Special Article

Value-Enhanced Crops: Biotechnology's Next Stage

Biotechnology's next quest, to provide field crops with value-enhanced qualities for end-users—output traits—is underway. Biotechnology's first stage featured crops with improved agronomic qualities—input traits—valued by farmers, such as resistance to pests. The industry now visualizes a system in which farmers grow crops designed for the specific needs of end-users in food manufacturing, the livestock sector, and even the pharmaceutical industry. Breaking with agriculture's traditional supply-side orientation may not be easy, however. Whether biotechnology's second stage is a wave or a modest ripple will hinge on several economic and technical factors.

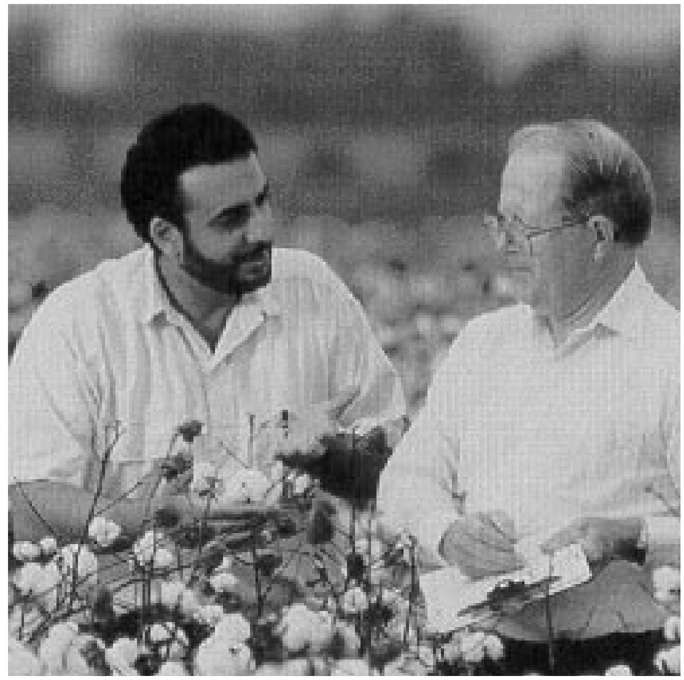
U.S. farmers already grow, on a relatively small scale, a number of high-value crops—such as food-grade soybeans and white corn—developed through conventional breeding. These commodities are typically classified as specialty crops that have fairly "thin" markets that can easily be swamped if production surges.

Genetic engineering promises to facilitate development of crops with more improvements in end-use characteristics than conventional breeding has been able to accomplish. In some cases, these traits will appeal to wider segments of the market than conventional specialty crops have, although in other cases their markets will be narrower. To succeed, however, the products first must be able to deliver—not just improved quality traits, but also good agronomic performance. Second, and no less important, the crops must prove their overall value to producer and user. In many cases, pricing and marketing arrangements will not be business as usual and may require several changes.

Farmers quickly saw the value of the first wave of biotech crops with built-in protection against insect pests or resistance to selected herbicides. Acreage of biotech-developed soybean, corn, and cotton has soared since their commercial introduction in 1996 (*AO* August 1998). Adoption of the next stage of biotech crops may proceed more slowly, as the market confronts issues of how to determine price, share the value, and adjust marketing and handling to accommodate specialized end-use characteristics. And competition from existing alternative products will not evaporate. Pitfalls that have accompanied the first generation of biotech crops, such as the trade dispute with Europe over approval and labeling of genetically modified crops, will also affect the next stage of products.

Value-enhanced crops may be produced through conventional breeding techniques as well as through genetic engineering.

USDA does not make official estimates of acreage or production of genetically modified varieties–the data are included in total estimates for the various crops. Numbers cited here were developed from industry sources, and are not official USDA data.



Agricultural Research Service

Some industry analysts believe the development of more end-use quality traits will largely "decommodify" the existing marketing system for field crops. In other words, there would be a movement away from bulk handling and blending of undifferentiated crops under very broad grades and standards categories and toward a system that can meet more specialized needs of buyers, even to the point of preserving the identity of a crop from the farm to the user. The added costs of such specialized handling will have to be justified by the value of the new crops to buyers.

What Are Some of the New Crops?

Many promising new value-enhanced or output traits are starting to appear among the major field crops, most—although not all—created through biotechnology. Some are already available; others are still a few years away from the market. Following are highlights of some leading developments.

High oleic soybeans, with around 50,000 acres planted in 1998, yield oil that contains less saturated fat than conventional soybean oil. Because it is more stable, the oil does not require hydrogenation for use in frying or spraying, which reduces processing costs. Moreover, hydrogenation creates trans fatty acids, which studies have associated with adverse serum cholesterol levels. In addition to its desirable health qualities, high-oleic soybean oil has a longer useful life, which appeals to the fast-food industry. High-oleic soybeans may also serve as a platform for stacking other traits—i.e., including more than one specialized biotech trait in a single variety.

Soybeans with improved animal nutrition that bolster the protein and amino acid content of soybean meal are near commercial introduction. Soybean meal is the most important protein source for U.S. livestock and poultry. Increased levels of the amino acids lysine and methionine in particular have potential to reduce the proportion of higher cost protein meals required in the ration.

Improved food-quality soybeans are currently in production. While most of the focus for soybeans is on improving oil and meal characteristics, since these uses represent the bulk of the market, some new varieties have improved food qualities. For example, high-sucrose soybeans that have a better taste (less "beany") and greater digestibility were introduced recently, and around 25,000 acres were planted in 1998. While soy protein has played a minor role in the U.S. food supply, improvements could help expand domestic consumption, as well as offer good export potential.

Although high-oil corn was not developed through biotechnology, it will likely be used as a common platform to stack new input and output biotech traits.

New varieties of canola, bred for superior oil qualities, are already on the market, although they are less important in the U.S. than in Canada, where canola is a major crop. *High-lauric canola* has been grown in the U.S. since 1995, and plantings reached 80,000 acres in 1998. It produces an oil composed of about 40 percent lauric acid. This fatty acid is a key ingredient in soaps, detergents, lubricants, and cosmetics, and the lauric acid in the oil from this canola variety replaces lauric acid from coconut or palm kernel oils produced in Southeast Asia. *High-stearate canola* is expected to be introduced within a few years. The oil from this variety, high in stearic acid, solidifies at room temperature without hydrogenation and would be used for baking, margarine, and confectionery foods that cannot use liquid oils. It would be a healthier alternative to tallow, currently the major source of stearic acid.

Mid-oleic sunflower seed, a conventionally bred type, has a modified fatty acid profile. It was grown on 100,000 acres in the U.S. in 1998, and plantings are expected to expand sharply this spring. Mid-oleic sunflower seed produces low-saturated-fat oils with 60-75 percent oleic acid, compared with 16-20 percent from standard sunflower hybrids. The oil has potential to replace cottonseed and partially hydrogenated soybean oils in frying and salad oils. Because the mid-oleic has higher yields that are comparable to standard hybrids, this type is expected largely to replace high-oleic varieties that contain 77-89 percent oleic acid and that currently account for 10-15 percent of U.S. sunflower acreage. The market for the high-oleic variety has tended to be limited to higher value uses as a cocoa butter substitute in cosmetics because its reduced yields have required high premiums.

Defining Biotechnology

Biotechnology can be defined as the use of biological organisms or processes in any technological application. Genetic engineering can be thought of as a subset of biotechnology, describing a set of techniques for altering the properties of biological organisms. Using genetic engineering techniques, individual genes can be transferred between organisms, or genes in an organism can be modified to create plants, animals, or microbes with improved traits for biotechnological applications. In this article, the terms "biotech" or "biotechnology," "genetically engineered," and "genetically modified" are used interchangeably.

Value-enhanced corn will offer several improved nutritional traits for livestock feeding. Since grain is fed primarily as a source of energy, many of the new value-enhanced varieties aim to increase the content or availability of energy. But some new varieties will also include more protein and better amino acid balances, which would reduce the need to buy supplemental feed ingredients. More variations on this theme are in the works, and a few varieties are already on the market.

High-oil corn, developed through conventional breeding, is the most important corn variety now available with an enhanced nutritional profile. This variety has been commercially available for about 6 years, and acreage has increased significantly each year, reaching 900,000 acres in 1998. Although its oil content varies, high-oil corn can contain as much as double the 3.5-4 percent oil in traditional "commodity" corn. The higher oil content means more energy, which improves feed efficiency; it also reduces the need to add fat to some rations and delivers higher levels of essential amino acids like lysine and methionine. In addition, the higher oil content reduces dust levels and improves palatability. Although high-oil corn was not developed through biotechnology, it will likely be used as a common platform to stack new input and output biotech traits.

Low-phytate or low-phytic-acid corn, providing increased availability of phosphorous, will be marketed within the next year. It has environmental appeal because its use in feed means hogs and poultry will pass less phosphorous in their waste, reducing pollution problems. And because of its greater digestibility, it holds the added promise of cutting feed costs, by allowing the animal to absorb more of corn's phosphorus content and eliminating the need for phosphorus supplements.

Several existing, conventionally bred corn hybrids have improved traits for food and industrial purposes. These include *hard endosperm* corn, desired by dry millers for preparing food products, and corn with altered starch content, such as *waxy corn* used largely by the wet milling industry. Further improvements in food and industrial use characteristics are expected through biotechnology research.

A substantial portion of cotton acreage is already planted to biotech varieties with crop protection traits, but most end-use traits are probably 3-4 years away. *Colored cotton*, a trait that would reduce the need for chemical dyes, is already available on a niche market basis. Another major area of research is *fiber quality improvement*, such as polyester-type traits, to make sturdier fabrics. Some researchers hope to develop *wrinkle-resistant cotton* and even *fire-retardant qualities*. Improvements in cottonseed are also envisioned that could make cottonseed oil more useful as an animal feed.

Wheat lags behind the other major crops—even first-stage input-trait biotech varieties are not commercially available. The lag in part reflects technical factors—it is more complex to breed wheat than corn, for example. The primary reason, however, is economic. The wheat seed market is relatively small; many farmers save seed instead of purchasing it—unlike corn seed, virtually all of which is purchased—creating fewer incentives for the private sector to invest in wheat research. But in recent years, investment in wheat research has increased substantially, and use of reliable genetic transformation methods portends payoffs in the next few years. Like corn or soybeans, the first biotech wheat, which should be introduced soon, will likely offer crop protection traits such as herbicide tolerance.

Wheat quality traits will concentrate on major end uses such as breadmaking, other baking, and noodlemaking. Current end-use trait research focuses on modifying gluten and starch content, creating uniform kernel size, bolstering mineral content, and numerous other traits that could improve wheat milling, dough properties, and bread and noodle texture. The case of hard white wheat (*AO* August 1998), a conventionally bred crop, may be instructive in switching crop variety development more to an end-use focus.

Nutraceuticals, a category of biotech or conventionally bred crops designed to produce medicines or food supplements within the plant, may be developed using any number of crops, depending on the nature of the pharmaceutical or nutritional supplement to be produced. Researchers claim nutraceuticals, also called "functional foods," could conceivably provide immunity to a disease or improve the health characteristics of traditional food—e.g., canola oil with a high beta-carotene content.

Will Farmers Adopt These Crops?

Farmers quickly adopted the first-stage biotech crops that enhance crop protection or lower input costs. The pace of adoption will likely be much slower for many value-enhanced crops, despite their excellent prospects. While both input and output traits involve higher seed costs—seed premiums often incorporate a technology fee—and may require some agronomic changes, the value-enhanced crops will require additional changes and costs to bring the crop to market.

To be a successful supplier of value-enhanced crops, producers may need to clean all harvesting equipment between uses on different output-trait crops, provide separate storage bins, and make substantial changes in marketing arrangements. These steps present few obstacles if higher product prices generate sufficient returns. But until some new products are well established, there may be a chicken-and-egg syndrome: buyers may be discouraged by an erratic or insufficient supply while growers confront a market that is too thin to support large enough premiums.

Farmers quickly adopted the first-stage biotech crops that enhance crop protection or lower input costs. The pace of adoption will likely be much slower for many value-enhanced crops, despite their excellent prospects.

USDA-Illinois Market News recently began a value-added grain survey of producers. While the survey primarily covers market opportunities for conventionally bred specialty corn and soybeans, it illustrates the types of issues that can arise with any specialty crops. For example, the survey reported that heavy signup by producers for 1999 white corn contracts squeezed premiums, and contracting opportunities were no longer available for some value-enhanced grains. The survey reported additional premiums for some high-oil corn were available from early contract signup bonuses and for certain crop chemical usages, although premiums for high-oil corn also weakened as more producers signed up.

Given the current low-price environment and the great amount of flexibility in planting decisions, farmers are certainly receptive to new products that offer potential for premium prices. However, there probably will be more interest in contracting and in other means of reducing risks than has been the norm in commodity markets. As demand for the new crops increases, new marketing channels will likely develop. Farmer interest will increase if improved technology can prevent the lower yields often associated with current specialty crops. Finally, the ability to stack genes—include more than one specialized biotech trait in a single variety—will likely mean that desirable input traits will be offered along with output traits to meet the needs of producers.

Distinguishing Commodities by Quality Traits

Early indications of the transformation from bulk handling and blending of undifferentiated crops to a system that can meet more specialized needs of buyers have appeared in connection with conventionally bred crops entering niche markets. For example, one snack food manufacturer, in order to maximize control over its final product, specifies the preferred corn hybrids it will purchase. Some buyers of soybeans for food use, including some for food products exported to Asia, specify varieties with particular end-use characteristics. For organic crops, the degree of product control extends beyond varietal selection to include production methods.

A large degree of institutional inflexibility exists in the current crop marketing system—margins are low and profits are a function mainly of large volumes. In general, it costs more to provide additional handling and storage facilities to isolate specific crop varieties than to handle conventional commodities; how much more depends on the quantity as well as the degree of control needed. Buyers who can obtain the traits or quality they need more cheaply through the conventional system will have little incentive to change.

Attempts to shift the commodity system to one that could better handle differentiation by end-use characteristics are not new and have been well documented by Professor Lowell Hill at the University of Illinois. Hill has noted, for example, that as early as 1954 USDA developed a quick method for determining the oil and protein content of soybeans so that farmers could market soybeans according to the value of the oil and meal they would yield. But the measure was never adopted in grain standards. Similarly, in the case of wheat, numerous attempts to incorporate protein content into grades and standards have failed over the years. Current grain standards basically describe physical characteristics with relatively little bearing on end-use performance, although wheat buyers routinely specify protein requirements, and supplemental testing is done at different points in the marketing chain.

In international trade, most buyers have long expressed interest in purchasing high-quality grain, but in practice have often balked at paying more for such quality. The Canadian Wheat Board has controlled varieties grown and exported from Canada to try to capture premium markets, but most exporters sell blended grain meeting minimum grade requirements. However, given the declining role of large state trading organizations in several countries in recent years, there are some signs of shifts in buying habits. As millers and other private buyers gain influence in import decisions, there are indications that quality concerns are becoming more important.

The critical difference now, in the era of biotechnology, from previous efforts to add quality dimensions is genetic engineering's ability to deliver vastly enhanced quality traits. New crops may lead to reduced processing costs or add to the marketability of the finished product to the consumer. However, the extent of the move away from the old commodity system will be determined mainly by costs and benefits—i.e., how much users are willing to pay for the additional value.

Changes to Come in Marketing & Coordination

The advent of additional value-enhanced crops, both biotech and conventially bred, may bring higher costs to preserve and deliver this value to specific end-users. The most stringent handling system, identity preservation, requires that a crop be completely isolated, from the grower's field through harvest and on-farm storage, to the elevator and subsequent shipment to the final destination—there can be no commingling with similar crops. For some traits, controls over storage and assembly from farm to processor may be less stringent if testing can verify the desired quality. For these traits, segregation, rather than the more stringent identity preservation, might be the more accurate term. Barley used for malting is handled in this way—it is separated from barley going into feed, but preservation of its identity is not required.

In any case, increased costs, such as for separate storage facilities at the farm or elevator, may be incurred to market value-enhanced crops. For complete identity preservation (organic crops provide an example), separate handling could mean dedicated rail cars, trucks, or holds in barges, or at least thorough cleaning of carriers before and after use. Use of intermodal containers for transporting crops may be appropriate in some instances, but this may increase costs even further.

The marketing arena will experience a clash of the traditional, volume-dominated system with the need to handle smaller quantities of specialized products at higher unit costs. In many cases, farmers may bypass sales through the country elevator and sell directly to the buyer. Some analysts expect that more marginal elevators that are unable to compete on volume with the bigger operations for commodity crops will improve their prospects by dedicating themselves to the special handling of new crops.

Signs are emerging that the major agribusiness firms, including grain merchandising companies and large cooperatives, are also preparing for these marketing changes. The 1998 annual report of Archer Daniels Midland Co. (ADM), for example, one of the largest grain firms in the world, extensively discussed the growing potential for more trait-specific grains. The company recognized that growing, handling, and transporting crops on an identity-preserved basis will become an increasingly large part of the domestic and export grain market. Cargill, another major agribusiness firm, has started a program through its seed division to provide farmers with bins for handling value-added production, to help producers gain entry into markets where they can gain premiums for their crops.

When farmers grow crops for specialized end uses, success requires coordination among technology providers, farmers, and end-users. More control will be required throughout the growing and marketing process, from selecting the seed to delivering the crop to the final customer, and the higher the investment, the greater the incentive to establish rigid specifications. This could mean a vertically integrated system owned largely by one firm.

Although a greater focus on end-use traits will probably mean further integration, such integration will not necessarily be accomplished through a vertical system under the same ownership. Even at this early stage, new alliances, joint ventures, partnerships, and other arrangements are being formed to take advantage of opportunities along the "value chain." Contracting is expected to become more common as a means of mitigating producers' risk and thus providing the farmer a greater incentive to grow a quality trait crop (see page 15). Although contracting, especially production contracting, has been quite limited for the major field crops, it is widespread for many vegetables and specialty grains (*AO* January/February 1999).

Of all value-enhanced crops, some of the nutraceuticals are the most likely to be grown in a system with tight controls from farm to end-user because of their very high value and the need for precision in their production. A few other new crops may fit this pattern, but many may not require such tight control. In these cases, where fewer controls are needed and thus costs for specialized production and marketing are lower, less coordination will be required and the process may remain closer to the current open market system.

Pricing Tied to Commodity Markets?

The prices of commodity crops are shaped mainly by supply and demand factors in the market, with sporadic influences from government policies. For value-enhanced crops, a central issue will be how to determine the price that reflects the quality attributes that account for added value to the buyer. Because existing grades and standards do not directly address most end-use concerns, and because there will be a diversity of new end uses to value, effective measurement technology will be critical to verify the presence of the trait and quantify the amount.

Currently, most specialty crops receive price premiums relative to a futures reference price or a spot cash price at a specific location, and many of the new output-trait crops may be priced similarly. The exact price discovery mechanism for output-enhanced traits, however, is uncertain and will require time to develop. The producer must cover costs of production and marketing, and the buyer must achieve a reduction in input costs and/or increased earnings before a market for an enhanced output trait can begin.

The willingness of the buyer to pay participants in the supply chain will depend on many factors, including price and market size for the final product, competing sources of the trait and their prices, potential for cost reduction to the processor, volume of the trait handled, and overall competitiveness of the market. A link to a futures market provides a useful means of price discovery; if value-added crops are successful enough, futures exchanges might eventually be compelled to modify contract specifications.

The marketing arena will experience a clash of the traditional, volume-dominated system with the need to handle smaller quantities of specialized products at higher unit costs.

An alternative approach would be a system of prices administered by the buying firm, which could well be adopted in a tightly controlled system like vertical integration or contract production. It would probably be more common for very high-value traits and perhaps for quality crops without substitutes.

The Case of High-Oil Corn: Early Evidence of Changes to Come

Although high-oil corn is a very promising product, its experience may illustrate many of the issues that other value-enhanced crops may also face. High-oil corn acreage has increased significantly each year since its introduction, but it has been dwarfed by acreage of pest-resistant Bt corn, which was commercialized later. In 1998, U.S. plantings of Bt corn—incorporating the leading biotech corn input trait developed from the bacteria *Bacillus thuringiensis*—reached about 16 million acres, while high-oil corn plantings amounted to about 900,000 acres.

But acreage data alone are misleading as an indicator of a crop's importance; high-oil corn serves as a prototype that might provide valuable lessons for other new crops. On the supply side, the high-oil seeds are widely available through many seed companies, and contracting opportunities are available through the Internet. Price premiums are paid on a sliding scale that has ranged as high as 30 cents per bushel, depending on the oil content of the delivered crop—tested at the elevator—and when the crop was delivered. A joint venture of technology providers and grain merchandisers has developed a large network of participating elevators; growers can sign up for specified delivery times throughout the year to avoid a post-harvest glut and even out the flow of product. A major transportation company is cooperating to create a supply chain.

From the use side, demand for high-oil corn is concentrated in two segments of the market: export markets, largely in tropical countries where the cost of fat is generally high, and U.S. farm-level livestock feeders. By using high-oil corn, the farmer saves the costs of purchasing and mixing supplemental fats. However, the industry likens the current marketing situation to picking the lowest hanging fruit off the tree first—the next stage of building demand will be tougher, because it will require a high degree of coordination between growers and end-users. The greatest share of the potential market is the large integrated poultry and livestock operations, which will need huge volumes of the product at levels that cannot yet be supplied. Another critical problem is competition on the energy side from this country's enormous and cheap supply of waste fats and grease generated by the fast-food and other industries, as well as competition from synthetic amino acids like lysine.

Nevertheless, development of the high-oil corn marketing system as it currently exists is a substantial achievement. If high-oil is stacked with other traits, it will be well positioned for future growth. Continental Grain has managed the export business for high-oil corn, a business that is likely an attractive asset in Cargill's proposed acquisition of Continental.

Several Issues Far from Settled

Despite the technical potential to develop a myriad of new quality traits, the marketplace is not likely to support designer or boutique crops to meet every specialized use, and the traditional commodity system for crops will not disappear. Stacking of numerous traits may expand survival prospects, but ultimately the benefits of the improved crops must exceed their additional costs.

The market will determine the economic viability of these new crops, for both domestic use and export. Some crops may not survive the marketplace test. Some new crops will remain small simply because of their agronomic limitations, similar to minor oilseeds like sunflowers or canola that can be grown profitably only in certain regions.

Competition from existing products will remain intense for some end uses. For instance, many new varieties of corn and soybeans will offer increased amino acid content for animal feeds. But two of the largest U.S. lysine producers have announced plans in recent months to expand production, which should lead to sharp price competition. Because of lower costs, commodity crops will continue to appeal to a large segment of the market, but new crops with broad appeal will benefit from economies of scale and declining costs as markets grow.

Many uncertainties accompany the newly forming institutional arrangements to price and market the crops, and to provide a means of sharing the value and bearing risks. Many farmers are apprehensive about tightly controlled production and marketing channels that could potentially reduce their independence. Technology firms have made huge investments that they will presumably try to recoup through favorable marketing arrangements, but the farmer will have to share in the added value to spur adoption.

Finally, several public policy questions could arise as value-enhanced crops gain popularity. For example, will market news reporting expand to cover many new crops? Should government grades and standards be modified? And what will be the role of the public sector if disputes arise over nongrade factors or verification of test results and equipment?

The rate of introduction of value-enhanced crops, driven largely by biotechnology, is expected to accelerate in the next few years, assuming consumer acceptance of biotech crops. While previous attempts to develop a more consumer-oriented, end-use crop focus have had limited success, indications are that this new effort may be different because of the vastly superior quality enhancements possible through genetic engineering. **AO**

Peter A. Riley (202) 694-5308 and Linwood Hoffman (202) 694-5298
pariley@econ.ag.gov

Testing May Facilitate Marketing of Value-Enhanced Crops

If the proportion of value-enhanced crops on the market increases significantly, as expected, there will be a parallel need for tests to verify and measure the presence of specific traits. Current grades and standards for commodity crops are supported by routine sampling, inspection, and measurement procedures specified by USDA's Grain Inspection, Packers, and Stockyard Administration (GIPSA). Grains are tested primarily for visual traits such as cleanliness or damage, and the testing procedures are well accepted, quick, and relatively inexpensive.

Testing of value-enhanced crops will likely require development of genetic markers to identify specific varieties as well as tests to verify the presence of added or altered traits or nutritional properties. The issue becomes more complicated if the new variety was produced by genetic engineering technologies. Recent European Union (EU) regulations require labeling of any products that contain DNA or protein from genetically engineered products; labeling regulations also have been proposed in Japan. It is also possible that a market for products produced from inputs that have not been genetically engineered will develop in the U.S. in conjunction with certification of foods as "organic."

U.S. grain is commonly blended at the elevator. In the absence of easy, cheap, or acceptable testing, the proliferation of value-added crops in the supply chain will require methods for identity preservation. Value-added crops might require a "field-to-table" paper trail for product identity to be strictly preserved. On the other hand, if a test can verify a minimum content of a certain trait that satisfies users' needs, it may be possible to allow some blending of crops. Thus, the availability of rapid, accurate, and inexpensive tests to verify or quantify the value-added trait could have a strong influence on the cost of marketing value-enhanced crops.

The need for testing raises several economic, technical, and possibly political issues that will shape future market arrangements for value-enhanced crops. Will the tests be acceptable to both buyers and sellers? Can the tests be performed economically, rapidly, and simply with reliable accuracy? Are there reliable techniques to ensure random sampling and adequate representation within a test sample? USDA's standard sampling protocols for testing grains and seeds could be adopted as standards for qualitative and quantitative testing of value-enhanced traits. In addition, work is in progress in both the U.S. and Canada to develop methods and standardize procedures for testing of grain quality and value-added traits.

Many new crops in development will offer enhanced nutritional properties, such as increased oil, protein levels, or starch content, or qualitative alterations in the amino acid content or the fatty acid composition of the oil. Tests to verify and quantify the presence of these properties are being developed primarily for pricing and marketing purposes.

One very promising technique for rapid assessment of these traits is near-infrared spectroscopy (NIRS). The pattern of absorption or reflection of NIR light is unique for each compound, and NIRS determines the quantity of a compound present by measuring the amount of NIR light absorbed or reflected. Following initial purchase of NIR spectrophotometers (about $20,000), the tests are inexpensive, rapid, and simple enough to be performed by on-site personnel with minimal training, and have been found to be accurate and reproducible. This technique has already become popular among grain elevator operators for on-site testing of high-oil corn (HOC), and it can also be used to measure protein and starch content as well as the levels of a specific amino acid or fatty acid in grain or processed products. GIPSA recently began offering a testing service upon request for corn oil, protein, and starch using NIR technology.

Other testing methods will be required to analyze new crop varieties for specific proteins or to quantify high-value products such as vaccines or pharmaceuticals, for example. One such test, the ELISA (enzyme-linked immunosorbent assay), analyzes for a specific antibody reaction that marks the presence of the expected protein. ELISA tests and similar assays are currently used to detect mycotoxins in corn and other grain. These procedures require minimal equipment, and only a very small amount of the product needs to be tested. Multiple samples can be processed in a few hours, making the assay relatively adaptable for on-site testing at grain elevators or processing plants.

Because of EU regulations, as well as the possibility that genetically modified foods will be ineligible for certification as "organic" in the U.S., EU researchers, private seed companies, and commercial testing services in the U.S. are developing quantitative tests to detect protein and DNA in genetically engineered crops and products. The ELISA test can be adapted to detect genetically modified protein. A number of methods are available to detect specific DNA sequences, the most powerful being the polymerase chain reaction (PCR). In PCR, specific DNA fragments are reproduced or amplified and separated on a gel, and the size and intensity of the DNA band produced indicates the presence and quantity of foreign DNA within the plant.

PCR is a very sensitive procedure, capable of detecting specific DNA sequences at very low levels, so reliable standards and controls are necessary, and the sensitivity of the technique can lead to false results if the methods are not precisely followed. As a result, PCR will not lend itself to easy adaptation for rapid, on-site testing. Several companies have recently begun offering PCR-based testing of biotech products, and the procedure will likely remain a service provided by contract labs.

If a need develops to certify that products contain no DNA or protein resulting from genetic modification, a consensus on an acceptable threshold level of detection will be critical—will there be a minimal level of genetically altered material allowed in a sample while still permitting a designation that it contains no biotech products? Current genetic testing methods are so sensitive that in a test for zero tolerance—a guarantee that the product contains no DNA or protein resulting from genetic modification—nonbiotech products would fail to meet the zero-tolerance standard if they have, for example, had minimal inadvertent contact with biotech products through minor storage and handling overlaps. It would be wise to set minimally acceptable standards high enough that detection by standard methods is meaningful and accounts for variation between testing facilities. Scientific and industrial communities in the U.S. and Europe are currently proposing to set a sample threshold of 1-3 percent genetically engineered material for designation of a product as containing no protein or DNA resulting from genetic modification. **AO**

Terri Dunahay (202) 694-5312
tdunahay@econ.ag.gov