniform sugar crystals. Pure sugar crystals are added to super saturated solution to seed it and thus hasten the process of crystallization. The process is instrumentally controlled to obtain a uniform product. The crystals are separated by centrifuging. The left over syrup is used to make brown sugar.

Sugar Consumption and Health

Increased sugar production has resulted in increase in consumption beyond desirable level. Sugar is bought and used as such and it is also consumed in a variety of manufactured foods.

High intake of sugar is undesirable for three reasons:

- It contributes to obesity.
- It increases rate of dental decay.
- It is possibly related to increased incidence of diabetes and coronary heart disease.

Use of Sugar

Sugars supply energy to our body. Each gramme of sugar supplies four calories. Sugar can be metabolized quickly to meet energy needs of our body.

It is mainly used as a sweetening agent in beverages such as tea, coffee, fruit drinks, in cereals and porridge, in puddings, pies, cakes, biscuits and frozen desserts such as ice cream.

When used in higher concentration, sugar acts as a preservative as well as a sweetening agent, e.g., jams, jellies, marmalades, squashes, sweetened condensed milk, *ladus* etc.

Confectionaries sugar is the major ingredient responsible for its shape and structure.

Brown Sugar is prepared by concentrating sugar cane juice. It is not refined and has a light to dark brown colour, due to impurities present. It contains about 96 per cent sugar, about 2 per cent moisture and traces of minerals and protein. The presence of other substances imparts a characteristic rich flavour to brown sugar. The presence of salts is noted by the slightly saltish taste.

Brown sugar is used to make *ladus* (sweet balls) with coconut, *til* or groundnut in some parts of India. It is also used in preparing toppings for cakes.

Honey is concentrated nectar of flowers, sweet exudates of leaves and plants manufactured by honeybee.

Chemically, honey is concentrated solution of fructose and glucose, in which small amounts of sucrose, dextrins, mineral matter, proteins (trace) and organic acids are present. It contains about 18 per cent water, 40 per cent fructose, 35 per cent glucose and 5 per cent sucrose. The flavour ingredients are present in minute amount, which are from the flowers. Thus, the flavour varies with the kind of flowers, from which the bees collect it.

Honey is used as spread for bread with butter. It is also used in a number of baked products, to impart a light texture and a moist feel to the product.

Glucose or Dextrose It is widely distributed in nature. It is found in fruits, honey and some vegetables. Commercially, glucose is made from corn starch by hydrolysis. Glucose is formed in sugar syrup if an acid is present.

Fructose It is mainly found in honey with glucose. It is present in fruits and molasses. It is widely distributed in nature and often is found with glucose or glucose and sucrose. It is the most soluble of all sugars and is also the sweetest of all natural sugars. Pure crystalline fructose is very expensive.

Maltose When starch is hydrolyzed with an acid, maltose is formed as an intermediate product. It is prepared commercially by enzymatic hydrolysis of starch. It is present in germinating cereals and malted products, hence the name maltose.

Lactose or Milk Sugar As the name indicates, lactose is the sugar present in milk secreted by females of mammals. Cow's and buffalo's milk contains on an average 5 per cent lactose while human milk contains about 7 per cent.

Sucrose It is common sugar available in the market. In India, it is made from sugarcane and is 99.9 per cent pure sucrose. In the temperate zone, it is obtained from sugar beet.

Properties of Sugars

Hygroscopic Nature The word hygroscopic means water attracting. Sugars absorb water on exposure and are known to be very hygroscopic by nature. Therefore, sugars should be stored in a dry place, in airtight containers. Sugar and confectionaries made from sugar tend to absorb moisture and become sticky when exposed.

Solubility Sugars are soluble carbohydrates. The sugars arranged in descending order of solubility are—fructose, sucrose, glucose, maltose and lactose. This property is important in predicting the procedure to be followed to obtain a particular product when mixture of sugars in used.

Flavour The sugars are mainly prized for their sweet flavour. Sugars vary a great deal in their sweetness. There is no objective test for measuring the degree of sweetness. All investigators agree that fructose is the most sweet and lactose the least sweet of the sugars. Glucose is rated as half to three-fourth as sweet as sucrose. Maltose is less sweet than glucose. Thus, the ranking in terms of sweetness is fructose, sucrose, glucose, maltose and lactose.

The flavour of unrefined sugars depends on the nature of the impurities present. It is sweet combined with other flavours present.

Ease of Crystallization Sugars crystallize out of solution with ease on concentration. This property is important in sugar preparations. The ease of solubility is inversely related to ease of crystallization. The least soluble sugar crystallizes even at low concentrations, but the most soluble sugar is not easily crystallized. These characteristics need emphasis and need to be understood for successful attempts in sugar cookery.

Crystallization Crystallization is a process where crystals of the solute are obtained from the solvent in which they are dissolved. Crystallization of sugar occurs when a saturated solution of sugar is cooled gradually. Crystals of sugar thus obtained are very desirable in sugar coated preparations like sugar coated nuts, *balushahi* and other such as icings and candies such as fondant etc. (Table 9.2).

Table 9.2 Sugar Syrup and Its Use in Various Preparations

Strength of syrup	Preparation
½ thread	Gulab Jam, Sudharas
1 thread	Rose Syrup
1½ thread	Ladus, Vadis
1½ thread	Sugar coated groundnuts
Soft ball	Sakharbhat, Candies
Hard ball	Murambba

Crystallization depends upon a number of factors. These factors include nature of the crystallizing medium, concentration of sugar in the preparation, temperature at which crystallization takes place, agitating the sugar preparation and the addition of other ingredients such as butter, ghee, lemon juice, and egg. In general, the greater the concentration of the sugar in the sugar preparation the faster is the rate of crystallization. The sugar preparation should be heated upto a temperature at which it is saturated. When this saturated sugar preparation is gradually cooled, it crystallizes at a particular temperature. Stirring vigorously or beating the sugar preparation during cooling helps to form a number of small crystals of sugar. This imparts a soft, velvety feel to the product as is seen in candies. (Table 9.2).

Presence of other ingredients such as starch, fats like butter, ghee (as in *ladus*, coconut burfi) and proteins such as egg proteins lower the rate of crystallization. The crystals of sugar adsorb these ingredients and as a result do not grow in size.

Inversion of Sugar Sugar is hydrolyzed by acids to glucose and fructose. This reaction is called 'Inversion of Sugar' and the glucose and fructose formed are referred to as 'Invert Sugar'. Invert Sugar is more soluble in water than sucrose, and therefore does not crystallize as readily as sucrose. Inversion of sugar in food preparation is observed when lemon juice is added to sugar preparations which are subsequently heated. In such cases, the rate of crystallization is slow. Therefore, acids such as lemon juice and other fruit juices, are added to sugar preparations towards the end of cooking.

Inversion of sugar can also be brought about by hydrolyzing enzymes present in foods.

Adsorption and Impurities in the Solution

The presence of foreign substances lowers the rate of crystallization. The rate of crystal growth is retarded because of adsorption of the foreign substances by the crystals.

The addition of other carbohydrates, such as glucose, fructose and starch to sucrose solution, retards the crystallization of the sucrose. The addition of acid to a sucrose solution brings down the rate of crystallization due to inversion of sucrose. Other substances strongly adsorbed by sucrose crystals are fat and proteins. Hence, butter, milk or egg white are used to retard the crystal growth, e.g., *dudhi halwa*.

Manufactured Foods Containing Sugar

Several sweets are manufactured with sugar as a major ingredient. These include boiled sweets, chocolates, toffees, pedhe, barfi, laddu and a variety of mithais. Bakery foods, such as sweet biscuits and cakes also contain sugar.

Boiled Sweets These are made by boiling sugar solutions to about 150°C with addition of cream of tartar, followed by cooling to a glass like solid. A familiar example is lemon drops. The addition of cream of tartar from 0.15 to 0.25 per cent of the weight of sugar helps to form 10 to 15 per cent invert sugar resulting in a non-sticky, non-crystalline candy. A variety of products are made by using different flavours and colours.

Toffee is made from fat, milk, sugar and glucose syrup mainly. The characteristic flavour of toffee is due to the caramelisation of milk solids during cooking. Toffee is manufactured by boiling the ingredients together. The temperature to which the ingredients are heated determines the consistency of the toffee produced. Very hard toffee contains usually 3 to 5 per cent of water whereas soft toffees such as ordinary toffees may contain 6 to 12 per cent of water. Ingredients are heated to 295–310 °F for making hard toffees whereas soft toffees are made by heating the ingredients to a temperature of 245–270°F. When the boiling is completed, the toffee is poured on to a slab, cooled, cut into the desired shape and wrapped.

Use of High Fructose Corn Syrup (HFCS) in Place of Sugar

The use of sweeteners based on glucose is increasing and it partially or completely replaces sucrose in food products. Maize starch is hydrolyzed by heating under pressure with dilute hydrochloric acid to produce a colourless syrup. The glucose content of the syrup varies according to the degree of hydrolysis. It is expressed as *dextrose equivalent* (*DE*). It is a mixture of dextrose, maltose and dextrin.

More recently, the glucose syrups are treated with the enzyme *glucose isomerase* to convert about half of the glucose to fructose to produce *high fructose corn syrup* (*HFCS*). The HFCS formed is at least as sweet as sucrose or more sweet, depending on the fructose content. It enhances fruit flavours. It is used in soft drinks, bakery products, jams, preserves, and many other convenience foods.

In USA and UK most of the new convenience foods are made using HFCS in place of sugar, as it is cheaper than sugar. These foods include soft drinks, biscuits and other bakery products, candy and a number of other convenience foods. The intake of these HFCS containing foods has resulted in extreme increase in obesity in these populations. Latest research studies conducted to study this problem, have revealed the deleterious effects of extensive fructose intakes on the health of the consumers. These include increased lipogenesis (fat formation), VLDL formation (very low density lipoproteins), leading to triglyceridemia (too high concentration of triglycerides in blood), too much insulin in blood and low glucose tolerance. Thus, there is high incidence of heart ailments and diabetes in these populations.

Fortunately in India, HFCS is not used in soft drinks and other food products due to its high cost. Sucrose is used in soft drinks and other food products. But, consumers and authorities have to be vigilant and avoid overuse of fructose in food products in place of sucrose.

Starch

As mentioned earlier, starch is a polysaccharide which upon complete hydrolysis releases glucose. Most of the starches and starchy foods used in food preparation are obtained from cereals (rice, wheat, maida, sago, maize, barley), roots (cassava, tapioca, arrowroot) and tubers (potatoes, sweet potatoes). Starch is present in small particles known as *granules*. These granules are of various shapes and sizes. Starch granules present in the corn grain is of a different shape and size from that of a potato tuber (Fig. 9.1).

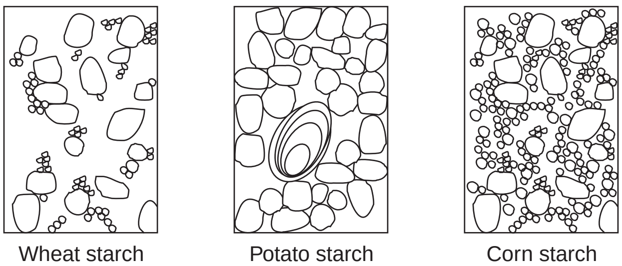


Fig. 9.1 Structure of Wheat, Potato and Corn Starch Granules

Starch is made up of two fractions *Amylose and Amylopectin*. The amylose fraction of starch is composed of straight-chain structure, while the amylopectin fraction has a branched chain configuration. The two possess different properties. Amylose contributes gelling characteristics to cooked and cooled starch mixtures. Amylopectin provides cohesive or thickening property but does not usually contribute to gel formation.

Uses In food preparation, starch is used either in the pure form (arrowroot starch, corn starch) or as cereal flour in which starch is mixed with other components (wheat flour, rice flour, corn flour, bajra flour). Cereal flours contain not only starch but protein, fat and fiber also. Starch accounts for 60–70 per cent of the flour. Starch may be used as:

1. Thickening agents as in soups, white sauces, dals.
2. Binding agents, e.g., Bengal gram flour is used to coat cutlets, bhajias etc.
3. To form moulded gels, e.g., corn starch puddings and custards.

Properties of Starch

The starch granule is completely insoluble in cold water. However, when a mixture of starch and water is cooked, a starch paste is formed. The starch granules absorb water, swell in size and as the temperature is increased, they burst. (Fig. 9.2). Some pastes are opaque, some are clear, semiclear or cloudy in appearance. In general, pastes made with cereal starches such as corn, or wheat, are cloudy in appearance, whereas those made from root starches such as potato, tapioca are clear.

When some starch pastes are cooled, they become rigid and form a gel on standing, e.g., corn starch. However, some starch pastes do not form a gel.

Preparation of Foods Containing Starch

Effect of Dry Heat When dry heat is applied to starchy foods, the starch become more soluble in comparison to untreated starch and has reduced thickening power when made into a paste. This is desirable in some preparations like *upma*. Some of the starch molecules are broken down to dextrins when exposed to dry heat. This process in known as *Dextrinization*. Dextrinization is accompanied by colour and flavour changes also. A characteristic brown, toasted colour and flavour develops. This change is observed when bread is toasted, and when rava or rice flakes are roasted.

Effect of Moist Heat When starch is heated with water, the granules swell and the dispersion increases in viscosity until a peak thickness is reached. The dispersion also increases its translucency. These changes are described as *Gelatinisation*. Gelatinisation is gradual over a range of temperature and occurs at a different temperature range for different starches. Gelatinisation is usually complete at a temperature of 88°C–90°C (Fig. 9.2).

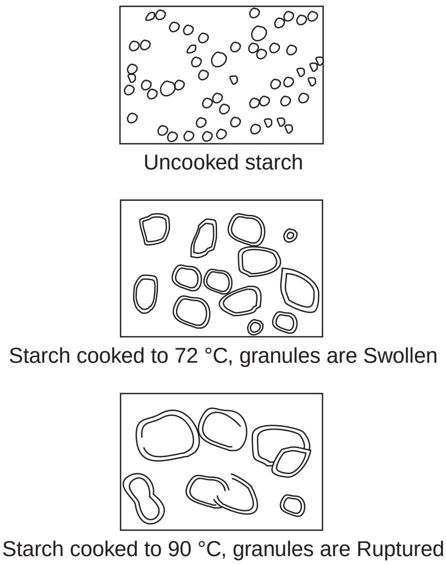


Fig. 9.2 Gelatinization of Starch Granules on Cooking

Gelatinization may be partial or complete. When the starch granules are dextrinized prior to being cooked in water, they undergo only partial gelatinisation. This is observed in the preparation of *upma, sheera, pulav,* where the cereal grains are first roasted with or without fat and then cooked in water. In such a case, because of partial gelatinisation, the cereal grains remain separate and do not stick together.

Gel Formation As a starch-thickened mixture cools after gelatinisation is complete, bonds form between the molecules of starch in the mixture. This bonding produces a three-dimentional network that increases the rigidity of the starch mixture and results in formation of a gel. Water is trapped in the network of starch. This rigid shape of the gel forms only gradually after the starch mixture has been allowed to cool. It has been found that starches containing relatively large amounts of amylose form firmer gels than starches with lower concentration of amylose. Hence, cornstarch gels are more rigid than gels formed from tapioca or potato which contain less amylose. This is because, the bond which form between the straight chains of amylose molecules are stronger and more readily formed than the bond which form between the branched chains of amylopectin molecules.

Syneresis As starch gels are allowed to stand for some time or age after gel formation is complete, additional bonds are formed between the straight chain amylose molecules. Some of these molecules get associated and aggregate in a particular area in an organized crystalline manner. As these molecules tend to pull together, the gel network shrinks, pushing out the entrapped water from the gel. This process of weeping from a gel is called *Syneresis* (Fig. 9.3).

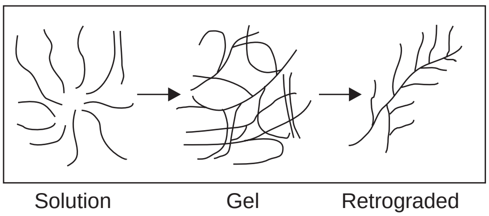


Fig. 9.3 Gel Formation and Syneresis of a Starch Dispersion

Cereals

Cereals are seeds of the grass family. The most commonly used cereals are: rice, wheat, maize (corn), and millets such as jowar, bajra, and ragi. Cereals are inexpensive and rich sources of carbohydrates. They contain approximately 65–75 per cent carbohydrates. Rice and vermicelli contain about 78 per cent carbohydrates. Cereal grains are the major staple food in many countries in the world.

Composition and Structure As shown in Fig. 9.4, whole cereal grains are composed of an outer bran coat, a germ, and a starchy endosperm.

The outer chaffy coat that covers the kernel during growth is eliminated when the grains are harvested. The outer layers of the kernel, which are called *Bran*, constitute 5 per cent of the kernel. During milling, the bran is discarded. The bran has a high content of fibre and minerals. It is also a good source of thiamin and riboflavin (vitamins of the B-complex group).

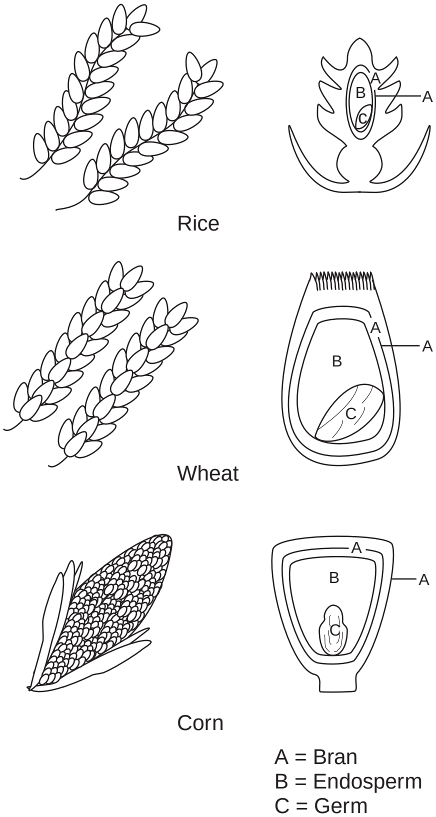


Fig. 9.4 Structural Parts of Rice, Wheat and Corn Grains

The *aleurone* layer is a layer located just under the bran. These cells are rich in protein, phosphorus and thiamin. They also contain some fat. The aleurone layer makes up about 8 per cent of the whole kernel. This layer is also lost in the milling process along with the bran.

The *Endosperm* is the large central portion of the kernel and constitutes about 84–85 per cent of the kernel. It contains most of the starch and protein of the kernel, but very little mineral matter or fibre, and only a trace of fat. The vitamin content of the endosperm is low.

The *Germ* is a small structure at the lower end of the kernel. It makes up 2–3 per cent of the whole kernel. It is rich in fat, protein, minerals and vitamin. The germ serves as a store of nutrients for the seed when it germinates. During milling, some of the germ is lost along with the bran and aleurone layer.

Nutritive Value Cereals are an important and economic source of energy. The chief nutrient which supplies energy, is starch. Cereals are also a significant source of protein in the diets of people whose staple food is cereals. But, cereal protein is incomplete in that it lacks in an essential amino acid, lysine. This lack is made up, when cereals are eaten along with other protein foods such as dals, pulses and milk.

The nutritive value of cereals varies with the part of the grain used. All whole cereals chiefly furnish starch, proteins, minerals, *B* vitamins and fibre, but refined cereals lose part of the protein, minerals and *B* complex vitamins in milling. They contain a little more starch than whole cereals. Whole grains contain more vitamins, minerals and fibre than refined grains and are valuable dietary sources of iron, phosphorus, thiamin and fibre.

Wheat Wheat is widely cultivated in the world. The average production of wheat in the year 1980–1981 was 1.65 tonnes per hectare. In India, Punjab is the leading state, which grows wheat. There are two crops in a year; the summer and winter crop. There are several thousand different varieties of wheat.

Wheat is commonly milled into flour or ground to obtain whole wheat flour. Refined flour or *maida* is commonly used in bread and other baked products while whole wheat flour or *atta* is used in the preparation of *chapaties*, *puries*, *parathas*, *khakras* etc. As mentioned earlier, whole wheat flour contains more protein, iron and thiamin than refined wheat flour. Wheat's used for flour is often classified into "hard wheat" or "soft wheat". Hard wheat is higher in protein than soft wheat and is better suited for making breads.

Products of wheat, commonly used are: broken wheat, semolina (*suji*), and extrusion products like vermicelli, noodles and macaroni.

Wheat Preparations

Whole wheat flour is used to prepare typical Indian unleavened breads such as *chapati*, *paratha, roti, khakra, puri* and variations of these. The ingredients of the dough are whole wheat flour, water and a little oil and salt. Of these, *chapati, khakra* and *roti* are roasted after rolling, *parathas* are shallow fat fried and *puris* deep fat fried.

Leavened products of wheat flour include *nans*, *bhatura* and bread. *Nans* and *bhaturas* are leavened by the addition of curd to the flour while making the dough. Yeast is used to leaven bread. *Nan* is roasted after rolling and *bhatura* deep fat fried. Bread is baked in an oven.

Rice Rice is the major food of many people living in Asia, and is the most widely used of all cereals next to wheat. The average production of rice in the year 1980–1981 was 1.34 tonnes per hectare.

Rice is available as milled, unpolished, polished, parboiled, flaked and puffed rice. Milling removes the bran, aleurone layer and some of the germ. Polishing further removes more than half the mineral matter and most of the vitamins. By a special process, grains of rice may be parboiled before milling. Parboiled rice contains more vitamins and minerals, because the steeping in hot water causes migration of these nutrients from the outer coats to the interior of the kernel and are not lost during milling. Parboiling also gelatinizes the starch and changes the cooking characteristics of the rice. Rice flakes are made after soaking the rice paddy in hot water and then pounding it. It is an important source of iron and thiamin in the Indian dietary and contains more minerals and fibre than the milled rice.

Millets

Millet is a common name applied to edible seeds of members of the grass family. These include bajra, jowar, maize, ragi and vari, which are the common millets consumed in India. Millets are hardy crops and require less care than do cereals. They grow under conditions of poor rainfall and soil.

The average calorie content of millets is 350 kcal per cent and is comparable to that of cereals. On an average, these contain 10–11 per cent of protein. Millet proteins lack in the essential amino acid lysine. The protein quality of millets may be improved if they are eaten along with dals or milk products. Millets are a good source of iron. Ragi is known for its high calcium content which is 344 mg per cent. Ragi is cheaper source of calcium than milk or nuts and oilseeds. Millets also contribute *B*-complex vitamins-thiamin, riboflavin and niacin to our diets. They are high in fibre content.

Millets are ground and the flour made into unleavened product like *bhakris, rotlas* etc. The ingredients of the dough are the flour, water and salt. These products are roasted on a hot skillet.

Ragi flour is roasted and used in preparations such as porridges. Water or milk may be used in the porridge. Addition of milk increases the nutritive value of the porridge. Ragi is often malted and used to make a beverage, which is a common weaning food given to infants. Preparations made of ragi or its flour are rich sources of calcium in an infant's diet.

Cereal Cookery Cereal cookery is fundamentally starch cookery, because starch is the predominant component of cereals. Fibre, which is chiefly exterior bran layers, until softened or disintegrated, will hinder the passage of water to the interior of the kernel and thus may retard swelling of starch in contact with water. If the fibre is finely ground, its affinity for water is greatly increased. Thus, whole grains take a longer time to cook than refined grains.

In the cooking of cereals, attention must be paid to the technique of combining finely ground cereals with water. Cereals in finely powdered form e.g., wheat flour, corn flour, should be first mixed with cold water with continuous stirring to prevent lumping and to obtain a paste of uniform consistency. This paste may then be added gradually to boiling water. Uniform consistency ensures equal exposure of all particles of the cereal to water and heat. If lumps form, dry material remains inside a gelatinous external coating. Alternatively, if the cereal is not in a very finely ground form, it may be gradually poured into boiling water with continuous stirring.

The principal factors that affect the cooking time of cereals are:

(a) The size of the particle: Cereal grains take longer to cook than flours made from these as the surface area of whole grains is much less, as compared to the flour.

(b) Soaking treatments swell the cereal grains partially. This enhances the speed of cooking. The cereal grains should be cooked in the water used for soaking, add more water if necessary.

(c) The presence or absence of the bran layer: As mentioned earlier, the bran layer interferes with the passage of water into the kernel and may thus delay the cooking time. But if the cereal grains are finely ground, then this effect may be minimized.

(d) The temperature: Boiling temperatures are normally used. Once the cereal mixture has been brought to a boil, the heat is reduced and it may be simmered until done. However, temperatures above boiling (100°C), as in pressure cooking, decreases the cooking time to a great extent.

Cooking of Rice Rice grains are normally cooked with twice its own volume of water. It is cooked till the grains are tender, and increases in weight to about three times the weight of dry grains. However, old rice that has been stored for a long time, requires more water for cooking than new rice.

Retention of identity of the rice grains is desirable, as in pulav. In such preparations, the rice grains are lightly roasted with hot fat/oil before being added to boiling water. This treatment causes partial dextrinisation of the rice grains, and helps to keep the rice grains separate after cooking.

Cooking of Wheat Wheat is mainly used as whole wheat flour in Indian cookery. Whole wheat flour is used to make *chapaties*, *puries, parathas* etc. Wheat flour contains specific proteins known as *Gluten*, which when hydrated develops into strong elastic fibres in the dough. Gluten is a protein made up of two fractions *Glutenin* and *Gliadin*. When water is added to wheat flour to form a dough, and the dough manipulated, glutenin and gliadin form gluten. When the dough is stretched and manipulated, gluten is developed. It forms a strong and elastic network in the dough. Gluten formation and development is desired in products such as *chapaties* and bread. It is minimized in muffins, cakes and *puries*.

Factors that Affect Gluten Formation and Development are:

1. *Variety of the wheat*: As mentioned earlier, hard wheat is better suited for making bread as it has more gluten than soft wheat. Thus, your choice of variety will depend on the characteristics desired in the final prepared product.
2. The amount of water added to make the dough/batter. Generally, gluten should be well hydrated to develop completely. If the liquid content is insufficient, a hard dough is formed and the gluten development may be poor. However, addition of excess water may produce a runny batter, which may be difficult to manipulate.
3. *Kneading time and keeping time*: Generally, greater the kneading or manipulation of the dough or batter, greater is the gluten development. However, over manipulation may break the gluten network. In cake and muffin batters, and in the preparation of biscuits, manipulation is minimal, as gluten development is undesirable, whereas *chapati* and bread dough is manipulated well. Keeping time ensures complete hydration of the gluten in the

dough. If keeping time of the dough is extended beyond a certain optimal value, it does not have any effect on the texture of the final product. Thus, *chapati* and bread dough is allowed to rest after being kneaded.

4. *Presence of fat/oil*: Fat or oil added to the dough in large quantities hinders the development of gluten. A small amount of oil is added to the puri dough. Refined oil, butter or vanaspati is used in cakes and biscuits.
5. *Fineness of Milling*: Wheat flour that has been milled finely, has a greater gluten development capacity than coarsely milled flour. Coarsely milled grains have less surface area than finely milled flour, and thus are hydrated to a lesser extent.

Buying and Storage of Cereals

Cereals Cereals, millets and their products are the staple foods in the Indian dietary. It is important that these be selected carefully as they supply a major part of our energy, protein, iron and thiamin needs.

Grain quality has two aspects. The first is physical quality, which refers to cleanliness, soundness of grain and freedom from foreign matter. The second is processing quality, which means suitability for use. For example, thin long grain rice, which does not clump after cooking, is considered suitable for making *pulao*, a particular type of wheat is required to prepare *puran poli* etc. Let us consider the specific criteria for selection of these foods.

Wheat is selected on the basis of the quality aspects mentioned above. Whole wheat is ground for individual use by the families. Whole wheat flour is mainly used to prepare unleavened bread (*chapati, roti, parantha* etc.) in India. In these preparations, very little nutrient loss occurs. Normally consumers buy the variety that suits their needs in terms of performance. Not much information is available about the performance of various varieties in indigenous wheat preparations. Therefore, selection is based on the consumer's personal knowledge and experience.

Rice is available as milled, hand-pounded and parboiled varieties. The degree of milling and polishing affects the nutrient content. The parboiled rice and hand pounded rice contain significant amount of thiamin; highly polished milled rice has very little thiamin.

A number of grain types such as long, medium and short are available. The selection is made depending on the intended use. For example, thin long varieties are preferred for table use, medium and short varieties are used for preparations of rice made after grinding.

Indians prefer the individual rice grains to retain their identity after cooking. Ageing appears to help develop this characteristic in the rice grain. Yet no visual criteria have been established, which could guide the consumer to judge the extent to which rice has aged.

Other grains include bajra, jowar, ragi, maize or any other millet, which is used as a staple.

Millets The criteria for selection are the same as for all grains—soundness of grain, cleanliness, freedom from admixture with other grains and trash. Most of these are ground and used to prepare unleavened bread (roti). As whole grain flours are used in most preparations, not much loss of nutrients occurs. It may be noted that ragi is an exceptionally good source of calcium and iron.

Processed Cereals Products

A number of processed products are made from cereals and pulses. These include wheat products such as cracked wheat, semolina (*rawa*), atta, maida, rice flakes, puffed rice etc. These are made by grinding to varying degrees of fineness (various particle sizes) or by roasting and pounding, or any other method. These processes increase the surface area of the product exposed to atmosphere, decrease the preparation time and also reduce the shelf-life of these products. While the whole grains have a shelf-life of a year or more, the shelf-life of these processed products may vary from two weeks to a few months.

Broken Wheat or Dalia is whole wheat coarsely ground into large particles. As the losses during milling are very little, it is a very nutritious food. Good quality is indicated by sweet taste and an absence of sour, mouldy odour and flavour. It spoils very quickly in storage, due to insect infestation. It can be cooked as such, made into *upma, shira* or porridge.

Semolina, Suji or Rawa is available in varied sizes. The fine grain varieties are used for the preparation of halwas, while the large grain varieties are suitable for preparation of *upma, shira* etc. These are selected on the basis of uniformity of size, freedom from insect infestation, freedom from oxidised or mouldy odour, grit and bran.

Maida is white finely extracted wheat flour. It is free from bran and has a lower content of protein, iron and *B*-vitamins. It has a lower shelf-life than semolina, as the large surface area permits faster rate of spoilage. Good quality maida is free from insect infestation, bad odours, and lump formation.

Processed Rice Products include rice flake and rice puffs. Rice flakes are made after soaking the paddy in hot water, parching it by roasting and then flattening it by force while it is hot to form flakes. It retains a large part of the iron and *B*-vitamin of the aleurone layer. The roasting helps to toast the grain, resulting in partial cooking of the grain. It needs very little the to prepare and is used as a snack. It should be free from bran, broken particles, fragments of the seed coat, insects, stones, trash and bad odour.

Rice Puff's are another ready-to-eat rice product. It is selected for crispness, freedom from stones, seed coats, sand and dirt.

Points to Remember

Carbohydrates Starch, the storage reserve in seeds, roots and tubers, is the main source of energy for human beings.

Carbohydrates are classified on the basis of number of sugars in the molecule into mono-, di- and polysaccharides.

Sugars are derived from fruits and cell sap of certain plants. Sugar, used in cookery is sucrose, extracted from sugarcane.

Uses of Sugar Used as a sweetening agent as such or a concentrated syrups, used to prepare crystalline candies. Decomposed at high temperature to form caramels.

Sugars are hygroscopic by nature, water soluble, sweet to taste, crystallize easily, hydrolyzed by acids to form invert sugar.

Starch Major source of starch are cereals, roots and tubers. Used as thickening agents, binding agents and to form moulded preparations.

Properties of Starch Insoluble in water. Absorbs water, swells and forms gel when heated.

In Preparation Starch dextrinises when roasted, with change in colour, flavour and texture. In the presence of water, absorbs water, swells, thickens and gelatinizes. Starch gels on ageing, weep with discharge of trapped water.

Cereals Rice, wheat and their products. Millets include bajra, jowar, ragi, maize and vari—are ground into flour and made into unleavened products such as chapaties, roties, paranthas etc., and leavened products such as bread, bhaturas etc.

Study Questions

1. What are carbohydrates? How do they occur in nature?
2. How are carbohydrates classified?
3. What different sugars are found in foods?
4. What are the uses of sugar in food preparation?
5. What is Honey?
6. List the different properties of sugar.
7. What is inversion of sugar?
8. What are starches? How do they occur in nature?
9. List the different uses of starch in food preparation.
10. Explain briefly the following:
    (a) Crystallization of sugar
    (b) Dextrinization
    (c) Gel formation
    (d) Syneresis
11. What are the different preparations in which cereals and millets are used?
12. List the different products of rice and wheat.
13. List the factors that affect gluten development in wheat.
14. What are the criteria of selection and purchase of cereals?