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On the evening of 23 October 2004, a huge earthquake struck Niigata Prefecture, especially Ojiya City. This city, the location of Echigo Seika Company Ltd., was the seismic center. I express my sincere sympathy to the people there, and, as it is now a very busy season for the coming New Year, I regret the damage to the rice-processing systems of the company, including the high-pressure machines, resulting from this earthquake.

Developing novel processes for incorporating the unique nutritional and functional properties of rice into value-added products

Elaine T. Champagne, Harmeet S. Guraya, Frederick F. Shih, and Ranjit S. Kadan

An expanding global rice market and diet diversification have presented the rice industry in the United States and other developed countries challenges and opportunities to develop new markets for rice. Global trade has expanded with advances in technologies leading to record yields of high-quality rice. Countries that at one time were importers or had only a small share of the export market are now major exporters. The United States, once the lead exporter of high-quality rice, has been hit hard by this shrinking export market. Outside of the U.S., countries such as Brazil, China, Japan, Taiwan, and India have been faced with declining per-capita consumption because of diet diversification. Value-added rice products that capture the unique nutritional and functional attributes of rice offer a means to keep rice as a mainstay of the diet and to expand domestic markets. This paper will highlight new product introductions in the U.S. and technologies recently developed at the USDA-ARS Southern Regional Research Center for value-added rice products.

New product introductions

Domestic usage of rice in the United States has tripled in the last ten years in response to consumer demand for more healthful foods, more convenient products, and a growing interest in ethnic foods. The market has been flooded with new product introductions. Foods that use rice now include baby food, bakery goods, breakfast cereals, candy, desserts, beverages and dairy items, side dishes, package mixes, entrees (frozen, shelf-stable, chilled), meats and meat substitutes, sauces and spreads, snacks, soups, and pet foods.

Rice usage in entrees has increased 10-fold in the last 20 years. Interest in ethnic foods has boosted this growth. Frozen ethnic entrees represented a $2.2 billion industry in 2000 (Brandt 2001). A popular new addition is bowl meals—a frozen entree in a microwaveable bowl usually containing individually quick-frozen rice, meat or poultry, and vegetables. They have contributed largely to the growth of the entree market.

Package rice mixes to serve as side dishes combine rice with seasonings, dehydrated vegetables, and other ingredients. The use of rice in packaged mixes doubled during the 1990s (USA Rice Federation 2000). Mixes for Louisiana Cajun and Creole foods, such as jambalaya, gumbo, and etouffee, and difficult-to-make dishes, such as risotto, are popular. Rice for mixes is either regular or parboiled, with a low moisture content around 6.5%. For a product in which distinct grains are important, such as a pilaf, or when a sauce will add moisture, parboiled rice often performs better than regular rice.

Snack bars using rice include granola, breakfast, and energy bars. Energy bars, introduced in the 1990s, account for 80 to 100 new product launches a year and represented about $500–700 million in sales in 2000 (Kreuzer 2001, Mintel International Group Ltd. 2003). Snack bars target the health-conscious consumer and are often enriched. A breakfast bar introduced in 2003 contains milk infused into the grains composing the bar to give one the taste of a bowl of cereal. Crisped rice is used in granola, breakfast, and energy bars. High-pressure extrusion processing is generally used for the manufacture of crisped rice for these snack bars.

Desserts with rice emerged in the late 1990s with waxy rice serving as a fat replacer in ice cream. The addition of 1.5% waxy rice starch improves the creamy mouthfeel and overall texture, allowing the product to mimic premium (higher fat) ice cream. The excellent freeze-thaw stability of waxy rice starch helps reduce iciness during storage (Bakal 1994, Wilkinson and Champagne 2004). Crisped rice provides texture to a number of chocolate dessert products.

Rice incorporated into a meat product can help reduce fat content, for example, in the manufacture of "light" sausages. Rice starch can be used to bind water in poultry products during vacuum tumbling or injection. Rice and rice protein are used in meat analogs to help bind the other ingredients.

Rice has also found new applications in dairy alternatives and electrolyte-replacement drinks. Rice offers a lactose-free, hypoallergenic alternative to cow and soy milk products. In soy milk, rice flour and syrup can be used to help mask beany flavors and keep insoluble proteins suspended in solution (Burrington 2002). In electrolyte-replacement drinks, the long-chain carbohydrates and proteins of rice enhance the absorption of fluid and electrolyte salts into the body's cells (Greenough 1998).

Novel processes developed at the Southern Regional Research Center

The postharvest rice research program at the Southern Regional Research Center is directed at (1) obtaining a fuller understanding of component structure-function relationships in rice and its coproducts that contribute to their unique nutritional and functional properties and (2) developing new technologies for converting rice components, *in situ* and isolated, into high-value, high-demand products that capture these unique properties. Technologies resulting from this research are highlighted.

Physical process for rice starch and protein separation

Rice starch has not been produced in the United States since 1943, except on a small scale in recent years. Seventy-five percent of the world's 25,000 metric tons of rice starch produced annually is made in Europe. The classical, commercial rice starch operation employed in Europe requires extensive soaking in dilute sodium hydroxide prior to the separation of starch and protein. This wet-milling process is water, energy, and time intensive and requires costly wastewater treatments. The usage of alkali results in a salt disposal problem and can impart bitterness to the protein component. The environmental and energy issues associated with this process have hindered the comeback of a rice starch industry in the U.S.

Dr. Harmeet Guraya under a Cooperative Research and Development Agreement (CRADA) and Small Business Initiative Research (SBIR) grant with Sage V Foods (Los Angeles, California) has developed a physical process for separating rice flour into starch and protein. In this process, protein-starch agglomerates of rice are physically disrupted in the presence of water by the use of high-pressure homogenization, as achieved by the use of a microfluidizer. The deagglomeration leads to better density-based separation of rice starch and protein. This process yields starch with low damage (5–6% versus 12% in commercial starches) and low protein content (< 0.5%). The protein has high solubility compared with that of commercially available protein concentrates, making it suitable for beverage applications. Sage V Foods has been granted an exclusive license for U.S. Patent 6,737,099 (18 May 2004), "Process for the Deagglomeration and Homogeneous Dispersion of Starch Particles." The company has scaled-up the process and will shortly begin manufacturing the starch product. This technology has the potential of reducing imports of rice starch and increasing profits for the U.S. rice industry.

Physical process for quick-cooking brown rice

Brown rice is rich in minerals and vitamins, making it a nutritionally valuable food. Consumption of brown rice, however, is low. A major drawback for brown rice is its long cooking time (45–50 min) because of the slow rate of hydration. This long cooking time produces an undesirable sticky, soft texture on the surface of the kernel. Existing commercial methods for producing quick-cooking brown and white rice involve precooking the rice, followed by drying. These methods require a significant input of water and energy, which, in turn, creates significant expense.

Dr. Guraya has invented a dry instantization process that reduces the cooking time of brown and wild rice from 45–50 min to that of white rice (20 min). This process "sandblasts" brown rice with parboiled rice flour. The bombardment creates microperforations in the waxy layer of the bran, allowing the kernel to absorb water more readily and cook more rapidly. Visually, the uncooked kernel looks the same as an untreated kernel. The cooked kernel has a texture similar to that of white rice and is not soft and mealy like that of untreated brown rice. The U.S. Patent 6,586,036 (1 July 2003), "Process for Increasing Rate of Hydration of Food Crop Seeds," has been licensed by three companies. One licensee, Progressive Technologies (Grand Rapids, Michigan), has manufactured a continuous system for production of these products by the other two licensees. The process cost is approximately 2 to 4 cents per kg of brown rice. The invented process reduces the cost of processing to make quick-cooking rice, reduces environmental pollution, and will make nutritious brown rice more appealing to consumers.

Gluten-free rice bread

Economical rice bread products are needed for consumers with Celiac Sprue disease and other disorders that prevent consumption of gluten-containing grain (e.g., wheat) products. Dr. Ranjit Kadan has developed formulations for rice bread using a home bread machine. The prototype bread has desirable flavor and texture comparable with those of wheat bread. A U.S. patent application has been submitted. The developed process will allow consumers to readily and economically prepare gluten-free bread. Ingredients cost \$0.65 kg^{-1} $loaf^{-1}$, with marketing cost 2–3 times this cost. This compares with \$4–5 $loaf^{-1}$ for commercial wheat bread.

Low-oil-uptake rice batter and donuts

Fried batters may enhance the sensory quality of the coated food, but they may also contain high amounts of oil and contribute to oil-related health problems such as obesity and heart disease. Therefore, in spite of their popularity, fried foods with excessively elevated oil are undesirable and should be avoided. Dr. Fred Shih and Ms. Kim Daigle (1999) found rice flour to have better oil resistance than wheat flour when formulated as a batter. However, rice-flour slurries, at concentrations such that the viscosity is appropriate for a batter, become brittle and hard during frying. These observations led them to discover that gelatinized long-grain rice flour and phosphorylated long-grain rice starch esters can be effective in enhancing both the viscosity and oil-lowering properties of rice-flour batters. These batters, when applied to chicken, absorb up to 60% less oil than a traditional wheat-based batter. U.S. Patent 6,224,921 (1 May 2001), "Rice flour-based low oil-uptake frying batters," was issued.

Following an approach similar to that taken for the batter development, Shih and Daigle (2002) developed low-oil-uptake rice donuts. The product formulated with long-grain rice flour and pregelatinized long-grain rice flour (30%) absorbed as much as 54% less oil than traditional wheat-flour donuts.

Fungi-free rice straw

Japan desires to import rice straw from the United States for cattle feed and requires that the straw be free of fungi. Dr. Guraya has invented an economical process for fungi-free rice straw. Research is under way, in collaboration with an industry partner through a CRADA, to make the process continuous and scale it up for a commercial operation. This process will allow the U.S. to export rice straw to Japan, which currently imports 2 million tons of forage other than that from rice.

New research thrusts

Current research efforts are directed at developing novel technologies for health-beneficial products from rice bran and hulls. These technologies include processes for (1) protein concentrates and isolates for infant formulas, beverages, and ingredient applications; and (2) fractions (rice wax, wax-rich fractions, hull and bran extracts) with cholesterol-lowering and antioxidative activity for various food applications. Technologies for new low-oil-uptake rice and sweet potato–rice products that suit the need of health-conscious consumers are also being developed. All of these applications target the unique nutritional and functional attributes of rice co-products and their components. The processes being pursued to achieve these products are efficient, environmentally friendly, and commercially viable.

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