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Recent Developments in Foods from Cereals

THE PER CAPITA CONSUMPTION of wheat flour in the United States has declined from 211 pounds in 1910 to an estimated 120 pounds in 1958, a 43% decrease in 48 years. During that period the population increased 85% (from 92 million to 172 million), so that total flour consumption rose only about 2%. The decline in per capita consumption is due to several factors including the lower requirement today for energy foods with the elimination of heavy manual labor, the higher standard of living, and the availability of a wide choice of attractive, nutritionally recommended foods in the grocery trade.

Developments in the Wheat Milling Industry

This trend toward convenience foods with "built-in maid service" which developed during World War II has greatly increased and it has led to marked changes in the milling industry. The sale of flour and other primary products of the milling industry to the homemaker has fallen off and large milling companies now supply the homemaker with many different products in the form of dry, refrigerated, and frozen mixes. Prepared mixes are now manufactured for use by institutions (such as restaurants, hospitals, hotels, orphanages), bakeries, and the armed services. The market for family mixes has increased about 30% in the past five years and now exceeds $300 million per year; the institutional market is about $18 million and the bakery mix market about $103 million per year.

Commercial baking is becoming more and more concentrated in large organizations which are rapidly mechanizing their operations as completely as possible. There is therefore a greater requirement for uniform flours with close specifications to ensure the desired bake-shop performance.

Mill Modernization

Methods of flour production have not undergone any basic changes since the roller mill system and purifiers were introduced in the 1870's. Many improvements have, of course, taken place, particularly since World War II. The need for equipment with interiors free from pockets and crevices where insect infestation can gain foothold, and the demand for economy of space, have led to the use of metal in place of wood. Modernization has brought improved purifiers and sifters, pneumatic conveyance of mill products, automatic controls and weighers, and better packing machinery. Until a few years ago, flour and other mill products were packed immediately in sacks which were stored in multi-floored warehouses. Today there is a marked trend toward use of large bins which hold many hours' production; flour is drawn from these for blending or for direct packing. Bulk handling of flour in portable bins also is rapidly increasing; a few years hence virtually all domestic bakery flour doubtless will be handled in bulk.

Impact Grinding and Air Classification

Flours of varying properties must be provided for different end uses. Breadmaking requires flours of relatively high protein content (11.5 to 14%) which yield a strong, tenacious gluten; in contrast, cake-making calls for very weak flours with protein contents ranging from 7 to 9%, and gluten of low coherence and extensibility. Today's miller is required to produce flours specifically suited to the production of hearth bread, pan bread, biscuits, crackers, pie crust, doughnuts, and cakes. Quality requirements for these specific uses are influenced primarily by protein content, which in turn is dependent upon that of the wheat from which the flours are made. By suitable selection of wheats, coupled with appropriate treatment with minute quantities of bleaching and maturing agents, the miller has been eminently successful in producing tailor-made flours for specific end uses. However, variations in the properties of available wheats make it difficult to maintain the desired uniformity in processing characteristics, particularly from one crop year to another.

During the past couple of years a major innovation in the method of milling wheat has made it possible to separate a wheat flour into fractions differing widely in protein content. This novel process involves specialized impact grinding, and air classification of the ground material.

It is based upon the fact that the endosperm consists of cells with thin cell walls (cellulose and hemicelluloses) filled with starch granules of varying size embedded in a protein matrix. In the normal roller milling process, these endosperm cells break up to yield various-sized agglomerates of endosperm flour cells, cell wall material, free starch granules, particles of free protein, and starch particles with adhering protein. In hard wheats the individual flour cells are not easily broken open, but in soft wheats the impact of the rolls breaks more of the cells, resulting in a greater release of their components. These fragments range in average diameter from about 1 to 150 microns, and are too small to be separated by the ordinary sieving systems used in flour milling. However, by air classification it is possible to separate from a soft wheat flour (8.5 to 10.5% protein) fractions of varying particle size which contain from less than 3% to over 20% protein. This represents a very marked "protein displacement"; with both hard and soft wheat flours, fractions of superior quality for bread, biscuit, and cake making have been obtained.

This new milling technique's full potential cannot be assessed at this time. It is obvious, however, that it will render the miller partly independent of the wheat he is milling, and permit production of uniform flours particularly suited for various baking purposes. Fractions of low protein and high starch content may find special food and industrial uses.

Developments in the Baking Industry

The manufacture of high quality bread requires adequate production of gas at the end of the fermentation period. Also, the doughs must be sufficiently mellow and pliable to machine properly, yielding a bread of good volume and crumb characteristics. Flours milled from sound wheat contain abundant supplies of beta-amylase but this enzyme is capable of converting completely into maltose only the amylose (linear) fraction of the mechanically injured starch granules; its action on the amylopectin (branched) fraction stops short at the branching points of the chains. Wheat flour is deficient in alpha-amylase, but this enzyme is present in malted wheat or barley. It attacks both amylose and amylopectin, producing new points for attack by the beta-amylase. Combined action of these two enzymes assures rapid maltose production. This is particularly important during the proofing period and the first few minutes in the oven when the supply of other sugars may be insufficient for adequate gas production.

It is a long established practice to supplement flour with alpha-amylase by the addition of malt flour. However, oversupplementation may lead to a gummy sticky crumb because the alpha-amylase of wheat and barley is quite thermostable and is not inactivated in the baking oven before gelatinization of the starch (which is very susceptible to amylase attack) has commenced. As a result, sufficient dextrin may be produced to give a baked loaf with a gummy stick crumb of poor eating quality. Malted wheat flour also contains proteinases, shown by research to be mainly responsible for the increase in extensibility and pliability of doughs during fermentation. This is of particular value with flours which yield "bucky" doughs.

Recognition of the important role played by proteases in breadmaking has led in recent years to increasing use of fungal enzyme concentrates in baking. *Aspergillus oryzae* is cultured in an appropriate medium, the mycelia are removed by filtration, and the various enzymes which were secreted into the medium by the growing organism are precipitated and standardized to a desirable proteolytic activity with wheat flour. Fungal enzymes are available with low amylase activity and high protease activity, as well as the reverse, providing means for individual control of the levels of these enzymes in doughs.

When fungal enzymes are added to the sponge the proteolytic action which occurs markedly reduces mixing time at the dough stage. Their proper use results in more pliable doughs, and yields bread with improved crumb grain, texture, and compressibility. The alpha-amylases of fungi are much less thermostable than those of wheat and barley, and their beneficial effects on maltose production during fermentation can be obtained without excess action during baking. (The fungal enzymes also contain alpha-glucosidase so that appreciable quantities of glucose are produced.) During fermentation and proofing, alpha-amylase activity is limited by the small percentages of mechanically injured starch granules present; in the oven fungal amylase is inactivated before any appreciable quantities of gelatinized starch are produced. Supplements of fungal enzymes, therefore, offer a considerable margin of safety against the occurrence of stickiness in the crumb. Fungal enzyme preparations from *Aspergillus oryzae* may be used in breadmaking under the Standards of Identity for Bread and Rolls of the Food and Drug Administration but they may not be added by the miller under the present Standards of Identity for Flour.

Use of Brews or Preferments

Researches have shown that the characteristic flavor of bread is associated with volatile substances produced from sugars by yeast fermentation, and as a result of the browning reaction during baking. Fermentation may therefore be carried out separately from the flour by permitting yeast to act on a sugar solution containing yeast nutrients in a buffered system; the fermented liquid may then be used to form a dough which can be immediately proofed and baked. In recent years there has been considerable interest in this process as a replacement for the sponge in the customary sponge and dough procedure. In the so-called Stable Ferment Process of the American Dry Milk Institute, first reported in 1954, nonfat dry milk is used as the buffer, whereas the Fleischmann preferment formula employs a mixture of calcium carbonate, ammonium chloride, wheat flour, calcium sulfate, and sodium chloride. Replacement of the sponge step through use of a brew results in considerable saving of labor and floor space (through elimmation of temperature- and humidity-controlled fermentation rooms); conventional breadmaking equipment is utilized for the remaining steps in bread manufacture. There is considerable commercial interest in this development.

Preparation of a brew is an integral part of the J. C. Baker Do-Maker Process of continuous bread manufacture which eliminates sponge and dough mixers, troughs, dividers, rounder, overhead proofer, molder, and panner. In this process, first described in 1954, the yeast broth, flour, oxidizing agent, and melted shortening are fed continuously at pre-determined rates into a premixer where they are thoroughly mixed. The resultant dough is metered into a developer from which it is extruded at a constant rate, divided, and deposited directly into baking pans. Elapsed time from metering of the ingredients to panning of the dough is only three minutes, and the entire operation is controlled from a central panel. The present machine can be operated to produce from 40 to 85 one-pound loaves or their equivalent per minute. According to the manufacturers, savings in floor space and increased economy and efficiency of operation render the unit suitable for bakers producing 80,000 to 100,000 pounds of white bread per week. One bakery organization has eleven units in operation. The replacement of mellowing fermentation by mechanical development yields an extremely fine, uniform cell structure; this results in eating characteristics which differ from those of bread of much larger and less uniform cell size made by conventional methods. However, consumer acceptance is said to have been entirely satisfactory.

(Since the oral presentation of this paper, American Machine & Foundry has announced a continuous fermentation and mixing process for breadmaking. The yeast, a nutrient mix, and part of the water are held in a blending tank for one hour at 86 to 90° F. Salt, milk, and 10 to 15% of the flour are added, and the mixture is pumped to a holding tank where fermentation proceeds under gentle agitation for about one hour. The liquid sponge is transferred to a trough which functions as a continuous feeder for the mixing system. The remainder of the flour, the shortening, and oxidizing improvers are blended with the sponge in an "incorporator." The dough is then passed to a "developer" where counter-rotating paddles shear and stretch it. The dough flows into a divider-panner that deposits the correct quantity of dough in the pans. This process is designed for use in large commercial bakeries with a volume of 4000 to 6000 pounds of bread dough per hour.)

Chemically Leavened "Instant" Bread

Another application of yeast brew or preferment is indicated by current research at the Quartermaster Food and Container Institute. Its goal is a bread-like product made without the conventional yeast fermentation and proofing steps—a complete bread mix which will be stable for long storage periods and from which acceptable bread can be prepared with a minimum of equipment and skill. Substitution of glucono-delta-lactone and sodium bicarbonate for yeast has yielded a chemical leavening system which produces a baked loaf quite similar in crumb grain and texture to conventional bread. A flavor component consisting of a yeast broth or preferment from which the yeast cells have been separated by centrifugation imparts a desirable flavor which resembles that of yeast-leavened bread. Experiments to find the best methods of drying the yeast-free broth for maximum retention of flavor are being conducted. Through use of the "instant" bread mix in a continuous dough mixer and extruder, the time from dry mix to oven is reduced to about 15 minutes.

Prepared Mixes

The phenomenal growth of prepared mixes results from the convenience, economy, and uniformly high quality of the finished baked products which they provide. They are formulated and produced under scientific control, and some of the ingredients—such as improved leavening agents, shortenings, emulsifiers, and non-fat dry milk specially prepared for bread production—are not readily available to the housewife. Large purchases, bulk handling, and modern methods of manufacturing provide economies which cannot be secured by housewives, small institutions, and small bakeries.

There are five general types of prepared mixes: (1) those leavened by chemicals, such as doughnuts, cakes, pancakes, and muffins; (2) those leavened by yeast, such as bread, rolls, buns, and yeast-raised doughnuts; (3) those leavened by aeration, such as foam type cakes (angel food, sponge, and the like); (4) those leavened with chemicals and flavored with fermentation products from yeast, such as "instant bread"; and (5) non-leavened products such as pie crust mix.

During the past several years lard has been extensively used instead of the hydrogenated vegetable shortenings in these mixes. This has been made possible by "rearrangement" of the fatty acids to provide a desirable plastic range, use of satisfactory antioxidants to inhibit the development of rancidity, and development of better fat emulsifiers.

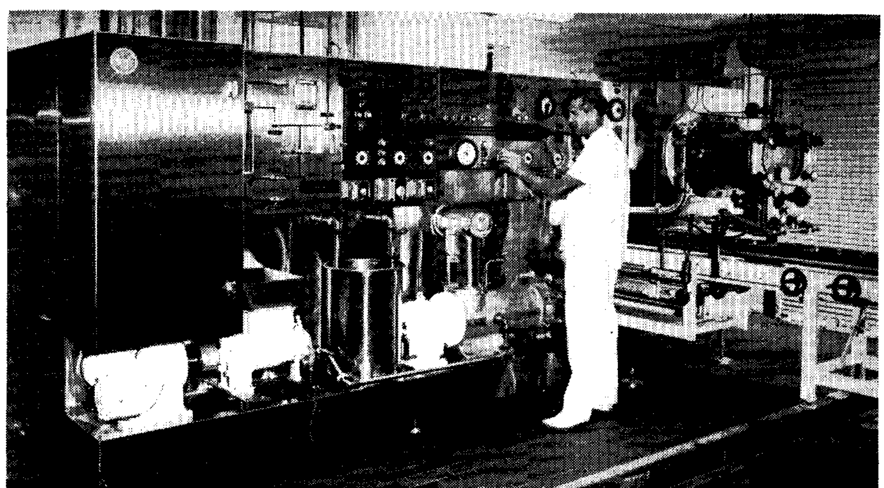
Refrigerated and Frozen Products

The principal refrigerated products are biscuit doughs (pre-cut, ready for baking) and cookie doughs. These products are very convenient for the housewife since individual servings can be removed from the package and baked as they are needed.

There has been a marked increase in the production of such frozen food items as coffee cake and cheese cake. Such frozen products of high sugar content retain their quality and are highly acceptable. In recent years there has been renewed scientific and commercial interest in the preservation of bread by freezing.

It has long been known that freezing arrests the increase in crumb firmness and the undesirable organoleptic changes associated with staling when bread is stored at ambient temperatures. The hardening of the crumb

Main graphic control panel of American Machine & Foundry's new Amflow process for continuous fermentation and mixing of bread dough



is, however, accelerated as the temperature is decreased from room temperature to the point at which the water begins to freeze; below the freezing point the rate of hardening slows down very markedly. Recent studies emphasize the importance of rapid freezing of strictly fresh bread, the maintenance of low uniform storage temperatures, and rapid defrosting. The freezing and defrosting of bread under conditions feasible commercially caused an increase in crumb firmness approximately equal to that for unfrozen bread at room temperature during the first 24 hours after baking. Storage at 0° F. or colder is required to prevent a significant increase in firmness during storage for longer than one week, although flavor changes could not be detected in bread stored 4 weeks at 10° F.

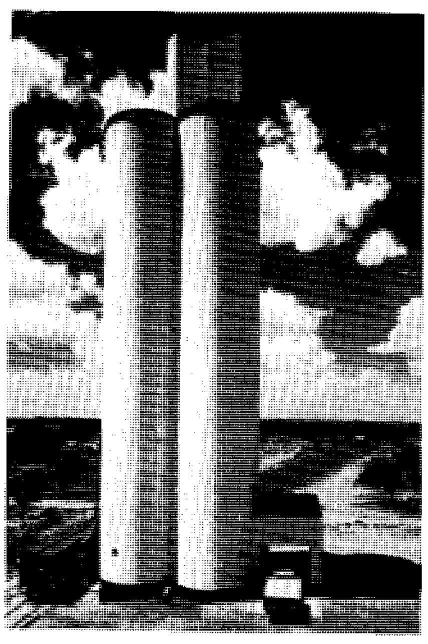
Bread Staling

During the past several years, much progress has been made toward understanding the changes that occur during the staling of bread. It is widely recognized that the development of undesirable flavor and odor is involved in addition to changes in the physical properties of the crumb, such as increases in crumb firmness and decreases in swelling capacity. Recent researches support earlier evidence that progressive crystallization of starch is primarily responsible for the development of a hard crumb. Thus far no method has been developed to stop the formation of starch crystals in bread, but the use of a heat stable bacterial amylase in breadmaking causes some degradation of starch in the crumb during storage, weakening the crystalline network and making it less rigid. (However, FDA Standards of Identity for flour and bread do not permit use of bacterial amylase preparations.)

Special Products from Wheat

Considerable quantities of wheat gluten have been commercially produced in the U. S. for several years. The usual commercial process is to mix wheat flour (usually clear grades, of high protein content) with water to produce a stiff dough, and allow it to stand for about an hour to permit hydration of the endosperm proteins with the formation of gluten. The dough is then transferred to a gluten washing machine in which it is kneaded under a constant spray of water to remove the starch and water-solubles. Where gluten is to be made with its dough-form characteristics intact (that is "vital" or "gum" gluten), it is dried to about 5% moisture under partial vacuum at low temperature. For certain food uses, stock feeds, and industrial purposes such as the preparation of glutamic acid and monosodium glutamate, it is unnecessary to avoid high temperatures, and the gluten may be dried on drum driers.

Recent emphasis on proteins in nutrition has led to increased interest in dried gluten, particularly vital gluten. A convenient source of concentrated protein (available at 80.0% protein, moisture-free basis), it is a hydration agent which imparts cohesive, adhesive, and dough forming and strengthening properties to food mixtures, simplifying certain engineering problems. These properties, coupled with the possibility of industrial utilization of some of our surplus wheat in the form of gluten, starch, and water-solubles, have stimulated research on more efficient and economical methods for preparing gluten. Canadian workers have reported that gluten may be readily extracted from wheat flour with 0.01 N acetic acid, and that the dispersion could be spray-dried to give a finely powdered product retaining much of its breadmaking quality. Some years ago, the Northern Utilization Research and Development Division found that starch could be more readily washed from a thin flour-water batter than from a stiff dough. Recent pilot plant studies have been directed toward improvement of the laboratory "batter process" and toward development of a simple method for drying wheat gluten to recover a vital product. The gluten separated by the batter process is dispersed in very dilute acetic acid and dried at atmospheric pressure on a conventional steam-heated dryer. The gluten is of high quality and suitable for food uses.



Bulgur

Bulgur, an important staple food made from wheat in the Near East for many centuries but relatively unknown in the United States (although two small plants in Fresno, California, have produced bulgur for many years, chiefly for local consumption by people of mideastern extraction), is now being produced in a modern plant in this country from white wheat. Essentially, bulgur is parboiled dried wheat with culinary uses similar to those of rice. It is being promoted as a possible outlet for wheat in both domestic and foreign markets, particularly in the rice eating areas. Its protein content and caloric value are similar to those of white milled rice, but it is much higher in thiamine, riboflavin, niacin, and iron.

Supplementation of Cereal Products

Cereal enrichment was inaugurated when it was established that widespread deficiencies existed in all age groups in thiamine, riboflavin, niacin, and iron intakes. A deficiency of calcium was found in certain population groups, while vitamin D deficiency was quite prevalent among infants and children. Standards of Identity for enriched flour providing for compulsory addition of thiamine, riboflavin, niacin, and iron, and optional enrichment with calcium and vitamin D, became effective in 1942.

Production of enriched bread which conformed to the Federal Security Agency's proposed definition was made mandatory a year later by the War Food Administration. This order was repealed in 1946 but production of enriched bread has spread widely since, although Federal Standards did not become effective until 1952. Thirty-four states have passed enrichment laws, and through private enterprise nearly all flour and bread is enriched even in states not having legislation. It is estimated that 80 to 90% of all white family flour and bread is enriched.

Federal Standards became effective for enriched macaroni products in October 1946 and for enriched corn meal and corn grits in August 1947. In Alabama, Georgia, Mississippi, North Carolina, and South Carolina degerminated corn meal and corn grits are staple foods, and their enrichment is compulsory. South Carolina took the lead in rice enrichment in the U. S. by enacting a law which took effect in July, 1956, prohibiting the sale of ordinary white rice. This law permits two types of enrichment. Non-rinse-resistant ingredients may be used for packaged rice which is clean and ready for use, provided it is labelled conspicuously "To retain vitamins do not rinse before or drain after cooking." Bulk rice must be enriched by means which will give rinse resistance to the enrichment ingredients; such rice must be conspicuously labelled "Do not drain after cooking." Federal Standards of Identity for enriched white rice became effective in February 1958.

Increased knowledge of the importance of protein in human nutrition, lysine deficiencies in the proteins of wheat flour and other refined cereal products, and commercial availability of L-lysine have led to great current interest in supplementation of cereals with this amino acid. About twice as much of the proteins of flour and bread would be required to supply the same amount of lysine as the protein of eggs (high quality protein). This fact has led to the concept that a two-fold increase in the lysine of flour by the addition of L-lysine would make flour and bread high quality protein sources. Animal feeding tests with young rats support this conclusion. However, the growing rat has a relatively much higher lysine requirement than the human, and caution must be exercised in translating animal feeding studies into terms of human nutrition.

Although there is no evidence of wide-spread protein deficiency in the U. S., there may sometimes occur in women during pregnancy and lactation, in infants, and in elderly people, deficiencies which could be alleviated by supplementation with lysine. But some scientists have serious doubts whether universal supplementation of bread and breakfast cereals would be of nutritional value. In a recent study, the American Institute of Baking found that the protein of wheat flour and bread had an essentially constant amino acid composition, despite variations in wheat source and in degrees of milling. The protein of bread made with 4% non-fat dry milk contained the essential amino acids in such relative proportions as nearly to meet the nutritional requirements of adults. Rat growth studies in the General Foods Research Center with lysine supplementation of wheat flakes fed with and without milk revealed a growth response when 0.5% DL-lysine was fed with the breakfast cereal; however when the diet included milk, no significant additional growth response was noted when lysine also was added. This finding is of particular significance since it is well known that the toasting of breakfast cereals may render much of the lysine of proteins unavailable. In the United States animal proteins comprise about two-thirds of the average protein intake; the supplementary effects of these high quality proteins largely compensate for deficiencies in the cereal sources in the diet.

Lysine supplementation's cost also must be considered. About 200,000,000 cwt. of white flour is consumed annually in the U. S. Addition of 0.2% lysine would require 40 million pounds of lysine and cost nearly $200 million at the present price of $4.95 per lb. The minimum addition of 0.25% lysine suggested by some advocates would cost about $250 million. The cost of lysine will doubtless continue to decrease with increased production. But enrichment of this amount of flour with thiamine, riboflavin, niacin, and iron at $0.04 per cwt. costs, by contrast, only $8 million. Since the diet should be considered as a whole, comprehensive feeding tests with humans on normal diets would be needed to determine whether the benefits of amino acid supplementation could justify such a costly enrichment program.

In a statement issued in 1957, the Food and Nutrition Board of the National Research Council pointed out that the imbalance in essential amino acids in some proteins cannot always be corrected by adding a single amino acid, and that multiple supplementation is generally required. At present, this is best achieved by mixed diets in which one food protein supplements another. The potential value of supplementation with amino acids is under intensive study by the Board's Committee on Amino Acids.

It is now established that vitamin B_6 is an essential nutrient. In the coenzyme form (pyridoxal-5-phosphate), it plays a part in amino acid metabolism; it is intimately connected with the metabolism of the essential fatty acids, and is involved in the development of teeth in growing children. In pregnancy, the demand for vitamin B_6 is increased. These and other observations and the fact that the vitamin B_6 content of wheat flour is much lower than that of wheat have led to suggestions that this vitamin might be added to cereals. The daily requirement is not established but is estimated to be from 1 to 3 mg. per day for the adult human.

Although present Standards of Identity for white flour and bread do not provide for the use of lysine (or vitamin B_6), the increased emphasis on proteins in nutrition has led to production of several "specialty" or "dietary" breads which are sold at premium prices. In some of these breads, the nutritional value of the protein has been improved by addition of such ingredients as lysine, defatted wheat germ, yeast, non-fat milk, dry milk, and lactalbumin. In others, the protein content of the bread is increased by two per cent or more through the use of high-protein spring wheat flour, special high-protein flour fractions, "vital" wheat gluten, soy flour, or the protein sources mentioned above.

The popularity of breakfast cereals and of infant foods is due not only to their convenience and palatability but also to the widespread application of the findings of nutrition research in their manufacture. The addition of B-vitamins and minerals containing calcium, phosphorus, and iron to improve the nutritional value of refined cereal products has long been common in the industry. In some infant foods supplementation has been extended to include lysine and vitamins B_6 and B_{12}. A recent trend has been the production of high-protein preparations; high-protein breakfast cereals contain 20 to 22% protein, and the high-protein infant cereals about 35%. These high protein levels are obtained in various ways, such as the use of high-protein fractions of wheat flour, and oat flour, defatted wheat germ, soy flour, non-fat dry milk, casein, and wheat gluten.

Starch in the Food Industry

The principal starch needs of the U. S. were supplied almost entirely by the wet milling of corn until 1948, when Corn Products completed a modern wet milling plant at Corpus Christi, Texas, for manufacturing starch from grain sorghums. Chemically and microscopically, normal sorghum (milo) starch is almost indistinguishable from corn starch. They have similar gelatinization characteristics, and can be used interchangeably in most food and industrial applications. However, milo starch is more bland in flavor and does not develop rancidity; hence it is somewhat more suitable for use in edible fillings.

Waxy milo starch has recently been introduced to the market in several modifications with uses similar to those of modified waxy corn starches. Both starches are now available in pre-gelatinized, spray dried form.

The starch industry has been very successful in "tailoring" starches for specific uses. In the food field new starches have recently been developed for use in canned, baked, and frozen foods, salad dressings, instant pudding mixes, and miscellaneous products.

Canners' starches include those employed in soups, cream-style corn, "Chinese-type" foods, prepared canned pie fillings, and bakers' starches. The new starches for soups have a more bland flavor, exhibit less viscosity decrease during processing of the soup, and form less opaque pastes than those hitherto available. Introduction of rotary cookers for cream-style corn has necessitated development of cross-linked normal and waxy corn starches; these can withstand the more drastic cooking conditions which caused older products to thin out. Improved starches have also been made for the more conventional canning methods. They maintain their thickening power without gel formation during storage, and retard the curdling of soluble corn proteins. High quality canned chop suey and other "Chinese-type" foods have been made possible by special cross-linked waxy starches with good paste clarity and viscosity stability. Prepared canned pie fillings have succeeded through development of modified waxy corn and waxy milo starches with superior thickening power and physical and chemical stability.

Pie bakers are using instant or pre-cooked modified waxy starches to speed up production and eliminate cooking. These starches, or stabilizers as they are often called in the industry, have the same clarity, stability, and gel properties as the "cook-up" types. Their reconstituted pastes do not thin out during heating. Another type for the baking industry is a corn starch mildly treated to give clearer pastes, softer gels, and less cereal flavor. Special starches have been developed for such frozen foods as meat pot pies and fruit pies. The former required special starches which would thicken the gravy and retain the desired viscosity and smoothness during processing and after thawing and heating. For this application, modified waxy corn and milo starches are used in conjunction with wheat flour; the latter imparts the flavor and appearance desired. For frozen fruit pies, pre-cooked modified waxy starches are employed, as cooking is not required and the prepared fillings need not be cooled.

Starches for salad dressings must give and retain the desired consistency, and keep the emulsion stable during transportation and over wide temperature ranges. The dressing must also be thixotropic so containers may be filled at maximum speed. The salad dressing manufacturer is no longer dependent on root starches, as the starch industry has produced tailor-made starches for this purpose. Corn starch, modified corn starch, and waxy corn starches comprise the major types.

For instant puddings, pre-cooked potato starches are currently used. The lower cost of potato starch in relation to waxy starches is the controlling factor. An instant pudding starch when mixed with sugars must rehydrate rapidly in cold milk or water and yield the desired consistency. Absence of cereal flavor is very important. Precooked, modified, and deflavored waxy starches have been used, and new modified and precooked starches are meeting with some reception.

Special starches have also been developed for use in cake frostings, doughnut mixes, baking mixes, and breakfast cereals.

High Amylose Corn Starch

Starch from ordinary corn contains approximately 27% amylose (the linear fraction) and 73% amylopectin (the branched fraction). Like other linear macromolecules, amylose will form strong flexible films and fibers, but the cost of fractionation of ordinary starches is too high for commercial exploitation. Although wrinkled-seeded peas have been reported to contain starch of 60 to 70% amylose, peas are a poor source of starch and industrial methods for isolating it have not been developed. On the other hand, corn is a high-yielding starch crop and commercial methods for corn starch production are well developed. Accordingly, about ten years ago, the USDA's Northern Utilization Research and Development Division sponsored a corn breeding program to develop strains with starch of high amylose content. Plant breeders have succeeded in developing hybrids containing over 70% amylose. Some strains with amylose percentages of 50 to 60% have satisfactory agronomic properties. Screening tests and further genetic studies may result in still better hybrids.

High amylose starch would be used for special purposes for which ordinary starch is unsuited, and it would thus provide a new outlet for corn. Amylose films might find extensive use in packaging foods as they are edible.

Rice and Rice Products

Extensive biochemical investigations on rice have been carried out for several years at USDA's Southern and Western Utilization Research and Development Divisions. The rice experiment stations of Arkansas, California, Louisiana, and Texas have active programs related to the production, harvesting, and storage of rice. The dreaded Hoja Blanca disease appeared in U. S. rice fields in 1957, and only one commercial variety, Colusa (a short-grain variety grown in California), is completely resistant to this disease. Major efforts are being made both to control the disease and to develop resistant strains, particularly long-grain types.

It is now recognized by the rice industry that processing quality, as well as milling characteristics and agronomic properties, must be considered in evaluating new selections in rice-breeding programs. To this end, a rice quality laboratory has been established at the Rice-Pasture Experiment Station in Beaumont, Tex. The USDA laboratories in New Orleans, La., and Albany, Calif., as well as Louisiana State University and the Institute of Human Nutrition (Washington), also are studying physical and chemical factors related to rice quality.

An extensive survey of rice investigations appears in the Annual Issue of *The Rice Journal* for 1957 and 1958. Studies have been carried out on the composition of rice, on quality preservation during storage, development of appropriate drying procedures and of new rice food products. General Foods Corp.'s extensive studies on methods for preparing a quick cooking white rice have led to the marketing of a convenience product.

The Future

Current trends toward continuous processing, and the development of new food products which are convenient to use and have high nutritive value, appetite appeal, and excellent keeping quality, will inevitably continue. Strong programs of basic research are needed to provide the fundamental knowledge to ensure a continuing flow of new and improved products. Increasing emphasis on detailed fundamental studies of the composition and properties of the proteins and starches of cereals, and of the changes which occur during fermentation and baking, may well lead to methods of producing bread and other processed food products of superior flavor and keeping quality. New knowledge obtained from basic studies provides the greatest potential for broadening the markets for cereals as human foods as well as for industrial purposes.

Acknowledgments

The author is deeply indebted to A. M. Altschul, J. S. Andrews, W. B. Bradley, N. Bruce, L. W. Elder, James W. Evans, W. L. Haley, C. G. Harrel, E. B. Kester, R. Larsen, J. W. Pence, F. N. Peters, W. F. Schroeder, F. R. Senti, I. Wolff, and S. A. Watson for material and advice in connection with this paper.

A detailed list of references is available from the Editor of AG AND FOOD.

Paper No. 4070 of the Miscellaneous Journal Series, Institute of Agriculture, University of Minnesota, St. Paul, Minnesota. Presented in abbreviated form in the Symposium on the Food Processing Industry, Division of Industrial and Engineering Chemistry, Fall Meeting, 1958, American Chemical Society.