Chapter 10

Application of Rheology in the Breakfast Cereal Industry

Jimbay Loh and Wesley Mannell

Ready-to-eat (RTE) cold breakfast cereal accounts for 75% of the total breakfast cereal consumption in the United States, nearing a value of $4.8 billion in 1986. These cereals are made mainly from corn, wheat, rice, and oats. A raw material blend is first plasticized with a combination of moisture and heat to gelatinize the native starch, and the gelatinized mass is then shaped and sized into the desired configuration. The product may be expanded and dried to develop structure and a crispy texture. Various processes such as flaking, puffing, extruding, shredding, toasting, frying, and coating are used to achieve specific product characteristics. Finally, the product may be fortified with vitamins and minerals. Based on differences in processing techniques, at least six basic types of RTE cereal are on the market: flaked, gun-puffed, oven-puffed, extruded, shredded, and granola-type products (Fast, 1987).

In comparison to the baking and other cereal industries, the use of rheological methods in the RTE cereal industry is extremely limited. In addition, little information is contained in the literature. Few manufacturers of RTE cereal routinely utilize rheological tests for evaluating or specifying raw material quality. The methods used are generally shared by other cereal industries and are not specifically designed for RTE cereal. These methods include use of the farinograph, mixograph, amylograph, falling number, and others. Rheometers capable of quantifying fundamental rheological properties may also be in use, although the importance of rheology in RTE cereal manufacturing has not been demonstrated by cereal scientists. The rheology of the material in process is commonly recognized as an important factor governing many processing steps, such as flaking, extruding, and shredding. Little or no work has been published on the rheological properties of specific materials in process, probably because of the great diversity of materials, processes, and products. In contrast, it is widely believed that the importance of the rheology of finished products is crucial to consumer acceptance and the success of the product. With the increasing use of fruit in RTE cereal, the texture of

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fruit pieces and fillings and its changes during storage are becoming of great interest to the industry. This subject will not be covered, however, to avoid drawing attention away from the main subject, cereal.

Because of the lack of industrial application of rheological methods to the characterization of raw and in-process materials and the overwhelming importance for the texture of finished RTE cereals, the following discussion emphasizes rheological methods used for finished RTE cereals. The discussion also includes a brief description of the manufacturing processes for selected RTE cereals and a microstructure model for RTE cereal.

**RTE CEREAL PRODUCTION**

Flaked cereals are traditionally made by using a batch process, from whole grains (e.g., wheat), chunks of grains (e.g., corn) or flour of single or multiple grains. To facilitate effective penetration of moisture, sugar, and flavors, whole grains are first bumped. Bumping is accomplished by mild steaming followed by gentle flattening of the kernel between rolls, just enough to break the bran coat and create fissures into the endosperm. The bumped grains are usually cooked in a pressurized steam cooker to an optimum moisture content and machinability, with or without added flavor materials such as sugar, salt, and malt. Cooked particles are then separated, sized, and dried slowly to a moisture content of 10–13% under controlled humidity. For floury material, a cooking extruder is necessary to cook and shape the grits in one continuous operation. After adequate tempering to allow moisture equilibration, the grits are flaked between rolls and sometimes are only bumped, depending on the desired thickness of the finished product. Toasting in an oven develops the structure, texture, color, and flavor of the finished product. Toasting also serves for final drying to lower the moisture content to 2–8%, which is essential to stabilize the porous structure and maintain shelf life.

Gun-puffed RTE cereals are made from whole grains of rice or wheat by heating the grains in a high-pressure vessel. Moisture and heat cause the starch to gelatinize. Upon rapid release of the pressure after cooking, rubbery starch masses of individual kernels expand, as steam flashes out, resulting in simultaneous expansion, dehydration, and cooling of the kernels. If flour is used as the originating material, a cooking extruder is used to mix, knead, and cook the dough, and then to shape and form the pellets. The extruded pellets are tempered and gun-puffed. Certain RTE cereals can be puffed by sudden release of pressure at the extruder die.

In making shredded RTE cereal, whole grain is first cooked in boiling water. Completely cooked grain is cooled and tempered to a certain uniform moisture distribution. Shredding is done by compacting soft/cooked grain between a smooth and a grooved roll. The packed mass in the groove is removed by a comb that is matched to the grooved roll, and the resulting shreds are laid down on a moving conveyor belt. Several layers of shreds are laid to form a