Technological Challenges of *Whole Grains*

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Whole grains have long been an important part of the human diet. The question is can whole-grain products meet the nutritional and sensory demands of consumers in the twenty-first century? Further, what challenges do these ancient foods present for modern food technologists?

This article highlights some of the chemical and functional issues surrounding the production of whole-grain food products. Product quality, processing concerns, nutritional effects, and economic considerations all play key roles.

Whole grains gained new stature in 1999 when General Mills successfully petitioned the U.S. Food and Drug Administration (FDA) (13) to authorize a health claim: "Diets rich in whole grain food and other plant foods and low in total fat, saturated fat and cholesterol, may help reduce the risk of heart disease and certain cancers." Foods that bear this health claim for whole grains must contain 51% or more whole-grain ingredient(s) by weight per reference amount customarily consumed (RACC) as specified by the FDA. A RACC could be a slice of bread, a cup of breakfast cereal, or another realistic serving size. Attempting to incorporate at least 51% whole-grain ingredients in a formulation has led to creative product development.

The petition specified that the total dietary fiber (TDF) content of whole wheat (11 g of fiber per 100 g of wheat) should be used as a reference to assess compliance, despite the fact that some whole grains have lower TDF levels than wheat. The FDA used the following formula to specify the qualifying amount of TDF required for a food to carry the claim:

$$11\ \text{g} \times 51\% \times \text{RACC}/100$$

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Effects of Grain Milling and Processing

Dietary fiber content is not the only, or even the most important, characteristic of whole grains. The bran and hulls are sources of fiber, as well as phytochemicals and color. The germ provides lipids, nutrients, and phytochemicals, as wells as some pigments, generally carotenoids or anthocyanins. The endosperm primarily contributes protein and starch. Whole grains, however, are more than the sum of their parts.

Adding bran to refined flour, for instance, may produce results that differ from those for whole-wheat flour, because the milling process may remove components that have functional and health benefits. Compounds lost in milling include tocopherols, tocotrienols, alkylresorcinols, phytic acid, phenolic acids, minerals, and vitamins. Endogenous natural antioxidants also may be removed or destroyed during milling. Decker and coworkers (1) reported that the antioxidant activities of whole-grain breads and cereals were 30–60% higher than for their milled counterparts.

Processing may also make lipids in whole grains more susceptible to oxidation. When antioxidants in grains are damaged during processing, lipids may lack protection. Whole grains contain more lipids than do refined products.

The aleurone layer contains many enzymes, including peroxidases, polyphenoloxidases, and amylases. Damage to the aleurone layer during milling can result in off-flavor development, darker color, and starch breakdown. In addition, polyphenoloxidases convert colorless phenolic compounds to dark polymers that can impart a gray color to foods.

Color is often deliberately removed from whole grains to improve consumer acceptability. Numerous patents detail how the color of whole-grain products can be lightened. A recent patent describes a process for bleaching whole-wheat kernels with a peroxide solution prior to milling (12). Hydrogen peroxide is an oxidizing agent and, thus, does have the potential to react with, and presumably inactivate, natural antioxidants in grain. This type of process raises questions, however. Does bleaching decrease phytochemicals significantly? Are whole-grain health benefits compromised? These questions have not yet been answered.

Product-Specific Issues

Traditional whole-grain applications include unleavened breads, porridges and soups, and popped kernels. To attract consumers, traditional products must be reformulated to meet demands for fast preparation times, convenience, and taste. For example, modern consumers desire quick-cooking grains, such as instant oatmeal. To successfully develop whole-grain products, food technologists need to explore new opportunities. Traditionally, popped corn has been one of the most popular whole-grain products consumed in the United States. To build on this popularity, popped products from other, underutilized whole grains could be developed. In addition to new product development, food technologists also need to find ways to incorporate more whole grains in existing applications.

Breads. Wheat bran and germ components alter gluten development during mixing and proofing. Breads made with whole-grain flours often exhibit reduced loaf volume, increased crumb density, reduced crumb softness, and increased crumb and crust darkness. The effects of whole-grain flours on shelf life are not clear. Whole-wheat flour absorbs more liquid than does refined bread flour. The larger particles found in whole-wheat flour absorb water more slowly, and incomplete hydration prior to baking can cause problems with grittiness in the final product. Bakers have several options when trying to optimize whole-grain bread quality. They can add more liquid or alter the process to allow for full hydration. Mixing and fermentation times also can be adjusted. High kneading intensity should be avoided to prevent dry, grayish bread (5).

If whole oats are used as a partial replacement for wheat flour, less shortening may be needed because oats contain higher lipid levels. Additional gluten and dough conditioners may also improve crumb structure. Soy flour and compressed yeast can improve processing of whole-wheat bread, and several surfactants can be used to improve loaf volume (8). Mettler and Siebel (11) used response surface methodology to evaluate additives that could improve crumb structure in whole-wheat bread. Based on their findings, the optimal formulation for whole-wheat bread is 0.3-parts monodiglyceride, 0.6-parts diacetyl tartaric ester of monoglycerides (DATEM), 0.15-parts guar gum, and 0.6-parts carboxymethylcellulose. Haros and coworkers (6) found that the addition of fungal phytase (250 µL/100 g of flour) reduced proofing time for whole-wheat bread by 25%, while bread volume and crumb texture were improved by the enzyme.

Cookies and Bars. Gluten development is less important in chemically leavened cookies. Whole-wheat flour, however, limits cookie spread (3), so bar cookies are better suited to whole-grain adaptation than are drop or molded cookies. Starch damage and flour particle size also affect baking properties. Options for dealing with the increased grittiness of whole-grain cookies after baking at high temperatures include adding more water or adding a prehydration step before mixing the whole grain with the other ingredients. Adding fruit to the formulation also may help maintain texture in storage.

Are snack bars a missed opportunity for adding whole grains to our diet? Although product names containing "grain" or "granola" may imply whole grain to consumers (7), they often contain only 1 g of fiber per 25- to 40-g serving or less. Intact kernels and seeds could be incorporated in snack bar formulations, using whole-grain flour used as a binder.

Pasta and Noodles. Bran and germ interfere with pasta or noodle dough development. Whole wheat reduces pasta lightness and yellow color and increases surface roughness. Whole-wheat pastas tend to have shorter cooking times and greater cooking losses. Starch damage may aid water absorption during boiling. Cooked whole-grain pasta is less firm, and checking (breakage) during storage can be a problem. Optimization of the whole wheat/semolina ratio is necessary to produce quality pasta. Processing aids may be used to improve smoothness and cooking properties. Drying at lower temperatures (40°C versus 70°C) also improves the firmness and appearance of whole-grain pastas (9).

Extrusion-Cooked Products. Extrusion technology has enabled the commercial development of many whole-grain foods, such as puffed and flaked ready-to-eat breakfast cereals, savory and sweet expanded snacks, croutons and bread crumbs, crisp flatbreads and breadsticks, and rice and pasta substitutes. There are still several challenges facing manufacturers, however. One of these challenges is instability during extrusion. For example, lipids and particles in whole grains may segregate during feeding and extrusion, and this separation results in limited expansion at the extruder die. Increased product color may also occur. Although bran obviously can increase product color, darkening can also occur due to Maillard browning, as well as enzymatic browning of chlorogenic acid and other phenolic acids. In addition, whole-grain products may undergo increased lipid oxidation during storage. Metal from the barrel and screw can literally be scraped off by abrasive grains. These metals can then act as pro-oxidants. Shear in the extruder barrel frees lipids from cells, making them more available to react with air postextrusion, which contributes to oxidation reactions. Increases in surface area due to air pockets that form as products exit the die also contribute to increased oxidation. However, extrusion denatures lipoxygenase and other enzymes involved in oxidation. Although browning from Maillard reaction compounds are often undesirable, these compounds may act as antioxidants.

Many options for improving the quality of extruded whole-grain foods are available to food product developers. Preconditioning—a step prior to extrusion that mixes grain with water or steam—can aid in hydration of bran to reduce grittiness, as well as partially gelatinize starch. Although this process is widely used with single-screw extruders, preconditioning has value for twin-screw extrusion as well. Screw configuration can be altered to minimize damage to starch and phytochemicals by reducing kneading blocks and reverse elements and adding more conveying screw elements. To increase expansion at the die, however, pressure must be built up within the extruder barrel to create a pressure greater than atmospheric pressure. Another option is to add ingredients that stabilize bubble formation as the product exits the die.

Opportunities To Increase Whole-Grain Consumption

New Side Dishes. Traditional side dishes may be temporarily out of vogue due to the popularity of low-carbohydrate diets, but whole-grain products still appeal to consumers who want healthy, exotic, or vegetarian foods. Brown rice, barley, and other intact grains can be combined with each other, pasta, or beans to create nutritious side dishes. For example, brown rice or bulgur can be added to pilafs to boost their whole-grain content. Interest in Northern African and Mediterranean cuisine has also brought products such as *couscous* to many restaurant menus. Precooking followed by dehydration can produce whole-grain creations that cook in considerably less time than those needed for raw whole grains. For example, precooked brown rice and brown- and wild-rice mixtures require only 10 min to cook. Faster cooking options such as microwaving or stove-top boiling appeal to time-strapped consumers.

Breads. Flat breads and tortillas have become mainstream foodservice items due to the popularity of gyros and wrap sandwiches. Unfortunately, adding whole grains to these dough formulations can have negative effects on product quality. Too much bran in the dough can cause the resulting breads to tear easily, while increasing the percentage of whole-wheat flour in tortillas results in sticky doughs that are difficult to process and that flake and crumble more easily during storage (2). Gluten can be added to improve machinability.

Soups and Snacks. Other targets for added whole grains include soups and snacks. Soups are a traditional vehicle for whole grains, yet few commercial soups include them. Pearl barley, while not considered a whole grain because part of the bran is removed, is used in many soups, both homemade and commercial. Snack mixes containing whole grains, including ready-to-eat breakfast cereals, could find niches as airline snacks and brown-bag lunch snacks for school and work.

Young Consumers. Many children in the United States avoid "brown" cereal foods, preferring white breads and sweetened breakfast cereals. So, what are the barriers to increasing the popularity of whole grains with children? Color, flavor, and texture are all possible culprits. Breeding programs have developed very light-colored white wheat cultivars (10) that could be used in a wide variety of food product applications. In addition to a darker color, whole grains may also contribute brown, bitter, or other flavors that can be masked or complemented using more appealing flavors (4). Kids often dislike heterogeneous textures; thus, products made from finely milled whole wheat might be more acceptable. Food neophobia—the fear of trying new foods—is typically high among children and teens. Increasing appealing whole-grain foods in school lunch programs and fast-food restaurants could make these foods more familiar and, thus, more acceptable to young consumers.

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Summary

Opportunities exist to increase whole-grain consumption through new product and process developments. Foodservice should be targeted because in the United States almost 20% of calories are consumed away from home, yet restaurants and fast-food franchises provide <6% of whole-grain servings (7). Utilization of whole grains in food products is challenging due to differences in color and texture from products containing refined grains. Consumer education about the importance of whole-grain foods must continue in parallel with the development of appealing whole-grain foods.

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