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Breakfast Cereals

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I. INTRODUCTION

In this century, cereal grains have found significant uses as breakfast foods. Breakfast cereal technology has evolved from the simple procedure of milling grains for cereal products that require cooking to the manufacturing of highly sophisticated ready-to-eat products that are convenient and quickly prepared.

Some of the first cereal products to be sold were milled grains of wheat and oats that required further cooking in the home prior to consumption. Efforts have been made to reduce the amount of in-home preparation required for these products through methods of precooking or special additives. Also, the advent of the microwave oven has made home use of these cereals more convenient.

Published information on the various processes and formulations of products that can be classified as breakfast cereals is limited. The proprietary nature of the breakfast cereal industry limits the information base to patent records and publications by individuals not directly associated with the industry. This chapter summarizes to the largest extent possible state-of-the-art breakfast cereal technology, explores current processing techniques, formulations, and products, and provides a simplified guide to processing cereal grains into breakfast cereal food products.

II. CEREAL CATEGORIES

Breakfast cereal products can be categorized into types based on use or physical nature of the product. Breakfast cereals will be discussed according to the following categories and respective definitions.

1. Traditional cereals that require cooking—cereals which are sold in the market as processed raw grains. Wheat or oat cereals typically consumed hot would be examples of this type of cereal.
2. Instant traditional hot cereal—cereals which are sold in the market as cooked grains and requiring only boiled water for preparation. Wheat and oat cereals are again examples.
3. Ready-to-eat cereals—a group of cereals manufactured from grain products having been cooked and modified such that they may be subdivided into flaked, puffed, or shredded products.
4. Ready-to-eat cereal mixes—cereals combined with other grains, legumes, or oil seeds and dried fruit products. Granola cereal mixes best describe this type of breakfast cereal.
5. Miscellaneous cereal products—cereal products which cannot be included in any of the above types because of specialized process or end use. Cereal nuggets and baby foods are products which may be considered in this category.

Familiarity with the U.S. cereal industry and products available permits one to identify additional products falling into the above categories.

III. INGREDIENTS AND ADDITIVES

Most breakfast cereal products contain large amounts of cereal grains and have very few additives. Additives are mostly used to improve the texture of the cereal or to change functional characteristics of the final product. A list of additives and common uses in breakfast cereals is given in Table 1.

Since cereal products are often the only food consumed for the morning meal, they are supplemented with vitamins and minerals to improve the nutritional quality. Addition of these ingredients is based on a specific percentage of the daily required intake for adults. The reader is referred to applicable literature on the addition of vitamins and minerals to cereal products for specific information.

IV. CEREALS REQUIRING COOKING

Breakfast cereal products which require cooking are mostly made form wheat and oats. Corn has been used extensively in the southern United States as a cooked grit. Few hot breakfast cereals are made from rice or rice products.

A. Wheat-Based Products

Wheat-based cereal products are made from wheat middlings (farina) obtained from the milling process. They are mostly endosperm pieces which are free from bran and germ. Careful attention has been given to the particle size of these middlings with the most acceptable products having the following minimum particle size specifications.

Through U.S. #20—100%
Through U.S. #45—<10%
Through U.S. #100—<3%

"Quick cook" cereals are prepared by steaming grain particles at elevated temperatures and pressure followed by flaking. Generally, this method of processing reduces the prepara-

tion time of the cereal to about one-third the time of the traditional raw cereals. Particle size during steam cooking is critical to an acceptable product since the extent of gelatinization during processing and the mouthfeel are affected by particle size (1). The smaller the particle, the more surface area available for heat transfer and, thus, the better degree of cook attainable.

Hard wheats have been found acceptable for making farina-based cereals since the end product does not get pasty (1). One disadvantage to hard wheat is the longer process time required to achieve a good cook and to gelatinize the starch in the wheat (2). Generally, no other cereal or cereal fractions are used as ingredients in these formulations.

Disodium phosphate has been used as a suitable additive to reduce the in-home preparation time to cook wheat cereals (3). Disodium phosphate modifies the pH of the mixture and promotes hydrolysis of the starch during heating. Soaking farina in a solution made of sodium hydroxide and ammonium salt during processing has also been found effective in reducing the time required to cook wheat products (4).

Gums incorporated into farina cereals are said to reduce cook time (5). The gum creates a viscous liquid which surrounds the particles and increases the heat transferred during cooking and adds to the overall texture of the cooked cereal. Special thickeners such as carboxymethylcellulose have also been used for improving texture and cookability of cereals (6). The thickeners are especially effective for instant cereal products since their presence results in prepared cereal consistencies similar to those made using traditional methods.

Special hydration mediums which are mixtures of sodium chloride, sodium tripolyphosphate, sodium bicarbonate, sodium carbonate, tetrasodium EDTA, and water have been effective in reducing cooking time of whole cereal grain products (7). These hydration mediums are claimed to tenderize cereal tissues at lower temperatures and pressure than the traditional steam cook process and to reduce the amount of in-home preparation time in half. The medium is removed by washing at the end of the process followed by drying.

Proteolytic enzymes have been used to prepare an instant type farina product (1). Proteolytic enzyme treatment of farina permits water access to starch granules within the middlings particles, thus reducing the time for water absorption and gelatinization.

Fruit-flavored farina products are gaining consumer acceptance. Techniques have been identified to make acceptable fruit flavored farina products through the addition of thickeners, preservatives, and special processing techniques [8.9]. General process information for farina based cereal products is listed in Table 2.

B. Oat-Based Products

Breakfast cereals are easily made from oat cereal (1). They have acceptable flavors and good nutritional qualities. To make these cereals, oats are first cleaned to remove foreign materials, then roasted. Roasting serves to soften the endosperm of the cereal and make the hull brittle, which permits decortication and easy separation of the groats from the hulls. The groats are then crushed between two steel rolls to form flakes. The flaked oats are cooled, mixed with any additives, and packaged (Fig. 1). "Quick cook oats" are made in a fashion similar to the traditional method outlined above. A cutter machine is employed between the dehulling and rolling steps, which slices the groats into pieces measuring from one-third to one-half the thickness of the whole groat. This step enables more surface area to be exposed to water and heat during the in-home preparation, reducing the cooking time to approximately 5 minutes. Traditional in-home preparation of oats requires 10– 15 minutes (1).

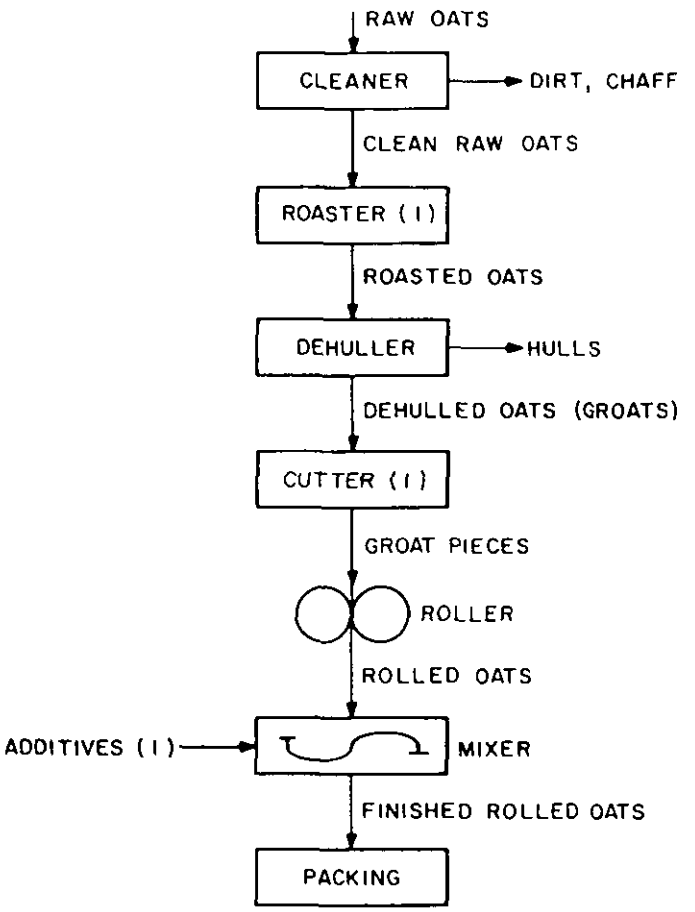


FIGURE 1 Process line to make oat cereals.

Oat-based hot cereals, are manufactured from a single cereal component. Dehulled oats or "oat groats" is the most acceptable raw material for manufacture of this product.

Additives to oat-based cereals are primarily used to improve the texture of the cereal when prepared. Pregelatinized starch (10), gums (11), and cereal hydrolysate (12) have been used effectively to improve the texture of oat cereals. The hydrolysate and gums both add consistency and thickness to the product, making it smooth and creamy in texture.

Proteinaceous fractions of oat groats have been used to prepare a quick-cooking oat cereal (13). These fractions when combined with processed oats at a level between 3.5 and 5.5% by weight results in a mixture that requires only the addition of boiling water to prepare.

A critical problem with oat cereals is the tendency toward thick consistency and excessive pastiness after extended heating. This is a problem for restaurants and institutional facilities where oatmeal is served from steam trays over several hours. Milk and cream addition (14) and monoglycerides (15) have been used effectively to reduce the sticky nature of the hydrated oat product. Specific process information for oat cereals is given in Table 3.

V. READY-TO-EAT (RTE) CEREAL PRODUCTS

The largest market for breakfast cereal products is for the ready-to-eat varieties. Consumer popularity of RTE cereal types is due to the minimal time required to prepare these products. RTE cereals are generally manufactured from cereal grains as flakes, shreds, or shaped materials.

A. RTE Cereal Grains—Flakes

Flaked cereal grains were the first form of ready-to-eat cereal products available to the consumer. Processes to make the flakes are simple and result in products that are well cooked and have acceptable flavor.

The traditional method (1.16–18) of manufacturing a flaked cereal product begins by cleaning the cereal grain, followed by decortication and milling to break the whole grain into pieces that are one-third to one-half the size of the original whole grain. These pieces are mixed with other ingredients as required and steamed for 2 hours or longer under pressure. The steamed mass is then broken into small segments and dried under carefully controlled conditions. The grit pieces are then either tempered for 24 hours (17) or directly flaked between steel rolls. The resulting flakes are then dried and toasted under high temperature to give a suitable flavor and color. A traditional process flow is shown in Figure 2.

Variations of this process have been used to improve and introduce new flaked cereal products (17–21). the primary difference between these processes and the traditional flaking process is the replacement of the steam-cooking step with extrusion processing. In additional to cooking the grains, extrusion allows formation of uniform pellets and thus flakes, which can be made from single or multicomponent formulations. A typical process flow to make a flaked product from the output of an extruder is also shown in Figure 2.

Flaked cereals are manufactured mostly from corn and wheat. A typical flaked cereal might have as a formulation approximately 90% cereal component plus 8% sugar, 1% salt, and 1% malt. Recently developed flaked breakfast cereals have included multiple cereal formulations and cereal formulations in combination with other grain seeds such as soybean.

Efforts have been made to use oats in flaked products (18.19). In one instance, a mixture of oat flour with other cereal grains was used to make a flaked cereal (19). Ranges for ingredients are as follows:

Oat flour: 60–70%
Rice flour: 7–12%
Soy flour: 5–10%
Sucrose: 5–15%
Lecithin: 0.5–.15%
Salt: 2–4%
Casein: 1.5–3.5%

Formulations for flaked cereals made directly from the output of an extruder have also been considered (22). In this case, oat type flakes were being manufactured from a formulation consisting of 57% oat flour, 33% water, and 10% sugar.

Flaked cereal products contain few additives since the process does not require specialized treatment of raw materials. Sugar and malt are frequently added to flaked cereal formulations in order to improve the flavor. The presence of sugar and malt in the formulation also promotes the Maillard reaction, which adds color and flavor to the flakes.

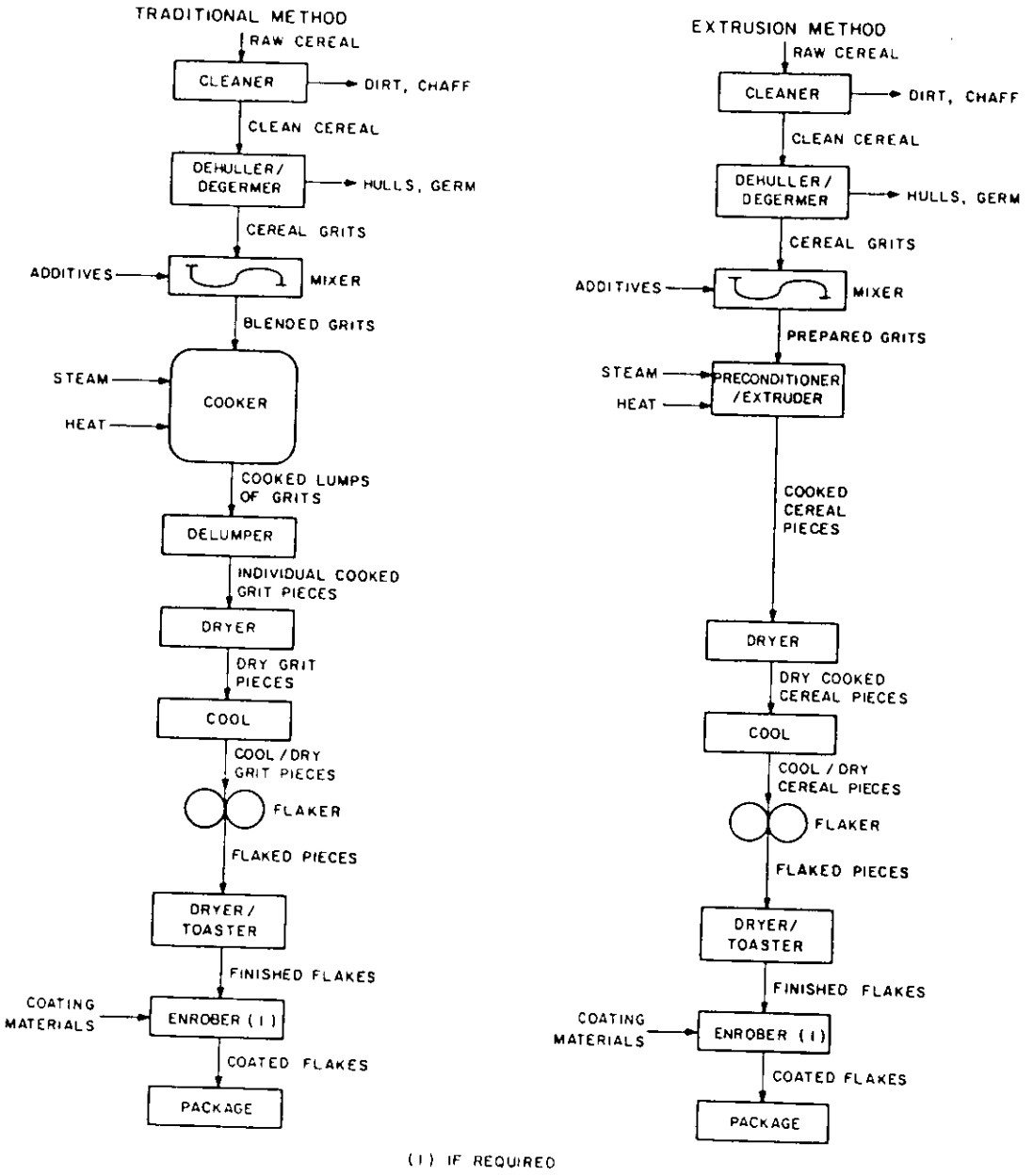
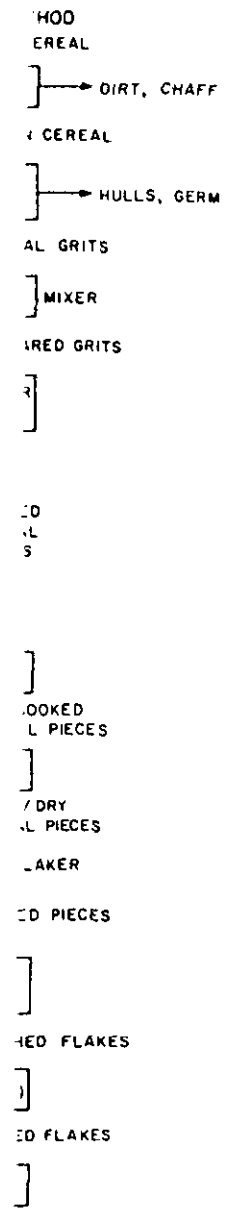


FIGURE 2 Process lines for cereal flake production.



An organic silicone-based additive which reduces the degree of liquid absorption when milk is added to a flaked cereal has been proposed (23). While results showed promise, use of this additive has been limited.

Papain has been used in formulations which incorporate soybean to enzymatically treat the bean and improve processing capability (24). sodium bicarbonate has been used to reduce unacceptable flavors in formulas containing soybean (25). Processing descriptions, additives, and ingredients found in flaked products are shown in Table 4.

B. RTE Cereal Grains—Puffed Products

Cereal grains are well suited to expansion type processes for the manufacture of breakfast cereals. The starch contained in these grains can be modified easily by forcing water into the starch molecules at high pressures and temperatures. Rapid release of this high pressure and water results in rupture of the starch granules forming a cellular structure piece which is uniformly delicate and brittle in texture. Puffed breakfast cereal products are popular because processes used permit shaping of the final product, making the product more appealing to the consumer.

Puffing of cereals was originally done using puffing guns (1,16). These devices were designed to heat and pressurize cereal products with steam, hold the cereal at these conditions over a specific period of time, and then release the steam pressure quickly from the chamber. The rapid release of pressure coupled with the flashing of the moisture results in an expanded or puffed product. Several variations to the traditional puffing apparatus have been proposed to improve (28) or change the traditional batch process puffing gun into a continuous process (26,27,29) and to improve operational conditions and controlling parameters for these processes (30).

Extrusion has also been found useful in making puffed or expanded cereal pieces. The extruder permits shaping of cereal grains, as well as cooking and mixing of cereal formulations. Extrusion has been used to process grains prior to puffing gun expansion and to make uniformly shaped spherical breakfast cereals (18,31). Direct expansion from the extruder has also been proposed to eliminate the puffing gun step (32–34). Dry raw materials are introduced into the extruder or, in some instances, into a preconditioner before extrusion. The raw cereal grains are allowed to pass through the extruder, which is normally operating at a high temperature and pressure. After passing the extruder screw, the mixed ingredients undergo a rapid pressure reduction upon exiting the die and expansion of the starch occurs. By carefully designing the die, shaped products with various textures may be achieved. The product is then dried and coatings are applied.

Improvements in extruders and extrusion techniques now enable new special products such as multiple cross-section products to be made. One product discussed (25) was made from two extruders combining flow into one outlet die. Using this design, one extruder might be used to process the cereal grain which would form the outer shell of the processed cereal piece. A second extruder would process materials which might fill the inner sections of the cereal piece with a soft filling or colored cereal product. These extrudates can be flaked or puffed to produce a product with varying colors or cross-sectional appearance and textures.

Another convenient way to manufacture puffed products is to follow cooking, which could be done in an extruder, with high-temperature drying in an oven or dryer. Extrusion, in this instance, is used to cook and gelatinize the cereal before puffing. Typically ovens are set for very high temperatures (274–288°C). Materials are held for very short times at this temperature to avoid excess heat, which can cause off-flavors. The high oven temperature drives off moisture, rapidly resulting in expansion or puffing of the individual pieces.

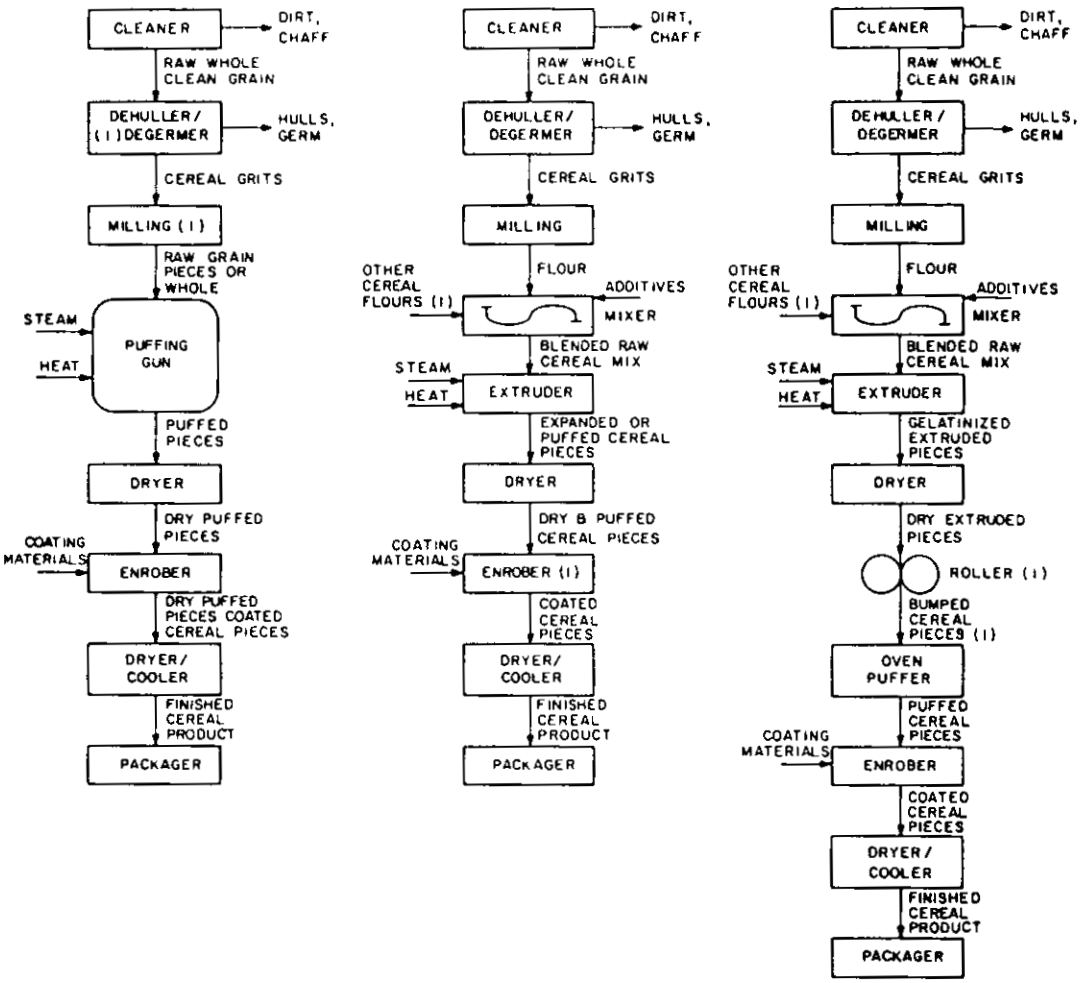
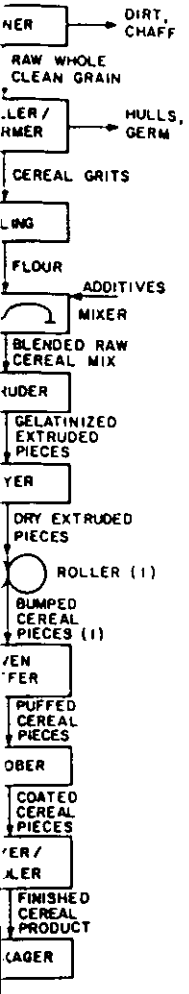


FIGURE 3 Process lines used to make puffed or expanded cereal pieces.

Fluidized bed driers (31) and microwaves (36) have been used to replace drier ovens with successful results. Processing schemes typically used for the manufacture of expanded breakfast cereals are shown in Figure 3.

Whole cereal grains which have been cleaned and sometimes decorticated are used as the raw materials for puffing guns. Such products as puffed wheat and rice are made in this fashion. A typical formulation when using extrusion processing will include one or two major cereal components such as corn and wheat. Additives, if necessary to achieve a special product characteristic, are mixed into the cereal components prior to cooking. For example, addition of special starch fractions to the cereal components have been used and shown to improve the expanded cereal piece by making it more delicate and uniform in texture and appearance (37). The addition of starch permits control of expansion and texture in these products and may be added at levels between 5 and 50%, depending on the type of starch used. Sugar adds flavor to cereal products but can also provide a certain degree of control on expansion (17).



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Sodium bicarbonate has been used in the puffing process in the presence of soybean to reduce the unacceptable bean flavor in the final product (25). Sodium bicarbonate has also been used as an ingredient with wheat and honey to make a honey-graham flavored cereal (38). Other additives, when required, are typically added during the coating process. Typical and published formulations and processes dealing with both extrusion and puffing gun technology are given in Table 5.

C. RTE Cereal Grains—Shredded

Shredded breakfast cereals are made from whole cereal grains and primarily wheat. New shredded products are being developed which use alternative cereals, such as rice or corn and some are now offered with soft center, fruit-flavored confections.

Typical processes have been described for making shredded products (1,16). Cereal grains are cleaned and boiled in water until tender. The moisture in these cooked grains is allowed to equilibrate in a tempering process for several hours before processing the grains into shreds with steel rollers. For this step, one roller is smooth and the other roller is corrugated to form the small strands. The strands exiting the rollers are cut into the bite-sized pillow-shaped products and dried or baked. The finished shaped products are then packaged or coated as required.

Extrusion is also being used to make shredded products (16). This process has been used more extensively for production of shreds from flinty corn and rice cereal is more versatile and permits incorporation of other cereal products, ingredients, and additives. Minor ingredients such as salt and sugar are included in some of these formulations. A few applications are shown in Table 5.

A large portion of the shredded cereal market is for bite-size, shredded biscuits. For this product, strands of the formed dough are passed between two rollers, one smooth and one with knives placed radially, which pinch and cut the strands into bite-size pieces (39).

D. Miscellaneous Cereal Products

A number of cereal products available in the market cannot be placed in any of the above categories because of their unique qualities. This section is devoted to these processes.

1. Granola

Granolas have become popular because they are an alternative to the processed cereal products discussed above. Granolas are typically a composite of several kinds of grains and additives, which are clustered together. A typical process for this type of product utilizes flaked products such as rolled oats, barley, or other cereal grains and combines these with other noncereal products, such as nuts, coconut, oil, water, and spices. These mixes are then dried, toasted, and broken into pieces for consumption (16).

2. Cereal Granules

Cereal granules are a cereal product made by a unique process (1). A stiff dough is made from cereal grain flours, such as wheat and barley, salt, dry yeast, and water. The dough is stored under controlled conditions for several hours, shaped into loaves, and then transferred to an oven to bake. The oven is set for 400°F, and the dough is baked for 2 hours. The baked loaves are cooled, then broken into pieces with shredding knives and returned to an oven set for 250°F for 2 more hours of baking. The pieces are removed from the oven and broken up into small granules.

3. Baby Food Cereals

Baby food cereals are typically fed not only for breakfast, but also for other meals as supplements to breast milk or to introduce infants to solids. The majority of baby foods sold are canned. However, there are some dry cereal products available that are used as RTE cereals. These are usually made from rice, barley, and sometimes wheat. The traditional method for making these cereal products is to cook the decorticated and degermed cereals in water followed by drum drying to form the flaked cereal products. Extrusion has been used in the manufacture of high protein cereal flakes for baby foods (40). Few additives and preservatives are used.

VI. COATINGS FOR BREAKFAST CEREALS

Breakfast cereals that have been processed into a flake or puffed product have very little flavor. The high temperatures used to process the cereals can distill flavors from the foods, making flavor addition or enhancement necessary for product acceptability. Sweet flavors are generally the most acceptable for breakfast cereals, and, therefore, the majority of coating materials have a sugar base. The largest problem with sugar coatings and their application is control of the quantity metered onto each cereal piece and the resulting appearance of the coating after application. Careful selection of the application process and additives helps overcome these problems.

Application of flavor coatings on cereals is difficult due to the hygroscopic nature of cereal products after they have been processed. Sugars required water as the solvent, which is absorbed rapidly by processed cereal products. The rapid absorption causes sticky pieces which are difficult to dry, and in some instances the coated cereals adhere to each other. To minimize this problem, the amount of water in the coating step is reduced or a coating technique is used.

An acceptable coating has been achieved by heating sugar with water to a hard candy condition and spraying it on cereal products under constant pressure to keep the cereal pieces fluidized (17, 41). The enrobed material is then heated to fuse the sugar to the cereal product.

An acceptable and novel method of providing sweetened cereals is through the use of a spun sugar coating. The sugar is spun into a blanket, processed cereal pieces are placed on top of the blanket, and then a second blanket is placed on top of the cereal pieces. The spun sugar is compressed around the cereal pieces and dried. The coating is said to dissolve in milk upon contact (42).

An alternative to coating is to provide the sweetener through sugar bodies. Sugar bodies are made by combining sugars with other ingredients, cooking these ingredients together to form a hard candy, cooling carefully, adding flavors and colors, followed by a process of kneading and vacuum expanding the material to shape the material into individual pieces (43).

Most cereal coatings use sucrose as the main ingredient. Variations in formulation can be achieved by changing the mix of sugar types and other additives to achieve a certain hardness or appearance to the coating. Variations and acceptable ranges for sugar components have been outlined (44) and are as follows:

Sucrose: 10–70%
Glucose: 1–30%
Invert sugar: 5–25%
Water: 15–40%

Application of sucrose and sugar syrups generally results in cereal pieces that stick together and a coating that crystallizes into an opaque appearance. To overcome these problems, nonsucrose sugar materials such as glucose or invert sugar are incorporated (44,45). Honey is one form of nonsucrose sugar which is used extensively since the flavor characteristic is acceptable and a transparent coating can be achieved.

Additives to coating formulations are generally limited to flavor enhancement and to improving the adhesion of the coating to the cereal. Acetic acid in combination with sodium acetate has been added to cereal coatings (44) and, the proper proportions, provides some flavor enhancement. To reduce problems with using water as a solvent, emulsifiers have been added to create emulsions of oil, water, and sugar (46). This reduces the amount of water that will penetrate the cereal piece and reduces the amount of drying that is required.

Thickening agents are sometimes employed to change the consistency of coatings. For the sugar body method of sweetening, several thickeners such a methylcellulose, gum alginate, dextrin, pregelatinized starch, and other hydrophilic colloids are considered acceptable (43). Another method of coating cereals has been devised and involves the addition of an encapsulating colloid material with a solvent, which is used as a carrier for the sweetener (47). The solvent is evaporated, and, in the process, the colloid and sweetener merge with one another to coat the cereal, giving a frosted appearance.

While sugar materials are considered to have limited nutrition, they are suitable as energy sources for breakfast cereal foods. There are also concerns about the effects on dental caries. The addition of monosodium dihydrogen phosphate at levels between 0.5 and 1.5% proved effective in reducing the occurrence of caries through consumer testing of the product (48).

VII. CONCLUSION

Breakfast cereal processors continue to develop new formulations and processes to improve and increase the selection of consumer products. A substantial number of the new products being introduced are tailored to compete with health foods. By-products of the milling industry continue to find application in RTE type breakfast cereals. Bran products such as wheat and oat bran are found in cereal products and are gaining popularity because of medical evidence supporting a connection between intake and reduction of cholesterol levels in the blood.

Processing is becoming more flexible due to the application of twin-screw extruders. These machines can be set up to perform multiple operations and provide a consistent and specific history to the material being processed. With the ability to modify and control the shear environment in these extruders, it should be possible in the future to use a wider range of specialized cereals, grains, additives, and sweeteners to result in a number of new and unusual products.

TABLE 1 Additives Commonly Used in Breakfast Cereals

Additive	Common usage in cereals
1. Annatto	Add butter or peach color to cereal products
2. Barley malt flour	Typically added to raw materials
	Source for α– and β– amylase (49)
	Enhances starch hydrolysis (50)
	Flavor enhancer
3. Butylated hydroxyanisole	Prevention of oxidative rancidity of oils (49)
	Added to food directly and/or to packaging materials.
	Sum of two methods no more than 50 ppm
4. Butylated hydroxytoluene	Prevention of oxidative rancidity of oils (49)
	Added to food directly and/or to packaging materials. Sum of two methods no more than 50 ppm
5. Brown sugar	Flavor enhancer added at raw material stage or a part of coating for cereal
	Effective in control of gelatinization of starch (49)
	Control of puff and cook (49)
6. Calcium carbonate	Mineral supplement (51)
	Dough conditioner (51)
	Dough–firming agent (51)
	Viscosity modification (17)
	pH modification (acidic) (17)
7. Calcium caseinate	Mineral supplement (52)
8. Carrageenan	Emulsifier (51)
	Thickener or gelling agent (51)
	Stabilizer (51)
	Used in cereal coatings
9. Carboxymethyl cellulose	Used for binding and thickening cereal–coating formulations
	Emulsifier (51)
10. Cereal malt syrup	Used as sweetener and flavor additive for raw materials and sugar coatings (49)
	Inhibits crystallization of sucrose during coating
	Imparts sheen to product surface (49)
	Color (Maillard reaction)
11. Corn syrup	Used as sweetener and flavor additive for raw materials and sugar coatings (49)
	Inhibits crystallization of sucrose during coating
	Imparts sheen to product surface (49)
	Color (Maillard reaction)

TABLE 1 (Continued)

Additive	Common usage in cereals
12. Dextrose	Sweet flavor enhancer (49) Color (Maillard reaction)
13. Dicalcium phosphate	Acidification of dough (52) Dough modifier (52,53)
14. Disodium phosphate	Promotes acid hydrolysis of starch in cereals (52)
15. Ferric phosphate	Iron supplement (52) Cooking aid for hot cereals at levels of 0.2–2.0% (52)
16. Fructose	Flavor enhancer added at raw material stage or a part of coating for cereal Effective in control of gelatinization of starch (49) Control of puff (49)
17. Gelatin	Thickener for sugar coatings Dough modifier (17,54)
18. Glycerine	Crystalline modifier—prevents improper crystalline formation in cereal coatings (49)
19. Guar gum	Adhesive used for coatings and glazes on cereal products
20. Gum arabic	Adhesive for icings, glazes, and sugar coatings (49,54)
21. Invert sugar	Used to control and modify crystalline structure (49) Used in sugar coatings Cereal flavor enhancer
22. Lecithin	Emulsifier (17)
23. Malic acid	Additive to cereal products to impart acidic flavors Used in Fruit–flavored products
24. Modified corn starch	Control of density of puffed cereal products (17,55,56) Alter strength characteristics of puffed cereal products (17,55,56) Used as additive to improve shelf life of cereals (17,55,56) Humectant (17,55,56) Flavor enhancer (17,55,56) Binder for oils and fats in cereal products (17,55,56)

TABLE 1 (Continued)

Additive	Common usage in cereals
25. Molasses	Flavor enhancer added at raw material stage or a part of coating for cereal
	Effective in control of gelatinization of starch (49)
	Control of puff and cook (49)
26. Maltodextrins	Carrier for water-insoluble flavors (49)
	Thickener and body improver in cereal flours (50)
	Reduce volatilization of flavor from mixes of cereals (49)
27. Monosodium dihydrogen phosphate	Additive to cereal coatings to prevent dental caries (48)
28. Oils or fats	Control of dough strength and viscosity during processing (17)
	Control of puffed cereal textures (17)
	Improvement or modification of mouth feel and product functional characteristics
	Food energy additive
29. Papain	Proteolytic enzyme used primarily in cereal foods containing soybean products
	Improves or alters cooking characteristic of cereals (1)
30. Salt	Flavor improvement
	Buffer
31. Sodium alginate	Gelling or thickening agent for fruit filled cereals
32. Sodium bicarbonate	pH modifier in doughs (51)
	Flavor modifier cereal products containing soybean (25)
33. Sodium phosphate (monobasic)	pH modifier in doughs (52)
	Control and enhancement of starch hydrolysis
	Antioxidant (52)
	Flour modifier (52)
34. Sodium phosphate (dibasic)	Buffer (51)
	Mineral supplement (51)
35. Sorbitol	Used as a sweetener in cereal flour products at acceptable levels of 1–3% (49)
	Crystalline modifier and control additive for sugar coatings (49)
	Humectant (49)

TABLE 1 (Continued)

Additive	Common usage in cereals
36. Sugar (sucrose)	Flavor enhancer added at raw material stage or a part of coating for cereal Effective in control of gelatinization of starch (49) Control on degrees of puff and cook (49)
37. Tricalcium phosphate	Anticaking agent (49,51) Buffer (49,51) Mineral supplement (49,51)
38. Water	Control of expansion in puffed cereal products Control of degree of cook in expanded cereal products Solvent for sugar and other cereal coatings
39. Wheat starch	Control of product texture in cereal food products (49) Control of protein levels in cereal flours through dilution Control of cellular structure of puffed cereals (17,55,56) Control of puffed cereal texture during extrusion and puffing (17,55,56) Adjustment of rate of hydration in water (17,55,56) Retention of oil in cereal flour mixtures (17,55,56)
40. Yeast	Flavor modification and enhancement Dough modifier Leavening agent (49)
41. FD&C colors (yellow, red)	Color modification to cereals Added before extrusion at 300 ppm (17) Soluble in water and glycerine

TABLE 2 Processing Information for Farina Type Hot Cereals

Cereals used	Process description	Process objective	Additives	Additive level	Additive function	U.S. Patent granted
Wheat (middlings)	Milling	Uniform grit for cooking	Gum	0.5–2.5%	Thickener to suspend particles and to improve cooking capability	No. 2,890,115
Wheat (middlings)	Steam/drum dry	Instant wheat cereal	Sodium carboxy–methylcellulose	0.1–10%	Viscosity modifier for drum drying	No. 3,526,513
Wheat (middlings)	Steam/drum dry	Fruit–Flavored instant wheat cereal	Sodium carboxy–methylcellulose	0.1–10%	Viscosity modifier for drum drying	No. 3,526,514
			Fruit preserves	4.5–40%	Flavor enhancer	
Wheat (whole)	Tempering in salts and acid with drying	Quick cook whole kernel wheat product	Sodium hydroxide	5–15%	pH modifier	No. 3,190,754
			Ammonium hydroxide	0.5–3%	pH modifier	
			Citric acid	1%	pH modifier to promote hydrolysis of starch	
Wheat	Tempering in pH modified solution followed by drying	Quick cook wheat cereal	Salts of sodium and ammonia	1–3%	pH modifier and protein dissociating solubi–lizing agent	No. 3,526,511 No. 3,190,754
Wheat (middlings)	Temper at 16% MC, 220°F, flake, and dry	Instant wheat cereal without additives	None	—	—	No. 3,620,761

dry additives

TABLE 3 Processing Information for Oat Type Hot Cereals

Cereals used	Process description	Process objective	Additives	Additive level	Additive function	U.S. Patent granted
Oats	Thin flaking and dry heat	Quick cook oat cereal	None	—	—	No. 3,490,915
Oats	Flaking followed by addition of milk, cream or cream substitute followed by drying	Quick cook nonsticky oat cereal	Milk	20–25%	Flavor, reduce stickiness	No. 3,494,769
			Sugar	3–4%	Flavor,	
			Cream	3–4%	Flavor, texture modifier	
Oats	Mixing in additives to quick cook oat flakes	Quick cook oat cereal	Polysaccharide Gum	0.1–1.0%	Encapsulate oat flakes with rapidly hydrating gum material to form gelatinous films on flakes	No. 2,999,018
Oats	Oat flakes are tempered, steam cooked, reflaked, dried, and blended with hydrolysate	Instant cook oat cereal	Cereal hydrolysate	2.25–2.5%	Add texture to the hydrated cereal mixture	No. 3,640,729
Oats	Oat fractions added to oat flakes tempered /steamed/cooked/reflake dried and blended with hydrolysate	High protein instant oat cereal	Oat fraction	4.25–5.0%	Improved nutrition without cooking	No. 3,640,728
Oats	Pregelatinized starch added to oat flakes, then tempered, steam cooked, reflaked, dried	Instant oat cereal	Pregelatinized starch material	2–5%	Improved texture and cookability during preparation	No. 3,704,134 No. 3,520,695
Oats	Quick cook oat flakes cooked and mixed with monoglycerides	Cooked oat cereal	Monoglyceride	0.3–3.0%	Reduce pastiness upon prolonged heating	No. 3,113,868

TABLE 4 Processing Information for Cereal Flakes

Cereals used	Process description	Process objective	Additives	Additive level	Additive function	U.S. Patent granted
Oats, Rice	Steam cooking extrusion/flake/ dry, and toast	Crisp light nutritious flake	Soy flour Sucrose Lecithin Salt	5–10% 5–15% 0.5–0.15% 2–4%	Protein source Expansion control Emulsifier Flavor	No. 3,318,705
Oats, Rice	Pelleting grains/ steam cook/dry/ flake/toast	Crisp light nutritious flake	Milk casein Soy flour Sucrose Lecithin Salt	1.5–10% 5–10% 5–15% 0.05–0.15% 2–4%	Supplement Protein source Expansion control Emulsifier Flavor	No. 3,121,637
Oats	Cook/extrude/ flake/dry/toast	Oat flakes	Milk casein None	1.5–10% —	Supplement —	
Oats, rice	Cook/extrude/ dry/flake/toast	Crisp flaked cereal	Soy flour Sucrose Lecithin Salt Sugar	5–10% 5–15% 0.5–0.15% 2–4% 8%	Protein source Expansion control Emulsifier Flavor Flavor, expansion control	No. 3,345,183 No. 2,998,317 No. 3,062,657
All cereals	Cook/extrude/ cool/flake/toast	flaked cereal				
Oats, wheat	Cook/extrude/ dry/toast	Flaked cereal by die design	Salt Malt Sugar	1% 1% 10%	Flavor Flavor Flavor, expansion control	No. 3,732,109
All cereals	Enzyme presoak for soy blend with cereal/extruded flake	Soy fortified flake product	Soy isolate Proteolytic enzyme	As required 445 ppm of soy isolate	Protein supplement Remove bitter flavor	No. 3,664,848
All cereals Rye	All Puff gun/grind extrude/flake/toast	Soy, fortified flakes Better flake	Sodium bicarbonate None	0.2–2% —	Improve functionality Suppress soy flavor —	No. 3,814,824 No. 3,556,802

	eal/extruded flake		Proteolytic enzyme	445 ppm of	Remove bitter flavor	
All cereals	All	Soy, fortified flakes	Sodium bicarbonate	soy isolate 0.2–2%	Improve functionality	No. 3,814,824
Rye	Puff gun/grind extrude/flake/toast	Better flake	None	—	Suppress soy flavor —	No. 3,556,802

TABLE 5 Processing Information on Puffed and Expanded Cereals

Cereals used	Process description	Process objective	Additives	Additive level	Additive function	U.S. Patent granted
Rice, wheat, corn	Puffing gun	To expand cereal grains into formed precooked product	Pregelatinized starch	5–50%	Expansion or puffing aid	No. 2,954,295 No. 2,954,296
Rice	Puffing gun	To expand cereal grains into formed precooked product	None	—	—	No. 3,128,690
Mixtures of cereals	Puffing gun	To expand cereal grains into formed precooked product	Vegetable oil	1.5–5%	Reduce sticking of puffed units to each other and to equipment	No. 3,246,690
			Sucrose	5%	Expansion control flavor	
			Salt	2%	Flavor	
			Coloring	0.03%	Food enhancement	
Corn wheat	Co–extrusion/dry/puffing gun	To combine two dissimilar products into a distinctive product	None	—	—	No. 3,499,766
All types of cereals	Extrusion cooking	One–step process expansion and cooking equipment	None	—	—	No. 3,117,006 No. 3,458,322 No. 3,458,321 No. 3,482,992 No. 3,054,677

TABLE 5 (Continued)

Cereals used	Process description	Process objective	Additives	Additive level	Additive function	U.S. Patent granted
Corn, wheat, oats	Extrusion cooking/ drying/enrobing	Puffed peanut butter–flavored RTE cereal	Sugar	10%	Flavor, puff control	No. 3,723,131
			Peanut butter	13.5%	Flavor	
			Oil	1.5%	Carrier base for flavor	
Wheat flour	Preprocessing/ extrusion	Honey graham flavored cereal	Sugar	20%	Flavor	No. 3,554,763
			Molasses	4%	Flavor	
			Honey	4%	Flavor, crystalline control	
			Salt	0.8%	Flavor	
			Sodium bicarbonate	0.4%	Buffer, pH adjustment	
Oats	Separation of oats into fractions for removal of β-glucans	Highly expanded cereal product	None	—	—	No. 4,620,981
Wheat or corn or rice	Extrusion/drying/ puffing either hot air or oil fry	Puffing by double processing	Oil	2–6%	Puff control	No. 3,703,379
Any cereal	Extrusion/case harden/bump/dry air expansion	Precise control of puff	None	—	—	No. 3,453,155

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