9.9.2 Cereal Breakfast Food

9.9.2.1 General[1]

Breakfast cereal products were originally sold as milled grains of wheat and oats that required further cooking in the home prior to consumption. In this century, due to efforts to reduce the amount of in-home preparation time, 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.

9.9.2.2 Process Description[1-3]

Breakfast cereals can be categorized into traditional (hot) cereals that require further cooking or heating before consumption and ready-to-eat (cold) cereals that can be consumed from the box or with the addition of milk. The process descriptions in this section were adapted primarily from reference 3 and represent generic processing steps. Actual processes may vary considerably between plants, even those manufacturing the same type of cereal.

Traditional Cereals –

Traditional cereals are those requiring cooking or heating prior to consumption and are made from oats, farina (wheat), rice, and corn. Almost all (99 percent) of the traditional cereal market are products produced from oats (over 81 percent) and farina (approximately 18 percent). Cereals made from rice, corn (excluding corn grits), and wheat (other than farina) make up less than 1 percent of traditional cereals.

Oat cereals. The three types of oat cereals are old-fashioned oatmeal, quick oatmeal, and instant oatmeal. Old-fashioned oatmeal is made of rolled oat groats (dehulled oat kernels) and is prepared by adding water and boiling for up to 30 minutes. Quick oat cereal consists of thinner flakes made by rolling cut groats and is prepared by cooking for 1 to 15 minutes. Instant oatmeal is similar to quick oats but with additional treatments, such as the incorporation of gum to improve hydration; hot water is added but no other cooking is required. The major steps in the production of traditional oat cereal include grain receiving, cleaning, drying, hulling, groat processing, steaming, and flaking. Figure 9.9.2-1 is a generic process flow diagram for traditional oat cereal production.

Oats arrive at the mill via bulk railcar or truck and are sampled to ensure suitable quality for milling. Once the grain is deemed acceptable, it is passed over a receiving separator to remove coarse and fine material and binned according to milling criteria. Raw grain handling and processing is discussed in AP-42 Section 9.9.1, Grain Elevators and Processes.

Cleaning removes foreign material, such as dust, stems, and weed seeds, and oats that are unsuitable for milling. The cleaning process utilizes several devices to take advantage of particular physical properties of the grain. For example, screens utilize the overall size of the grain, aspirators and gravity tables utilize grain density, and discs with indent pockets and/or indent cylinders utilize the grain length or shape. After completing the cleaning process, the grain is called clean milling oats or green oats.

In the hulling process, most facilities use the impact huller, which separates the hull from the groat by impact, rather than traditional stone hulling. The groat is the portion of the oat that remains

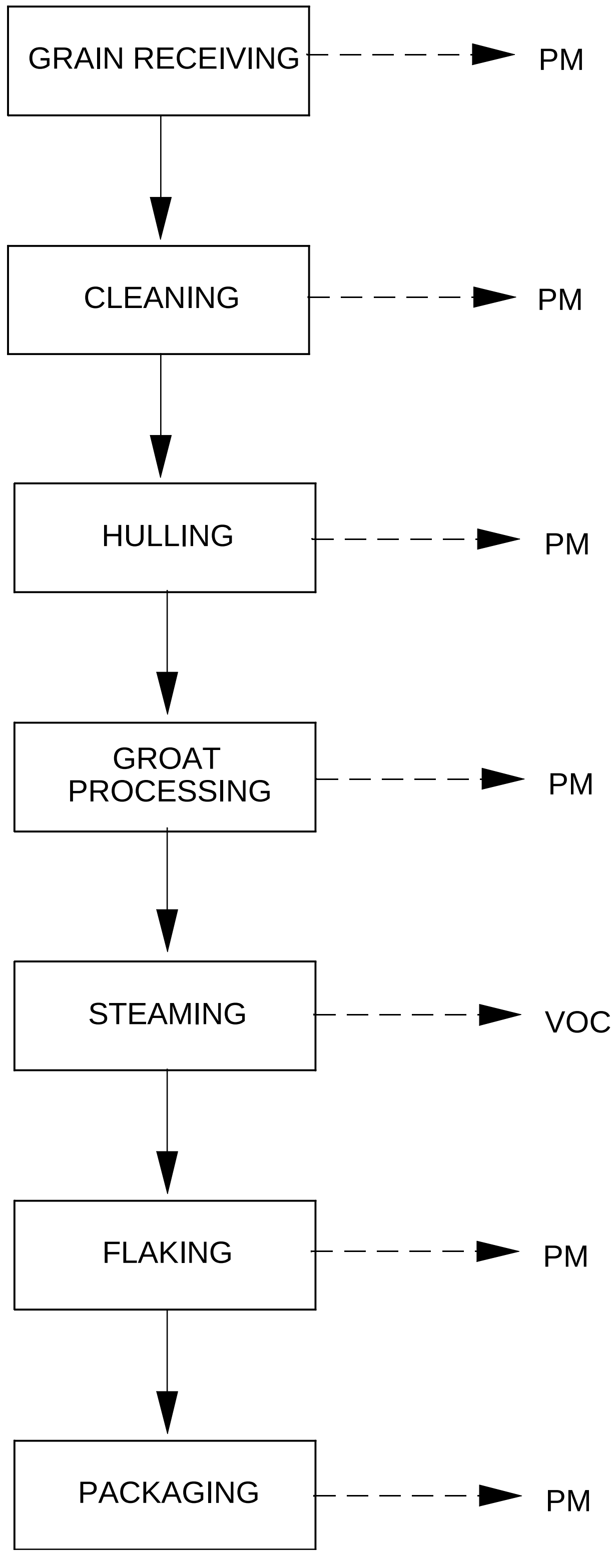


Figure 9.9.2-1. Traditional oat cereal production.

after the hull has been removed and is the part processed for human consumption. In impact hulling, the oats are fed through a rotating disc and flung out to strike the wall of the cylindrical housing tangentially, which separates the hull from the groat. The mixed material then falls to the bottom of the huller and is subjected to aspiration to separate the hulls from the groats. Impact hulling does not require predrying of the oats, although some facilities still use the traditional dry-pan process to impart a more nutty and less raw or green flavor to the final product. In the traditional dry-pan process, the green oats are dried in a stack of circular pans heated indirectly by steam to a surface temperature of 93° to 100°C (200° to 212°F). However, most facilities utilize enclosed vertical or horizontal grain conditioners or kilns to dry the groat after it has been separated from the hull because of the inefficiency of drying hulls. The grain conditioners have both direct (sparging) steam and indirect steam to heat the oats and impart flavor to the groats comparable to that resulting from the pan drying process.

After the groats are hulled, they are sized to separate the largest groats from the average-sized groats. The large groats are used to make the so-called old-fashioned oats and the other groats are cut using steel cutters to make quick oats. After groat processing, the groats (either whole or cut pieces, depending on the end product) typically pass through an atmospheric steamer located above the rollers. The groats must remain in contact with the live steam long enough to achieve a moisture content increase from 8 to 10 percent up to 10 to 12 percent, which is sufficient to provide satisfactory flakes when the whole or steel-cut groats are rolled.

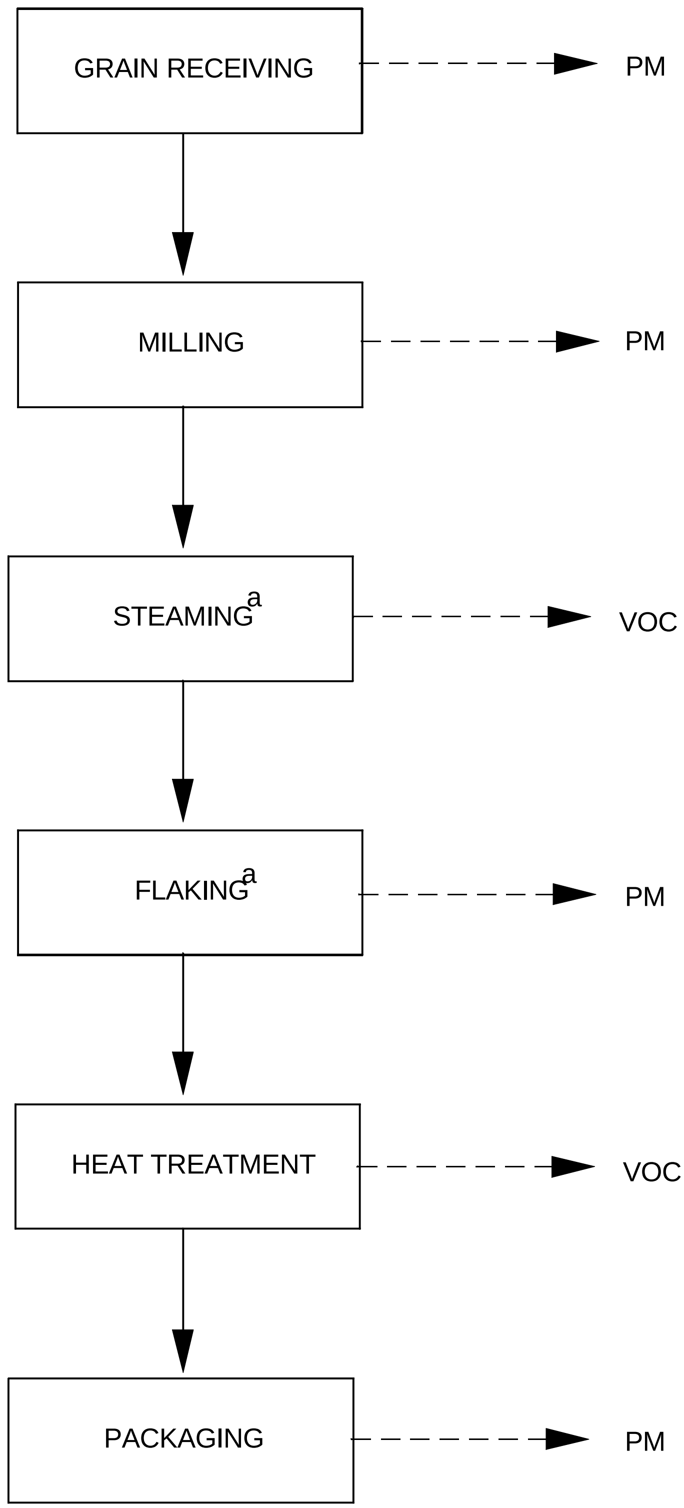
The production of old-fashioned oat and quick oat flakes is the same, except for the starting material (old-fashioned oats start with whole groats and quick oats start with steel-cut groats). Both products are rolled between two cast iron equal-speed rolls in rigid end frames. Quick-oat products are rolled thinner than old-fashioned oats. Following rolling, the flakes are typically cooled and directed to packaging bins for holding.

Instant oatmeal is processed similarly to quick oatmeal through the steaming stage. After the groats are steamed, they are rolled thinner than those of quick oatmeal. The final product, along with specific amounts of hydrocolloid gum, salt, and other additives, is packaged into premeasured individual servings. The most important difference between instant oatmeal and other oatmeal products is the addition of hydrocolloid gum, which replaces the natural oat gums that would be leached from the flakes during traditional cooking, thus accelerating hydration of the flakes.

The standard package for old-fashioned and quick oatmeal is the spirally wound two-ply fiber tube with a paper label. Folded cartons are also used to package old-fashioned and quick oatmeal. Most of the instant hot cereals are packed in individual, single-serving pouches.

Farina cereals. Cereals made from farina are the second largest segment of the traditional hot cereal market, making up 18 percent. Farina is essentially wheat endosperm in granular form that is free from bran and germ. The preferred wheat for producing farina is hard red or winter wheat because the granules of endosperm for these types of wheat stay intact when hot cereals are prepared at home. As shown in Figure 9.9.2-2, farina cereal production begins with the receiving and milling of wheat. Information on wheat receiving, handling, and milling can be found in AP-42 Section 9.9.1, Grain Elevators and Processes. After milling, traditional farina cereals are packaged. Quick cook farina cereals are prepared primarily by the addition of disodium phosphate, with or without the further addition of a protcolytic enzyme. An instant (cook-in-the-bowl) product may be made by wetting and pressure-cooking the farina, then flaking and redrying prior to portion packaging.

Wheat, rice, and corn cereals. Other traditional cereals include whole wheat cereals, rice products, and corn products. These cereals make up less than 1 percent of the traditional cereal



[a]Not required for traditional or quick-cooking farina cereals.

Figure 9.9.2-2. Typical instant cook farina cereal production.

market. Whole wheat traditional cereals include milled, rolled, and cracked wheat products. Milled cereals are made in a hard wheat flour mill by drawing off medium-grind milled streams. Rice products have yet to find acceptance as a hot cereal, although rice can be ground into particles about the size of farina and cooked into a hot cereal resembling farina. Corn products include corn grits, cornmeal, corn flour, and corn bran. Corn grits are served primarily as a vegetable accompaniment to the main breakfast item and are not usually classified as a breakfast cereal although they can be consumed as such. Cornmeal, corn flour, and corn bran are used primarily as ingredients in the preparation of other foods and are not classified as breakfast cereals.

Ready-To-Eat Cereals –

In the United States, the word "cereal" is typically synonymous with a processed product that is suitable for human consumption with or without further cooking at home and is usually eaten at breakfast. Ready-to-eat cereals are typically grouped by cereal form rather than the type of grain used. These groups are flaked cereals, extruded flaked cereals, gun-puffed whole grains, extruded gun-puffed cereals, oven-puffed cereals, shredded whole grains, extruded shredded cereals, and granola cereals.

Flaked cereals. Flaked cereals are made directly from whole grain kernels or parts of kernels of corn, wheat, or rice and are processed in such a way as to obtain particles, called flaking grits, that form one flake each. The production of flaked cereals involves preprocessing, mixing, cooking, delumping, drying, cooling and tempering, flaking, toasting, and packaging. A general process flow diagram for cereal flake production is presented in Figure 9.9.2-3. Grain preparation, including receiving, handling, cleaning, and hulling, for flaked cereal production is similar to that discussed under traditional cereal production and in AP-42 Section 9.9.1, Grain Elevators and Processes. Before the grains can be cooked and made into flakes, they must undergo certain preprocessing steps. For corn, this entails dry milling regular field corn to remove the germ and the bran from the kernel, leaving chunks of endosperm. Wheat is preprocessed by steaming the kernels lightly and running them through a pair of rolls to break open the kernels. Care is taken not to produce flour or fine material. Rice does not require any special preprocessing steps for the production of rice flakes other than those steps involved in milling rough rice to form the polished head rice that is the normal starting material.

The corn, wheat, or rice grits are mixed with a flavor solution that includes sugar, malt, salt, and water. Weighed amounts of raw grits and flavor solution are then charged into rotating batch cookers. After the grits are evenly coated with the flavor syrup, steam is released into the rotating cooker to begin the cooking process. The cooking is complete when each kernel or kernel part has been changed from a hard, chalky white to a soft, translucent, golden brown. When the cooking is complete, rotation stops, the steam is turned off, and vents located on the cooker are opened to reduce the pressure inside the cooker to ambient conditions and to cool its contents. The exhaust from these vents may be connected to a vacuum system for more rapid cooling. After pressure is relieved, the cooker is uncapped and the rotation restarted. The cooked grits are then dumped onto moving conveyor belts located under the cooker discharge. The conveyors then pass through delumping equipment to break and size the loosely held-together grits into mostly single grit particles. Large volumes of air are typically drawn through the delumping equipment to help cool the product. It may be necessary to perform delumping and cooling in different steps to get proper separation of the grits so that they are the optimum size for drying; in this case, cooling is typically performed first to stop the cooking action and to eliminate stickiness from the grit surface. After cooking and delumping, the grits are metered in a uniform flow to the dryer. Drying is typically performed at temperatures below 121°C (250°F) and under controlled humidity, which prevents case hardening of the grit and greatly decreases the time needed for drying to the desired moisture level. After drying, the grits are cooled to ambient temperature, usually in an unheated section of the dryer. After they are cooled, the grits are tempered by holding them in large accumulating bins to allow the moisture

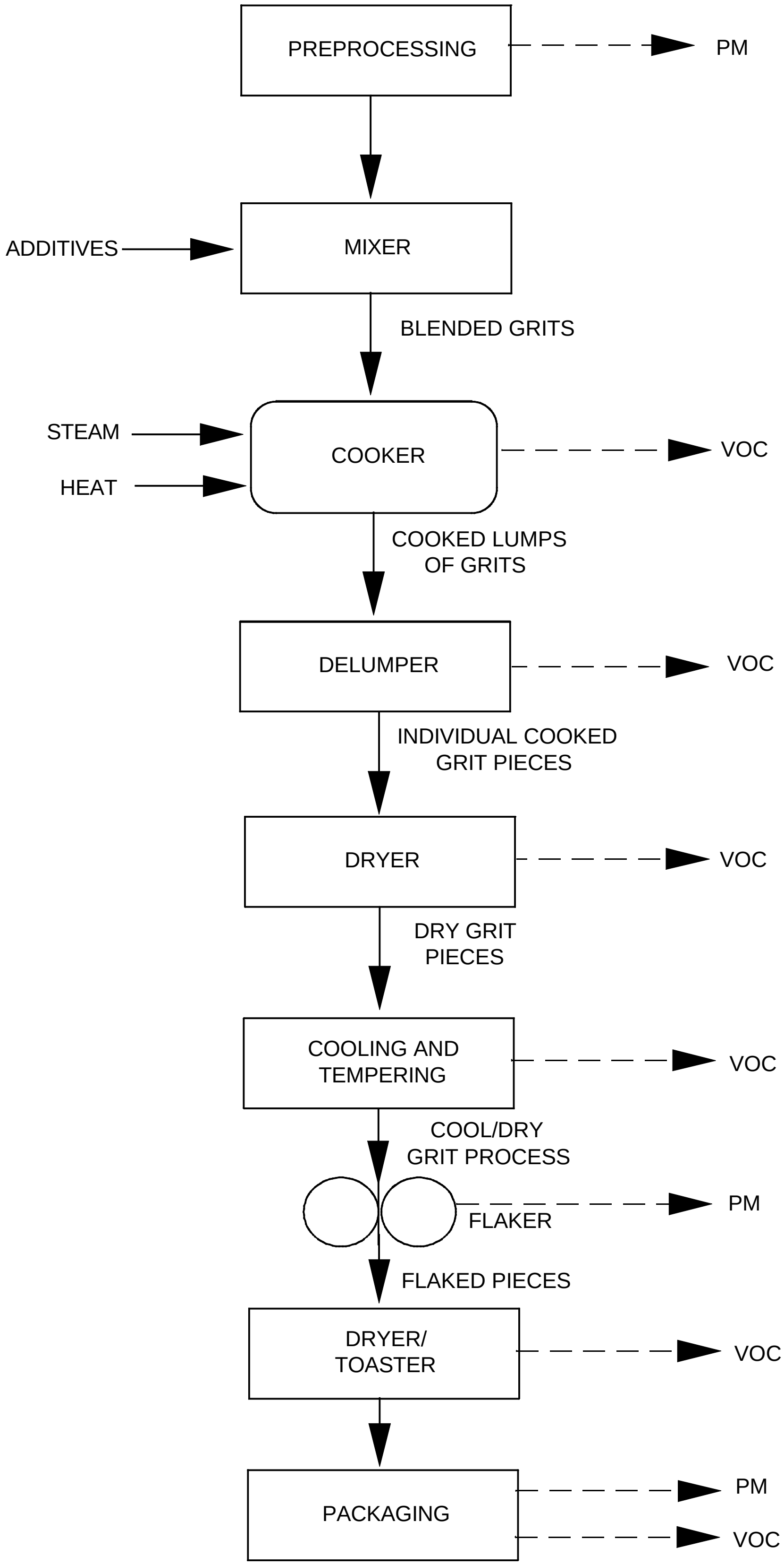


Figure 9.9.2-3. Process diagram for cereal flake production.[1]

content to equilibrate between the grit particles as well as from the center of the individual particles to the surface. After tempering, the grits pass between pairs of very large metal rolls that press them into very thin flakes. Flakes are toasted by suspending them in a hot air stream, rather than by laying them onto a flat baking surface. The ovens, sloped from feed end to discharge end, are perforated on the inside to allow air flow. These perforations are as large as possible for good air flow but small enough so that flakes cannot catch in them. The toasted flakes are then cooled and sent to packaging.

Extruded flake cereals. Extruded flakes differ from traditional flakes in that the grit for flaking is formed by extruding mixed ingredients through a die and cutting pellets of the dough into the desired size. The steps in extruded flake production are preprocessing, mixing, extruding, drying, cooling and tempering, flaking, toasting, and packaging. Figure 9.9.2-4 presents a generic process flow diagram for the production of extruded flake cereals. The primary difference between extruded flake production and traditional flake production is that extruded flakes replace the cooking and delumping steps used in traditional flake production with an extruding step. The extruder is a long, barrel-like apparatus that performs several operations along its length. The first part of the barrel kneads or crushes the grain and mixes the ingredients together. The flavor solution may be added directly to the barrel of the extruder by means of a metering pump. Heat input to the barrel of the extruder near the feed point is kept low to allow the ingredients to mix properly before any cooking or gelatinization starts. Heat is applied to the center section of the extruder barrel to cook the ingredients. The die is located at the end of the last section, which is generally cooler than the rest of the barrel. The dough remains in a compact form as it extrudes through the die and a rotating knife slices it into properly-sized pellets. The remaining steps for extruded flakes (drying, cooling, flaking, toasting, and packaging) are the same as for traditional flake production.

Gun-puffed whole grain cereals. Gun-puffed whole grains are formed by cooking the grains and then subjecting them to a sudden large pressure drop. As steam under pressure in the interior of the grain seeks to equilibrate with the surrounding lower-pressure atmosphere, it forces the grains to expand quickly or "puff." Rice and wheat are the only types of grain used in gun-puffed whole grain production, which involves pretreatment, puffing, screening, drying, and cooling. A general process flow diagram is shown in Figure 9.9.2-5. Wheat requires pretreating to prevent the bran from loosening from the grain in a ragged, haphazard manner, in which some of the bran adheres to the kernels and other parts to be blown partially off the kernels. One form of pretreatment is to add 4 percent, by weight, of a saturated brine solution (26 percent salt) to the wheat. Another form of pretreatment, called pearling, removes part of the bran altogether before puffing. The only pretreatment required for rice is normal milling to produce head rice. Puffing can be performed with manual single-shot guns, automatic single-shot, automatic multiple-shot guns, or continuous guns. In manual single-shot guns, grain is loaded into the opening of the gun and the lid is closed and sealed. As the gun begins to rotate, gas burners heat the sides of the gun body causing the moisture in the grain to convert to steam. When the lid is opened, the sudden change in pressure causes the grain to puff. Automatic single-shot guns operate on the same principle, except that steam is injected directly into the gun body. Multiple-shot guns have several barrels mounted on a slowly rotating wheel so that each barrel passes the load and fire positions at the correct time. The load, steam, and fire process for any one barrel is identical to that of the single-shot gun. After the grain is puffed, it is screened and dried before it is packaged. The final product is very porous and absorbs moisture rapidly and easily so it must be packaged in materials that possess good moisture barrier qualities.

Extruded gun-puffed cereals. Extruded gun-puffed cereals use a meal or flour as the starting ingredient instead of whole grains. The dough cooks in the extruders and is then formed into the desired shape when extruded through a die. The extrusion process for gun-puffed cereals is similar to that for extruded flake production. After the dough is extruded, it is dried and tempered. It then undergoes the same puffing and final processing steps as described for whole grain gun-puffed cereals.

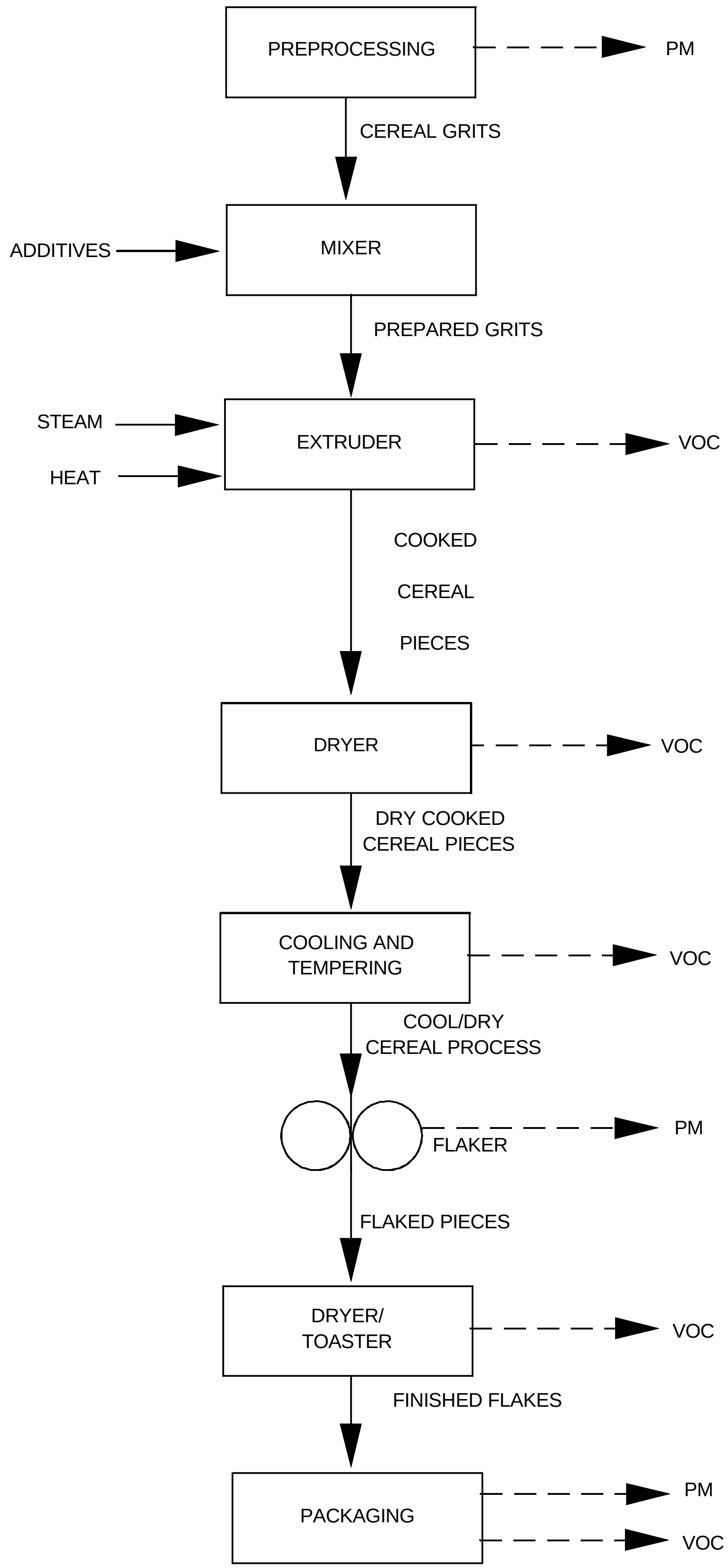


Figure 9.9.2-4. Process diagram for extruded flake production.[1]

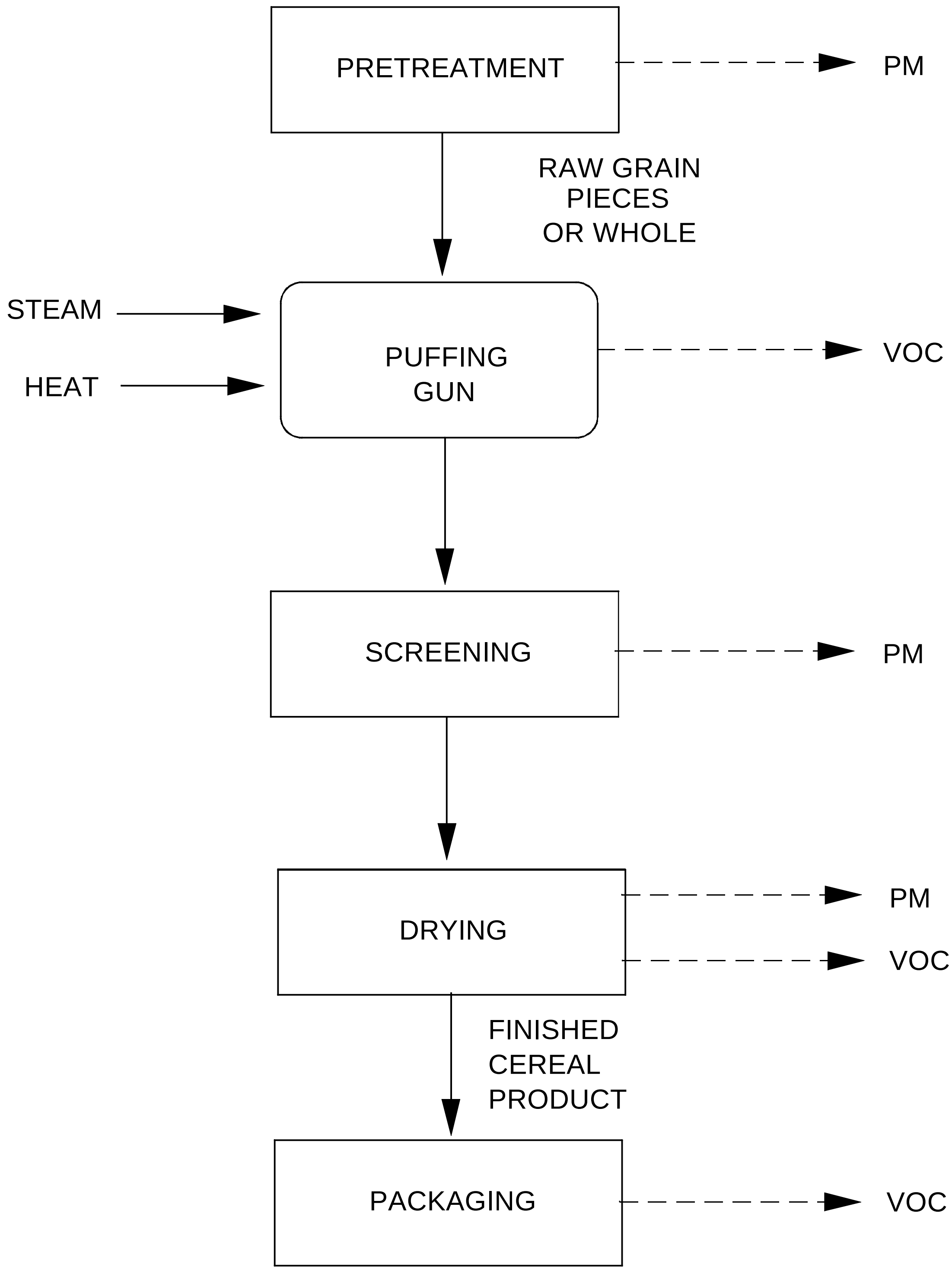


Figure 9.9.2-5. Gun-puffed whole grain production.[1]

Oven-puffed cereals. Oven-puffed cereals are made almost exclusively using whole-grain rice or corn, or mixtures of these two grains, because rice and corn inherently puff in the presence of high heat and the proper moisture content. The grains are mixed with sugar, salt, water, and malt and then pressure-cooked. After cooking, the grain is conveyed through a cooling and sizing operation. After cooling and sizing, the kernels are dried and tempered. The kernels are then passed through flaking rolls to flatten them slightly. The kernels are dried again and then oven-puffed, which requires a proper balance between kernel moisture content and oven temperature. After puffing, the cereal is cooled, fortified with vitamins (if necessary), and frequently treated with antioxidants to preserve freshness. The final product is then packaged.

Whole-grain shredded cereals. Wheat (white wheat) is primarily used to produce shredded whole grains. The steps involved in producing whole-grain shredded cereal are grain cleaning, cooking, cooling and tempering, shredding, biscuit formation, biscuit baking, and packaging. A generic process flow diagram for shredded cereal production is presented in Figure 9.9.2-6. Cooking is typically performed in batches with excess water at temperatures slightly below the boiling point at atmospheric pressure. Cooking vessels usually have horizontal baskets big enough to hold 50 bushels of raw wheat. Steam is injected directly into the water to heat the grain. After the cooking cycle is completed, the water is drained from the vessel and the cooked wheat is dumped and conveyed to cooling units, which surface-dry the wheat and reduce the temperature to ambient levels, thus stopping the cooking process. After the grain is cooled, it is placed in large holding bins and allowed to temper. The shredding process squeezes the wheat kernels between one roll with a smooth surface and another roll with a grooved surface. A comb is positioned against the grooved roll and the comb teeth pick the wheat shred from the groove. There are many variations in the grooved roll. After the shreds are produced, they fall in layers onto a conveyer moving under the rolls. After the web of many layers of shreds reaches the end of the shredder, it is fed through a cutting device to form the individual biscuits. The edges of the cutting device are dull, rather than sharp, so that the cutting action compresses the edges of the biscuit together to form a crimped joint, which holds the shreds together in biscuit form. After the individual biscuits are formed, they are baked in a band or continuous conveyor-belt oven. After the biscuits are baked and dried, they are ready for packaging.

Extruded shredded cereals. Extruded shredded cereals are made in much the same way as whole-grain shredded cereals except that extruded shredded cereals use a meal or flour as a raw material instead of whole grains. Raw grains include wheat, corn, rice, and oats, and, because the grains are used in flour form, they can be used alone or in mixtures. The steps involved in extruded shredded cereal production are grain preprocessing (including grain receiving, handling, and milling), mixing, extruding, cooling and tempering, shredding, biscuit formation, baking, drying, and packaging. The preprocessing, mixing, extruding, and cooling and tempering steps are the same as those discussed for other types of cereal. Shredding, biscuit formation, baking, drying, and packaging are the same as for whole-grain shredded cereal. Extruded shredded cereals are typically made into small, bite-size biscuits, instead of the larger biscuits of whole-grain shredded wheat.

Granola cereals. Granola cereals are ready-to-eat cereals that are prepared by taking regular, old-fashioned whole-rolled oats or quick-cooking oats and mixing them with other ingredients, such as nut pieces, coconut, brown sugar, honey, malt extract, dried milk, dried fruits, water, cinnamon, nutmeg, and vegetable oil. This mixture is then spread in a uniform layer onto the band of a continuous dryer or oven. The toasted layer is then broken into chunks.

Packaging –

The package materials for ready-to-eat breakfast cereals include printed paperboard cartons, protective liners, and the necessary adhesives. The cartons are printed and produced by carton suppliers and are delivered, unfolded and stacked on pallets, to the breakfast cereal manufacturers.

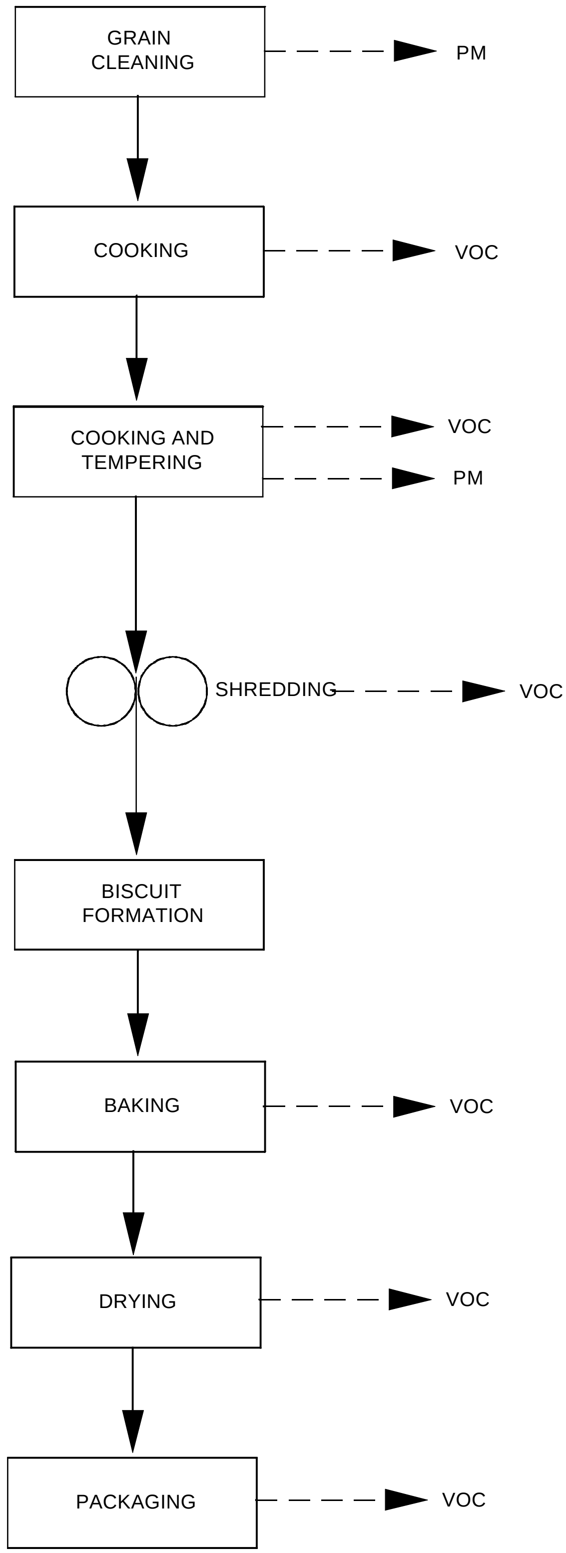


Figure 9.9.2-6. Whole grain shredded cereal production.

The liners, also supplied by outside sources, must be durable and impermeable to moisture or moisture vapor. However, cereals that are not hygroscopic and/or retain satisfactory texture in moisture equilibrium with ambient atmosphere do not require moisture-proof liners. The most common type of liners used today are made of high-density polyethylene (HDPE) film. The adhesives used in cereal packaging are water-based emulsions and hot melts. The cereal industry is the second largest user of adhesives for consumer products. Several variations of packaging lines may be used in the ready-to-eat breakfast cereal industry, including lines that fill the liners either before or after they have been inserted into the carton and lines that utilize more manual labor and less automated equipment.

9.9.2.3 Emissions And Controls

Air emissions may arise from a variety of sources in breakfast cereal manufacturing. Particulate matter (PM) emissions result mainly from solids handling and mixing. For breakfast cereal manufacturing, PM emissions occur during the milling and processing of grain, as the raw ingredients are dumped, weighed, and mixed, as the grains are hulled, and possibly during screening, drying, and packaging. Emission sources associated with grain milling and processing include grain receiving, precleaning and handling, cleaning house separators, milling, and bulk loading. Applicable emission factors for these processes are presented in AP-42 Section 9.9.1, Grain Elevators and Processes. There are no data on PM emissions from mixing of ingredients or packaging for breakfast cereal production.

Volatile organic compound (VOC) emissions may potentially occur at almost any stage in the production of breakfast cereal, but most usually are associated with thermal processing steps, such as drying, steaming, heat treatment, cooking, toasting, extruding, and puffing. Adhesives used during packaging of the final product may also be a source of VOC emissions. No information is available, however, on any VOC emissions resulting from these processes of breakfast cereal manufacturing.

Control technology to control PM emissions from breakfast cereal manufacturing is similar to that discussed in AP-42 Section 9.9.1, Grain Elevators and Processes. Because of the operational similarities, emission control methods are similar in most grain milling and processing plants. Cyclones or fabric filters are often used to control emissions from grain handling operations (e. g., unloading, legs, cleaners, etc.) and also from other processing operations. Fabric filters are used extensively in flour mills. However, certain operations within milling operations are not amenable to the use of these devices and alternatives are needed. Wet scrubbers, for example, are applied where the effluent gas stream has a high moisture content. No information exists for VOC emission control technology for breakfast cereal manufacturing.

References For Section 9.9.2

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