Cornucopious Nutrition

Though QPM looks like regular corn, nutritional analysis shows it's anything but ordinary

By JANET RALOFF

Today, farmers grow about 449 million tons of corn worldwide. In terms of area under cultivation, it's the world's second or third largest crop. Providing 19 percent of the world's food calories and 15 percent of its food-crop protein, global corn production yields about 200 pounds of the cereal for every individual alive. It should come as no surprise, then, that corn – also known as maize – is a staple for some 200 million people, including nearly half the world's chronically malnourished. However, conventional corn is deficient in the vitamin niacin, and roughly half its protein lacks lysine and tryptophan – two essential amino acids. As a result, this staple is not a sufficient protein source, especially for children, the sick, and pregnant or lactating women.

Because so many people depend on this grain as a primary source of protein, researchers at the International Center for the Improvement of Maize and Wheat (CIMMYT), outside Mexico City, set out in the mid-1970s to build a better corn. And their result "appears to be an outstanding product," according to the National Research Council (NRC) Board on Science and Technology for International Development.

Its analysis, published last month, reports that although the new quality-protein maize (QPM) "has about the same amount of protein as common maize, it has twice the usable protein because the quality and biological value of its protein is so much higher." In fact, unlike regular maize, which has about 40 percent of the biological value of milk protein, QPM's protein approaches that of milk – a common standard of nutritional excellence.

In maize-loving countries where dietary protein shortages are endemic – including much of Latin America and Africa – QPM "could provide a nutritional safety net," the NRC panel found. By halving the acreage required for protein production, the new crop could also effectively double the efficiency of subsistence farming. "Indeed," the report says, "in most areas it should allow a family to combat its own malnutrition without outside help."

QPM was developed from a mutant strain – "opaque-2 maize" – discovered in 1963 by researchers at Purdue University in West Lafayette, Ind. Like the mutant, QPM contains the two missing amino acids. But in sharp contrast to the pure mutant, it has the look, taste, high yields and good storage qualities of conventional corn. Moreover, though QPM remains deficient in niacin, the body converts this grain's high levels of tryptophan – niacin's precursor – into niacin.

J. Maner

On all-you-can-eat diets, the pig (labeled O) fed corn carrying the opaque-2 gene grew normally, while the one (labeled C) fed regular corn was stunted.

Agronomists initially thought opaque-2 would become the high-quality grain to tackle protein malnutrition. But after a decade of trying to introduce opaque-2 to developing nations, the world's cereal breeders gave up. Opaque-2's desirable characteristics seemed tied to undesirable ones. Farmers, for example, objected to its yields – as much as 15 percent lower than those of traditional varieties – and its greater susceptibility to fungi and insects. Millers objected to its moisture, which meant poor storage qualities. And consumers objected to its soft kernels and dull, chalky appearance.

Enter CIMMYT, a research center to improve cereals for Latin America, the Middle East, Africa and Asia. Under pressure to help alleviate protein-aggravated malnutrition, its researchers picked up the all-but-discredited opaque-2.

In a painstaking process, CIMMYT maize breeders began crossing Purdue's opaque-2 against a range of conventional tropical maizes, hoping their progeny would incorporate the higher-quality protein in kernels resembling conventional corn. Because the gene coding for opaque-2's higher amino-acid content is recessive, all the initial crosses produced maize with normal proteins. But recrossing these progeny against each other yielded some plants that expressed the opaque-2 gene. It took several generations of such crossing to truly incorporate the opaque-2 gene in conventional corn.

Kernels from maize carrying the gene varied considerably. To identify which ones on any ear contained the desired proteins, CIMMYT scientists drilled into individual kernels – taking care not to harm their embryos – and extracted a microscopic portion of endosperm, the nutritive starchy tissue surrounding the dormant embryo. Initially, breeders focused on kernels with a mottled appearance – part chalky (like opaque-2) and part glossy. If analysis showed they contained high enough levels of lysine and tryptophan, such kernels were planted, becoming the parents for another generation of crosses.

In some seasons, researchers drilled and analyzed 25,000 or more kernels in this way. Their ability to remove and analyze such small portions – without harming the kernel's viability – was one key to the breeding program's success. Another was CIMMYT's attention to manipulating opaque-2's "genetic modifiers" – genes with the ability to weakly influence the expression of a major gene.

The result was QPM – conventional maize carrying opaque-2's gene for enhanced protein quality. CIMMYT's germ plasm today encompasses about 30 experimental populations offering widely different maturation periods, grain types (including white and yellow, soft and hard) and adaptability to climate, altitude, temperature, rainfall and soils. Last year, researchers from 40 countries requested seed for 127 trials.

Says Ronald Cantrell, CIMMYT's director for maize programs, "We feel at this point that we have QPM that's as good as normal [maize] for use in several major environments." One type is commercially available in Guatemala. Others are performing well in tests in China, El Salvador, Brazil and Senegal.

Such regional testing is essential to identify limitations in the existing grain.

For example, Cantrell points out, "we don't have a lot of downy mildew here, but it's a very serious problem in Southeast Asia." During QPM tests in Thailand, this blight obliterated an entire crop. Far from ruling out QPM's promise for Thailand, Cantrell says, such experiences indicate that in some cases, "QPM may have to be worked on — customized — where it will ultimately be used."

Popular throughout the Western Hemisphere, maize constitutes 85 percent of the cereal grain consumed in Mexico and Central America. This New World export also has become a staple in Africa, where one-quarter of the world's corn is now consumed. "In most areas [of Africa], its importance is as great as that of wheat in the Mideast and rice in Southeast Asia," note the authors of the NRC report.

Ironically, despite conventional corn's low protein quality and quantity, its consumption tends to be highest among the impoverished. "In Central America," the report says, "poverty-stricken adults commonly consume only maize." The diets of children are hardly better. According to the report, "The prevalence of protein-calorie malnutrition among village and slum children in dozens of African and Latin American countries demonstrates the underlying inadequacy of maize-dependent diets."

One of the first researchers outside CIMMYT to study QPM's potential advantages in human nutrition is Ricardo Bressani with INCAP (Nutrition Institute of Central America and Panama) in Guatemala City, Guatemala. A biochemist, Bressani has found the human body uses high-quality maize more efficiently than regular maize. Conventional corn's lower levels of lysine and tryptophan limit the body's ability to utilize protein. Bressani's data, derived from studies involving both children and adults, indicate that only about 40 percent of the protein digested from common corn is ultimately used. In contrast, roughly 90 percent of QPM's digested proteins is used.

Bressani is now investigating the use of vitamin-fortified cooked-QPM flour as a weaning food for low-birthweight babies now 3 to 7 months old. Though final data on the 4-month-long feeding study won't be tabulated before the year's end, he says, "the results we have obtained so far indicate that [QPM-fed] children are responding very well" — growing at a rate equal to that of normal-birthweight children on regular weaning foods.

A weaning diet should provide babies with solid foods offering nutrition comparable to what they had received in breast milk. But in many regions, the NRC panel says, "babies are switched abruptly from mother's milk to adult foods. For young bodies, frequently fighting off diseases and parasites, these are usually inadequate in quality to sustain normal growth and health, even when plentiful enough to satisfy hunger." That's why the panel says that compared to all other stages of life, the period between 6 and 24 months of age "is the stage of greatest nutritional hazard."

In a 3-month-long study recently completed in Peru, George Graham of Johns Hopkins University in Baltimore served maize as the sole source of protein and fat to recovering malnourished children about 20 months old. He says his data show that when the grain is QPM, "children grow as well on maize as on milk."

Conventional-maize-based diets incorporating legumes can also provide protein-sufficient nutrition. However, the NRC report notes, "beans are more expensive to buy than maize; they cost more to grow and they yield less. Also, they require long cooking" — another problem as firewood becomes harder to find in developing countries.

Though QPM was designed with needs of the developing world in mind, "you can make a very good argument for using it in the United States," says William L. Brown, chairman of the NRC panel and a former board chairman of Pioneer Hi-Bred International, one of the United States' leading grain-seed producers. However, he adds, the types and uses most likely to appeal to U.S. consumers would probably be quite different from those being created for the developing world.

For starters, Brown notes, at least 80 percent of U.S. corn goes to feed livestock. Moreover, virtually all U.S. corn growers plant hybrids — not the "open-pollinated" varieties preferred in developing countries. Though hybrids yield more, seeds for each planting must be purchased new. To date, CIMMYT has not focused on hybrid-QPM development.

A. John Bockholt at Texas A&M University in College Station is one of the first U.S. researchers developing experimental QPM hybrids. "This is only our first year," he says, "but visually they look very good." Though firm data will not be in for another few weeks, Bockholt says the 70 different hybrids he's growing appear to be yielding somewhat less than commercial U.S. hybrids. But by using standard techniques to cross the better-producing individuals, Bockholt believes he can achieve competitive yields within "three or four [corn] generations" — about two years.

And once QPM becomes available, livestock producers may line up for it. Based on his just-completed swine-feeding trial, Bockholt reports, "QPM is far superior to regular U.S. corn." Because it's nutritionally balanced, he says, hog farmers would not have to supplement it with soybean meal as much as they do today. In fact, his calculations indicate U.S. hog farmers could pay an extra 80 cents per bushel of feed — a premium of about 44 percent — "and still make money" if that corn is QPM.

But QPM's U.S. prospects extend beyond feed grain. While QPM won't do much about the high fat content of many snack foods, it does offer one way to naturally fortify them, according to Texas A&M cereal chemist Ralph Waniska. For this reason, he says, the new maize "would offer a marketing advantage to snack-food companies" — essentially allowing them to advertise QPM-based foods as having double the protein-nutrition quality. It might even transform some junk foods into nutritious snacks.

Waniska and his colleagues already have shown that QPM can be substituted for ordinary corn in the commercial production of tortillas and tortilla chips without production changes. The same was not true of the original opaque-2 maize. Moreover, he says, the switch from regular corn to QPM gives these foods "a little better taste." He describes that taste as more full-bodied and a little less like corn.

The NRC panel concludes that "although QPM has shown outstanding promise, to date it is only a promise," adding that "any lingering doubts need to be resolved by an organized, international, cooperative effort."

Specifically, it calls on cereal researchers to assess the grain's use under real-world conditions — those of the subsistence farmer and malnourished family. It also recommends that major efforts be developed to customize today's QPM germ plasm — which it regards as "an intermediate product" — for those areas where it's most needed.

CIMMYT's Cantrell would add one more measure: development of simple, low-cost methods to test for the presence of the higher-quality protein in harvested crops. Because unintentional cross-pollination with a neighbor's non-QPM corn plants will yield identically appearing lower-protein maize, Cantrell says farmers, buyers, millers and local inspectors need a means of testing whether the grain being marketed as QPM indeed carries the quality protein. Such testing might not be necessary, he says, if new farming, marketing and regulatory practices were set in place to ensure such contamination would not occur. However, he notes, "to date very few if any of the national programs in developing nations have such an infrastructure," much less the capacity to conduct the chemical analyses required in its absence.

"In any scientific development there is a time for caution and a time for boldness," the NRC report says. "[Our] panel is convinced that with QPM the time for action has arrived." □