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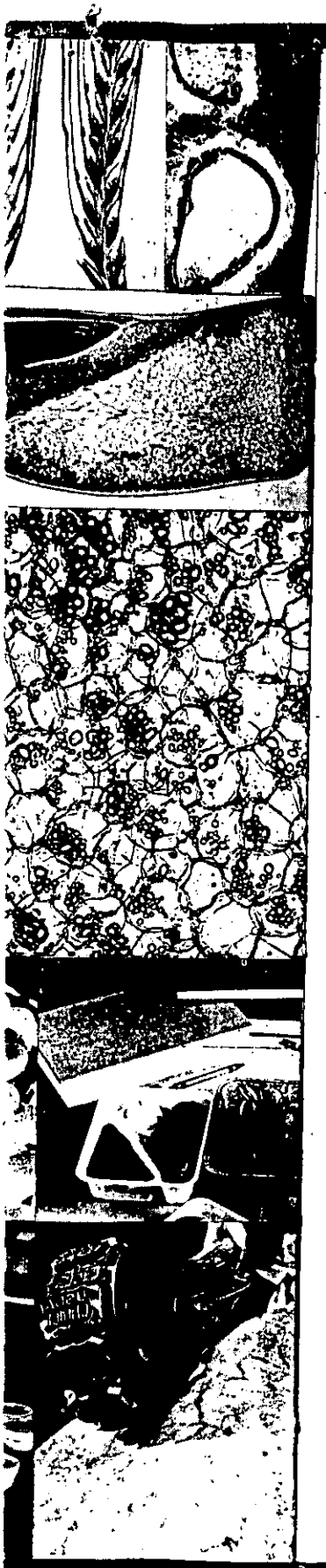

ELEMENTS OF FOOD TECHNOLOGY

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Contents

6

Cereal Technology

The most important higher plant structures used as food are the dry fruits and seeds. These would include all the cereals and small grains, the legumes and nuts. Because they are dry, they store easily and are not difficult to transport. In this chapter, we will study cereals and small grains, and in the next, the legumes and nuts.

CEREALS AND GRASSES

Cereals are the dry seeds of those members of the grass family grown for their grains and are by far the most important plants eaten by man. Of the cereals, wheat, corn, and rice are the most important. One or more of the cereals is adapted to each type of climate on earth: barley and rye grow in the northern regions, wheat in the temperate regions, corn and rice in the warmer temperature regions and in the tropics. Cereals have a wide range of requirements of moisture and soil types. They can be grown with little labor and the yield of food is high for the work involved. Cereals are a principal source of carbohydrates although they contain proteins, fats, some vitamins, and minerals. Cereals in their native dry state are alive. They respire just as we do, giving off carbon dioxide, water and heat. Grain with about 12 to 14 percent moisture can be stored for long periods of time. The optimum range in moisture content varies somewhat for the different grains.

WHEAT

John A. Shellenberger and S.A. Matz

The wheat grown today is believed to have evolved from cultivated einkorn which developed from a type of wild grass native to the arid pasture lands of southeastern Europe and Asia Minor.

Emmer, which is generally regarded as one of the ancestors of today's wheat, closely resembles a wild species of wheat found in the mountainous regions of Syria and Palestine. It is a much better wheat than einkorn, which gives low yields

and dark, somewhat bitter kernels. Since and emmer, and many wild species of gra concluded that bread wheat originated as wild species of grass.

Bread wheats, such as we know toda southern Russia about 2000 BC. Wheat i the Arctic Circle in the Northern Hemisp navian countries, and beyond the 40th para

The cultivation of wheat varies from pr areas of the world, to complete mechani preparation to harvesting. In the more i plowed, prepared for seeding, and sowed crop is harvested by self-propelled combir or to railway terminals by truck.

Time of Harvesting

As shown in Table 6.1, somewhere in t month in the year. In the United States, Texas, reaches its peak in the hard red June, and ends in October in the northern

Hard Red Winter Wheats

It is a general rule throughout the be grown, it will be. Planting in the fall,

TABL

THE WORLD'S

Month	Country
January	Australia
	New Zealand
February	Egypt (Upper)
March	India
April	Middle East
	Egypt (Lower)
	Mexico
May	China
	Japan
	Morocco
	United States (Texas)
June	France
	Greece
	Italy
	Spain
	Turkey
	United States
July	Austria
	Hungary
	Bulgaria
	England

lated in a matrix composed of protein. Some protein is stored in the form of small spherical structures, protein bodies, that are scattered throughout the endosperm.

The germ is firmly embedded in the kernel and is very difficult to remove during processing.

The starchy endosperm is the major portion of the sorghum kernel. The bran consists mainly of the pericarp and aleurone layer. Nearly 80% of the total protein is located in the endosperm whereas the germ contains 75% of the fat in the kernel. A carnauba-like wax is the major component of the ether extract of the bran. The protein and fat content of the endosperm are highest in the peripheral area and lowest in the center of the floury area. Approximately 95% of the starch is in the starchy endosperm. The mesocarp contains the remaining starch granules. The highest concentration of starch is located in the center of the floury area.

World Use of Sorghum

Sorghum is the staple food in parts of Asia and Africa. Preparation of sorghum for food is simple. It is usually consumed as a porridge or stiff paste prepared by adding pounded flour to hot water. Sometimes a flat cake is prepared and the grain may be parched, popped, or boiled whole.

A common Nigerian food is "tuwo" prepared by stirring flour into hot water and allowing the thick paste to cool and gel. Pieces of the cooled gel are eaten with soup. Occasionally, unripe sorghum panicles are roasted similar to U.S. sweet corn. Pop sorghum varieties are grown and popped similar to popcorn.

Bantu or kafir beer is a popular beverage consumed in parts of Africa. It differs from beer made from barley malt in that it is an opaque reddish-colored fluid with good body which contains 5-6% solids, has a yeasty sour taste, low alcohol content, and high nutritional value. Red sorghum grains are preferred for malting and brewing.

In India, sorghum grain is ground or cracked, prepared into a dough and baked as flat, unleavened bread (rotti) or cooked like rice. White, pearly grains are preferred for bread. Whole grain is parched or "fried" in a hot pan and then ground and mixed with salt, buttermilk, or molasses. Special sorghums for popping, roasting or other uses are frequently grown in small quantities. "Vani" jowars are harvested in the dough stage, roasted, and consumed with a spicy noodle. A major use of sorghum in China is for wine production. In addition, red glumes are steeped in water to make a dye used for reddening wine.

Japan and Israel import large quantities of sorghum grain for use as feed grain in poultry, swine, and cattle production. Israel obtains most of its sorghum from the United States. Japan imports sorghum grain from the United States, Argentina, Australia, and Thailand.

BREAKFAST CEREALS

Donald L. Maxwell and John L. Holohan

In the United States, the word "cereal" in current usage refers to an array of products nearly ready for consumption and usually eaten at breakfast, as well as to the grains from which they are largely derived. Cereal products can be classified in part according to their methods of processing: puffed, flaked, shredded, and a few products prepared as granules. "Hot" cereals are milled grain products intended to

be heated just before consumption. Some of the products in the above classes are also presweetened, that is, sweetened to a level appropriate for use without further addition of sugar.

About 1½ billion pounds of cereal were produced in the United States in 1971. This total included roughly ½ billion pounds of puffed, ½ billion pounds of flaked, and 100 million pounds of shredded cereals. Some 300 million pounds of hot cereals were produced. The principal producers included Kellogg Co., General Mills, Inc., Post Division of General Foods Corp., Quaker Oats Co., Nabisco, and Ralston Purina Co.

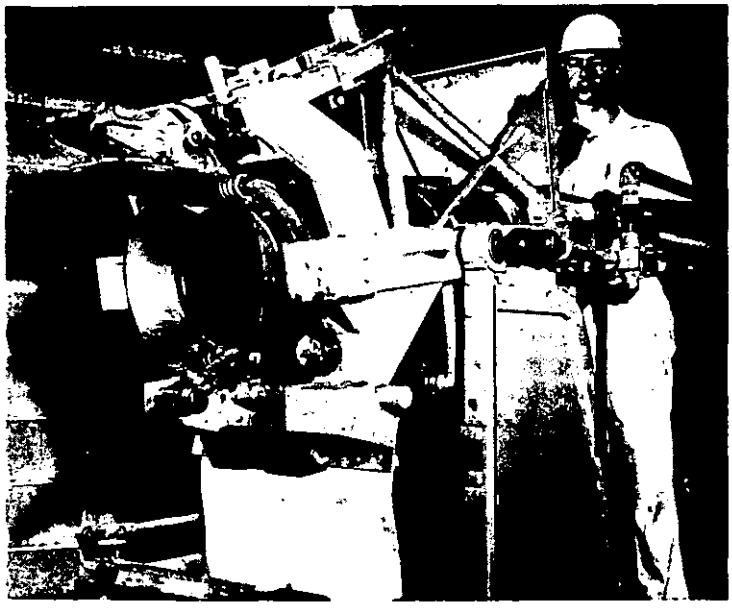
Grain ingredients used in cereals in 1971 included (approximately): 500 million pounds of wheat, bran, or farina, (mostly soft Michigan white winter wheat), 400 million pounds of oatmeal or oat flour, 300 million pounds of corn grits (maize), and 150 million pounds of rice.

Puffed Cereals

Puffed cereal products may be "gun" puffed, oven puffed, or extrusion puffed. Gun puffing is so called because equipment used for expansion of the cooked grain somewhat resembles an old cannon. Technology for puffing of cereals was developed by A. P. Anderson in the early 1900's and his patents led to the marketing of puffed rice and wheat. In Anderson's process, still used today, these grains are cooked, generally without other ingredients, adjusted to proper moisture content, and sealed in the puffing gun. This consists of a horizontal cylinder rotated about its axis, with gas burners or other heaters placed to heat the outside of the cylinder, and means to tip the cylinder for loading and unloading. One end of the cylinder is permanently closed, the other has a closure equipped for instant release. The mass of grain tumbles in the rotating cylinder, becomes heated within a few minutes, and is pressurized by the heated air and by vapor of its own moisture. When the appropriate pressure (in the range of 90-250 psig) is obtained, the closure is released; the contents erupt with a loud report and the cereal pieces are expanded by the sudden volatilization of internal moisture. With proper control of gelatinization and moisture content prior to puffing, the grain remains expanded during cooling and final drying. The exact conditions of the puffing step have important effects on flavor and stability of the product; surface temperatures of 180°C or more inside the gun are likely, and the product temperature is increasing very rapidly in the last few moments of the gun cycle. Firing time must be controlled within a few seconds to avoid either underexpansion or burning of the product (Fig. 6.15).

In 1939, F. A. Collatz developed and patented methods for making puffed cereals from flour rather than whole grain or grits. This technology made possible puffed products based on oats, which could not be puffed as whole grains. It also provided for the use of mixtures of grains and the incorporation of additional ingredients for flavor and nutritive purposes. The process involves extrusion of a viscous dough to form pellets which are then puffed as above. The extrusion step allows the product to be made in various shapes. In 1942, T. R. James patented a continuous means for the cooking and extrusion into pellets of milled grain products. These techniques are still of commercial importance.

Several methods for semicontinuous puffing have been developed. These generally involve chambers or cylinders with screw conveyors to move the product through, and rotary or intermittent valves for inlet and outlet. Other workers later developed fully continuous means for carrying out the puffing step, using continu-



Courtesy of General Mills

FIG. 6.15 BATCH PUFFING GUN SHOWING THE QUICK-RELEASE LID IN OPEN POSITION

ous expansion through a nozzle at the outlet.

Oven puffing is used for some products, principally rice. The grains are pressure cooked at a moisture content of about 30% with sugar, salt, and other ingredients. After drying to about 15% moisture and "tempering" or holding, the grains are subjected to hot air. Temperatures of 173°-318°C and either tumbling of product or air flow at or near fluidization velocities are necessary: heat transfer rates must be high enough to bring about puffing rather than simply drying. Ovens in the form of a perforated rotating horizontal drum have been used. Puffing takes place within seconds, but the product is left in the oven longer to complete drying and flavor development. Accurate control of residence time is important because browning occurs rapidly as the cessation of evaporative cooling allows product temperature to rise.

Cooked pellets or grains being prepared for gun or oven puffing may be impacted by passage between rolls prior to puffing. The partial flattening appears to modify the puffing behavior, presumably by partial disruption of the starch structure. For some formulations, coating of the pellets with 0.2 to 2% of a lipid, such as coconut oil, or a monoglyceride is necessary to keep the pellets from agglomerating in the puffing step.

Several puffed cereal products are made by a process closely related to oven puffing. Granular or floury ingredients are continuously mixed and moistened in a steam atmosphere under pressure, extruded to form a strand, surface dried, cut to appropriate piece size, and dropped into a stream of heated air to be puffed under air conveying conditions.

Processes have been developed for extruding and puffing cereals in a single step. A high-powered extruder is used. With input of sufficient mechanical energy, pressure and temperature of the dough are raised enough so that it puffs upon release

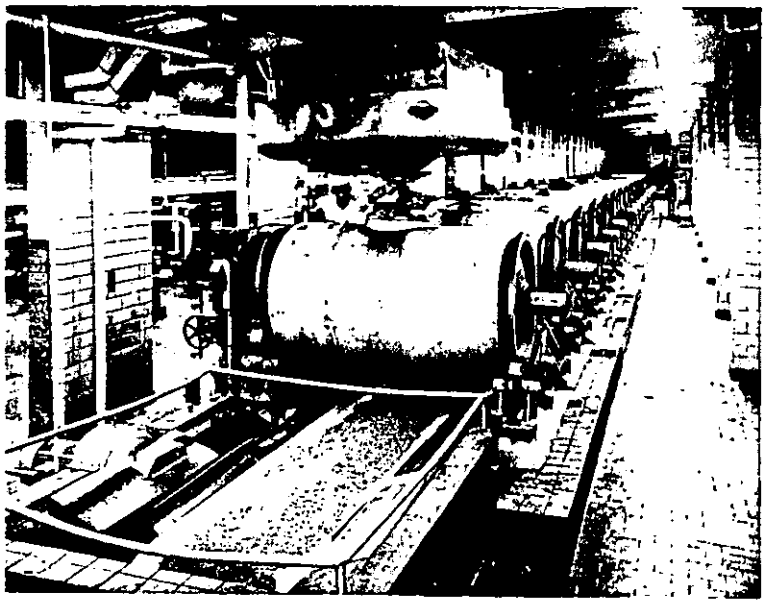
of pressure at the extrusion die outlet. The dough may be cut at the die face or th strand conveyed for cooling and drying before being cut.

Flaked Cereals

The principal flaked cereals are made of corn and wheat. Corn flakes are mad from grits—pieces of corn endosperm with hull and germ completely remove Wheat flakes are made from whole grain. Bran flakes are made from chunks of th wheat kernel from which part of the endosperm has been removed. Most flake cereals are made by cooking whole grain or pieces with various flavorings such a sugar, salt, and malt; drying to a firm but slightly plastic state; flaking by passag between rolls; and toasting or drying to final moisture.

Cooking is usually done batchwise. The cooker used is a rotating horizontal cy inder with provision for direct steam injection. A syrup containing flavoring ingr dients is charged to the cooker with the grain and absorbed by the grain as it tum bles under steam pressure. (Cooking may alternatively be carried out as a continu ous process by conveying the grain through a steam pressure vessel with pressur lock ports.) Steam pressures used are usually 10-30 psig. After cooking, the grai is cooled and dried with agitation to separate the particles in preparation for fu ther processing.

In some cases, a pelleting step is carried out at this point in the process. Pelletin allows the manufacturer to obtain a larger and more uniform flake size than th original grit or kernel would provide. It also allows the mixing of different cooke grains into a single flake, or the incorporation of ingredients not stable under cool ing conditions. Pelleting may be carried out by extruding and cutting to form pe lets at the extrusion die face. An auger-type extruder similar to those used for e truding macaroni or plastics is used.



Courtesy of Kellogg Company

FIG. 6.16. BATCH COOKERS IN CEREAL FLAKE PROCESS SYSTEM

In a few cases, flaked products are prepared from flour or other milled grain products by forming a dough, cooking, and extruding to form pellets.

Properties of the finished flake can be modified by a heating or roasting step immediately before flaking. This can be done by spreading the pellets or grits in a thin layer, for example on a conveyor belt or vibratory pan, using radiative heaters for rapid heating with a minimum of drying. The heated particle apparently deforms with less rupture of starch cells and yields a flake that is slower to absorb liquid (such as milk) and softer.

Toasting or finish drying of flaked cereals is done in a reel oven or belt oven, with sufficient air velocity through the bed of flakes to provide rapid heat transfer. The conditions used are closely related to those for oven puffing. Corn flakes can be observed to expand, or bubble, after some seconds of exposure to oven conditions; this bubbling appears to be necessary if the product is to have a crisp and tender, rather than flinty, texture. Toasting is carried out at temperatures of 149-318°C and times of about 1-5 min. Toasting time must be accurately controlled to achieve the proper degree of flavor development and sufficiently low moisture (Fig. 6.16).

Shredded Cereals

Shredded wheat, the oldest mass-produced cereal, is still of commercial importance. The original process was described by Henry Perky in a remarkably detailed series of patents from 1893 to 1901 which described the entire shredded wheat factory, including packaging and conveying equipment.

Wheat with no added ingredient is still the most important shredded cereal. Whole grain wheat is cooked, partially dried, and tempered. Then it is passed between rolls, one of which is smooth, the other circumferentially grooved. Heavy forces—of the order of magnitude of 1000 lb per in. of roll length in some cases—are required to maintain the rolls in tight contact. The moist grain becomes plasticized in the nip of the rolls and flows into the roll grooves, issuing as a set of strands roughly 1 mm in diameter. These strands are accumulated in multiple layers and formed by pinch cutting into biscuits of desired size. The biscuits are then baked. Oven conditions would tend toward those used in bakeries, with elevated humidity and low air velocity; the vigorous heating conditions used for oven puffing or toasting are not appropriate for the larger shred biscuits.

A refinement of the shred process added cross grooves to the shred roll to provide lateral strands of dough which tie the shreds together into a coherent perforated sheet; the sheets are layered and cut as described above. The shred sheet allows more precise forming of smaller cereal pieces of only a few layers thickness. This form has been used for corn, wheat, and rice. These grains are flavored with sugar, salt, malt, or other ingredients and cooked approximately the same as they would be for making flakes. The shred sheet is also utilized for raw or lightly cooked mixtures of flours with proteins or other ingredients.

Presweetened Cereals

Some cereals have sugar added prior to cooking to influence the development of desirable flavors during processing. The amount of sugar added for this purpose is generally 12% or less. Most users will add sweetener to such a product at time of use. At some higher level of sugar, depending on type of product and age of users, the product will be consumed by most users without additional sweetening. This

presweetening is most often achieved with an enrobed sugar coating.

Sugar, sometimes with corn syrup or other ingredients, is heated with a amount of water to make a sugar syrup. The heated syrup is sprayed or dr on a rolling mass of cereal particles in a rotating drum called an enrober or c reel; heat may be applied to the reel. If necessary, the coated particles are the ther dried in a belt dryer.

By variation of formulation and mechanical treatment, a range of coating ch teristics can be obtained, from glazed or shiny to highly crystalline or frosty. G coatings can be obtained by the addition of invert sugar, honey, and other n crose sugars. Rather than the addition of invert sugar, some of the sucrose pr may be inverted by heating the sugar syrup with an acid such as citric acid pre Crystallization can be minimized by avoiding mechanical movement or disturb of the product during critical parts of the drying and hardening of the coa More frosty or crystalline coatings are obtained by using all or mostly sucrose by providing tumbling or other agitation during the cooling and drying of the ing. Flavoring materials such as citrus oils or spices are sometimes incorpor into the sugar coating.

Other additives to cereals are also used as sweeteners. A simple physical ture of raisins with bran flakes has been commercially important for many y The products usually contain about 25% raisins; the raisins have about ½% h or invert sugar syrup and 10-15% granular sugar added during their preparat to add sweetening and to prevent them from sticking together.

Several cereal products are sold in mixture with dried grained marshmallow p es; these pieces contribute texture and flavor effects and also constitute a sweetening means. Other sweetening additives such as freeze-dried fruits h been used from time to time without significant commercial success.

Hot Cereals

Hot cereals are those designed to be heated just before use or prepared by a ing hot water or other liquid. They are usually milled products of a single grain a simple mixture. The principal product of this type, rolled oats ("regular" rol oats), consists of dehulled, steamed, flattened, and dried oats. "Quick" oatmeal u oat groats that are steel-cut into several fragments after dehulling, then flatter a little thinner than for regular rolled oats, to reduce the time of preparation.

Instant or "cook in the bowl" oatmeal is prepared in such a way that the u need only add hot water and stir to make the product ready for consumption. Bas on quick oatmeal, instant oatmeal is given some additional treatment—such as t incorporation of 0.1-1.0% of an edible gum on the surface of the oat particles—improve its hydration.

Wheat farina, alone or mixed with wheat germ, bran, malted barley, cocoa, other flavoring materials, is packaged for use as a hot cereal. Milled rye is also use Such products are normally steamed and dried or toasted to enhance stability t ward enzymatic or other degradative changes.

Stability of Cereals

Although the amounts of fats present in most cereals are quite low—about 0. 6%—the stability of the fats present is critically important to the product. Most ce eals can be expected to deteriorate by oxidative rancidity at low moistures, or b

related staling reactions at higher moistures. The naturally-occurring antioxidants present are not entirely known, and subtleties in processing conditions can drastically affect resistance to rancidity. Proper degree of browning in toasting or puffing processes is generally regarded as necessary for adequate stability of cereals. Unexpected failure of natural antioxidant systems has had disastrous effects on some products in the marketplace. A stable shelf-life of six months at moderate to high temperatures is a minimum requirement for cereals in ordinary distribution in the United States at this time, and the absence of obnoxious odors or flavors for several more months is highly desirable.

Nearly all cereals in the U.S. market are now protected by the antioxidants BHA or BHT, applied either directly to the product or dissolved in wax used for packing materials, whence a portion of it diffuses into the product after packaging.

Cereals also go out of condition due to loss of texture (crispness) at a moisture characteristic for the product, generally in the range 5-10%. Cereal packages are designed as moisture barriers so the product, initially at about 1-4% moisture, will remain crisp until consumed.

Nutritional Characteristics

Breakfast cereals are regarded as having origins in the "granola," parched grain mixtures, of the Nineteenth Century. The growth of the present industry was catalyzed by the work of Dr. John Kellogg, a vegetarian and health food advocate, who developed grain food products as replacements for the heavy breakfasts of the day, which were likely to be fat pork and fried foods. Entrepreneurs such as Kellogg's brother Will and competitors C. W. Post and Henry Perky soon found markets for their products. The markets expanded as the population made its transition from a largely agricultural society highly dependent on manual labor, to a largely urban, machine-aided one.

The early patent literature of the industry abounds with references to nutritional aspects of the products. The state of knowledge of nutrition was at that time rudimentary. As new knowledge of nutrition was gained, more use could be made of breakfast cereals as carriers of nutritional entities. After the decrease of vitamins and minerals values by milling or heat processing of grains had been identified and the nutritional significance understood, a practice of "restoration" was adopted: certain nutrients which had been present in the whole grain in significant amounts were added to the processed product to bring it to raw whole-grain levels. Accordingly, niacin, iron, thiamin, and to a minor extent, riboflavin, were added to many breakfast cereals beginning in the 1940's.

Cereals have become regarded as useful carriers of vitamins and minerals, including some that are not present in consequential amounts in the original grains. The relatively regular pattern of consumption of cereals—both as to quantity and frequency—provides a rationale for such efforts. Various cereals now on the market contain as much as ¼ or more of the Recommended Daily Allowances of some vitamins and minerals per ounce of cereal. Depending on their stabilities under processing conditions, various vitamins may be incorporated by inclusion in the cooking step, by inclusion at an intermediate step such as extrusion, by spray application to the cereal surface after processing, or by inclusion in a sugar coating.

Various methods for incorporating additional protein into breakfast cereals have been attempted. The protein supplementation results in significantly altered product flavor and texture properties; in a few cases, such products have been well-ac-

cepted by consumers. One product is made by coating oven-puffed rice with a batter of wheat gluten. Another method is the inclusion of dry protein supplement in the extrusion step for forming pellets for a flaked cereal. Another product is obtained by incorporating protein into a moist dough which is then formed into a shred sheet. All these methods avoid exposing the protein material to the cooking of the grain base. Cereal products without protein supplementation contain about 5-15% protein; the supplemented products are formulated to contain up to about 20% protein.

SUMMARY

As noted at the outset, cereals are the dry seeds of those members of the grass family grown for their grains and are by far the most important plants eaten by man. Of the cereals, wheat, corn, and rice are the most important. One or more of the cereals is adapted to each type of climate on earth: barley and rye grow in the northern regions, wheat in the temperate regions, corn and rice in the warmer temperature regions and in the tropics. Cereals have a wide range of requirements of moisture and soil types. They can be grown with little labor and the yield of food is high for the work involved. Cereals are a principal source of carbohydrates although they contain proteins, fats, and some vitamins and minerals. Cereals in their native dry state are alive. They respire just as we do, giving off carbon dioxide, water and heat. Grain with about 12 to 14 percent moisture can be stored for long periods of time. The optimum range in moisture content varies somewhat for the different grains.

In this chapter, we have studied cereals and small grains; next, we will discuss legumes and nuts.

Bean, Nut and Seed T

Legumes are second to the cereals as impo
are the "meat" of the vegetable world and a
value. Soybeans are one of the oldest kno
considered edible until after being processe
of all the vegetables consumed throughout th
Field and garden peas are also legumes
mainly livestock feed, while the garden p
fresh, or preserved by freezing, canning, or
pods of string or snap beans, and many ty
peanut is also a legume and is a good sour
legumes.

A nut is a one-seeded, one-celled fruit wi
and filberts are truly nuts. Other plant tis
Brazil nuts (seeds), peanuts (legumes), or w
(dry fruits). We distinguish three groups of
those with high protein content, and those
fat "nuts" are the Brazil nuts, Cashew nut
high protein "nuts" are the almonds, beech
hydrate "nuts" are acorns and chestnuts.

BEANS

Carl W. Hall

Production

Beans for human consumption include pri
dry edible beans. The dry edible beans incl
kidney, and lima beans. The varieties are na
mercially important bean-based food prod
becoming increasingly important as a food s
producer of soybeans. Soy flour, a product
industrial products.