Biotechnology and Identity-Preserved Supply Chains

A Look at the Future of Crop Production and Marketing

by Nicholas Kalaitzandonakes and Richard Maltsbarger

After decades of research and development, agricultural biotechnology now delivers part of its long-awaited commercial value. In the past three years, crops with herbicide tolerance and resistance to particular pests have led the way to commercialization. Quality-enhanced crops, such as corn with high oil or lysine content and soybeans with high oleic or sucrose content, are also being developed and in some cases marketed on a limited scale. Biotechnologies targeting quality enhancement could change crop production and marketing in the future.

Technological advances initially focus on large markets. Livestock feed uses over 75 percent of the world corn and soybean production. Anti-nutritional factors, however, constrain the value of these feeds. Soybean meal, for example, is the most commonly used protein supplement in animal feed but is nutritionally constrained by trypsin inhibitors. Processing overcomes some of these constraints but also downgrades its feed value. Removal of nutritional-inhibiting factors through genetic engineering eliminates processing degradation.

Genetic engineering can also enhance food value. Three-fourths of the vegetable oils consumed worldwide derive from soybeans, canola, sunflower, and palm. All commodity oils are rich in polyunsaturated fatty acids that are prone to degrading oxidation during storage. Preservation by hydrogenation forms trans-fatty acids with properties similar to those of fully saturated fats associated with high cholesterol. Genes that encode enzymes in soybeans, canola, and other crops are being used to modify their fatty acid profiles.

Bioengineering may enhance the economic value of crops in still other ways. Genetically engineered crops may produce bioplastics, enzymes, and enhanced nutritional and pharmaceutical agents—known as nutraceuticals. Agracetus, a wholly owned subsidiary of Monsanto, has begun clinical trials with human antibodies purified from genetically engineered corn and soybeans. These plantibodies are to be used as anti-cancer agents.

While most quality-enhanced crops are currently at a developmental stage, some have been brought to the market. Preliminary data show their significant value potential. Yet, for such value to be realized, plant identity must be preserved in production and marketing supply chains (identity preserved, or IP). If co-mingled with commodity crops, quality differentials and value are lost. Existing supply chains are not well organized for identity preservation. What factors will shape the new IP supply chains, and how will they look and operate? We begin with a look at the supply chain of high-oil corn and then new IP crops on the horizon.

The case of OPTIMUM high-oil corn

High-oil corn (HOC) has been the most visible IP grain to reach market. HOC averages 6–8 percent oil content compared to 3 percent for conventional corn varieties. It also exhibits increased levels of crude protein and amino acids. Virtually all high-oil corn varieties are marketed under the OPTIMUM brand developed by DuPont. In the United States, OPTIMUM was first introduced in 1992 and was planted on approximately 1 million acres in 1997, indicating a brisk interest by end users.

Initial estimates for HOC show added value up to $0.44/bu in livestock production. The added value stems from projected savings in supplemental fat and improved digestibility and feed efficiency. The values of HOC change with prices of substitutes, complementary inputs, or the final products.

In 1997, 70 percent of all HOC was produced by farmers or feeders who fed it directly to their livestock. HOC growers contracted the remaining 30 percent for export, sold typically at premium prices to countries where fat additives are in short supply. Widely differing market values between domestic and export markets encourage a two-tiered marketing strategy for OPTIMUM HOC. In the domestic market, value is captured by premium prices on seed corn sold by more than eighty licensed seed companies, including market leaders DeKalb and Pioneer. In export markets, DuPont captures value by contracting with end users and with farmers. Identity preservation and supply chain logistics are managed through a strategic alliance with Continental Grain.

DuPont contracts with farmers include a fixed premium per bushel delivered. For 1998 the premium paid for OPTIMUM HOC is $0.25 per bushel, an amount which more than offsets the $0.07 per bushel seed premium paid by the grower. HOC may be delivered to the contracting elevator or stored on farm for an extra premium payment. Buyer calls for delivery of grain stored on the farm allow elevators to coordinate storage and transportation and manage capacity utilization helping to avoid management error if deliveries were to arrive during peak harvest operation times. In 1997, the on-farm storage premium was $0.05 per bushel for buyer-call delivery contracts.

Table 1. Pipeline of biotechnology quality traits in major crops

Product	Technology	Developmental stage	Value
Corn	High lysine	Pre-commercial	Moderate
	Low N fertilizer need	R&D	High
	Low phytate	R&D	Moderate
	Modified starch	Pre-commercial	Low
	Phyto-manufacturing[a]	R&D	Moderate
Soybeans	High oleic	Commercial	Moderate/high
	Improved protein	Pre-commercial	High
	High stearic	Pre-commercial	Low
	Phyto-manufacturing[a]	R&D	Low
Canola	High laurate	Pre-commercial	Low
	High oleic/low linoleic	Pre-commercial	High
	High saturates	R&D	Low
	High erucid	Pre-commercial	Low/moderate
	Phyto-manufacturing[a]	R&D	Low

Source: Developed through personal interviews with leading biotechnology developers.

[a]Phyto-manufacturing, also known as molecular farming, involves production of substances at molecular levels (e.g., enzymes, plantibodies).

Delivery systems coordinated through Continental Grain utilize grain stocks from elevators and on-farm storage to fulfill export agreements developed by DuPont. Grain delivered to one of over eighty export contracting elevators is shipped in segregated loads to a port location where it is packaged for delivery in 50,000-bushel loads. Near infrared technology is used to assess nutritional composition at each delivery point in the chain. The grain is often analyzed for oil content and other characteristics up to three times at elevator, rail, and barge port facilities.

Future identity-preserved crop technology

Most quality modification biotechnology has focused on corn, soybeans, and canola. Table 1 reports key technologies, their developmental stage, and our estimates of their potential value. Estimated values reflect both the size of the anticipated markets and the degree of technological advance. Wheat, alfalfa, sorghum, sunflower, and other crops are also being genetically modified for improved quality traits, but at a slower pace.

Commercialization of biotechnology quality traits will likely follow the current trends of the computer software markets in which increasingly sophisticated versions of technology continually supplant previous models. "Old versions" become less valuable upon release of "new versions" but they may still be valuable in the market depending on the needs of end users. In the case of OPTIMUM Quality Grains, HOC and the newly released high-oleic soybeans are positioned to become the platforms for stacking traits valuable to end users (table 2).

Both the domestic and international crop markets will change to capture the benefits of genetically modified crops. High-value and low-volume IP crops, such as plantibodies, will likely be produced in vertically integrated systems in which technology companies can better capture innovation profits while maintaining tight controls on quality. For crops with relatively small added value per unit of product, such as HOC, technology originators will likely capture innovation profits through loosely coordinated activities such as licensing agreements.

Some variants of coordinated activities in IP markets have emerged. Mycogen, a U.S. biotechnology and seed company, develops, produces, and delivers proprietary high-oleic sunflower seeds exclusively to AC Humko, the world's largest marketer of edible oils. Similarly, DuPont, through its recent equity investment in Pioneer Hi-Bred (the largest commercial seed company in the world), and its acquisition of Protein Technology International (with over 70 percent market share of the food-quality soybean protein market), is preparing for tight coordination of IP supply chains, from seed to the end user. Farmland Industries, the largest U.S. cooperative with some 500,000 members and major positions in grain production and distribution, as well as livestock production, processing, and distribution, offered HOC contracts to selected members in 1998. Through its newly launched System 21 program, it hopes to coordinate IP supply chains for all major crops. Monsanto and Cargill are preparing to jointly develop and commercialize quality-enhanced bioengineered crops targeting the feed and other processing industries. Their joint venture combines Monsanto's capabilities in biotechnology and seed with Cargill's global processing infrastructure and marketing and logistics capabilities.

Factors shaping IP supply chains

The success of identity-preserved products and coordinating marketing chains ultimately depends on their ability to add value. Tangible gains in the form of premiums, growth, or increased value-in-use will entice producers, merchandisers, and end users into IP production/marketing chains. For most IP chains, the distribution of added value will be determined by three factors: • the bargaining position of each participant, • the amount of risk assumed by each participant, and • the perceived costs relative to traditional commodity systems.

The strength of intellectual property rights, uniqueness and desirability of technology advance, ownership of unique physical and/or intangible assets, and command over market segments will shape the bargaining position of IP supply chain participants. Those with stronger bargaining position will naturally command a larger share of the added value and may have multiple options for positioning and asset ownership along the chain.

The amount of added value distributed to each participant along the chain must also be related to the price risk, output quantity risk, and product quality risk assumed by each participant. Different coordinating activities may be used to appropriately align risks and returns. For example, production contracts with pre-set delivery levels shift output quantity risk to the producer and, therefore, usually involve higher premiums. Similarly, variations in quality may be tied to a sliding premium scale to align quality risks with the share of value added. Participants better positioned to diversify one or more of such risks will typically have a larger claim on the added value.

Finally, perceived losses shouldered by individual participants must be compensated to maintain participation, as the following example illustrates. Elevators can often generate profits by "blending." They accept delivery of many different quality levels of No. 2 yellow corn and discount price for quality

Table 2. OPTIMUM Quality Grains: product pipeline and per acre added value

Year	Product	Added Value
Corn		
1998	HOC+high oleic	\$65–\$90
1999	HOC+high lysine	\$80–\$85
2001	HOC+high lysine+high methionine	\$95–\$100
Soybeans		
1997	High oleic	\$25–\$30
2000	High lysine	\$35–\$40
2001	High lysine+high oleic	\$40–\$45
2001	High lysine+high methionine	\$35–\$50
2002	High oleic+low saturate+high lysine, high methionine	\$45–\$50

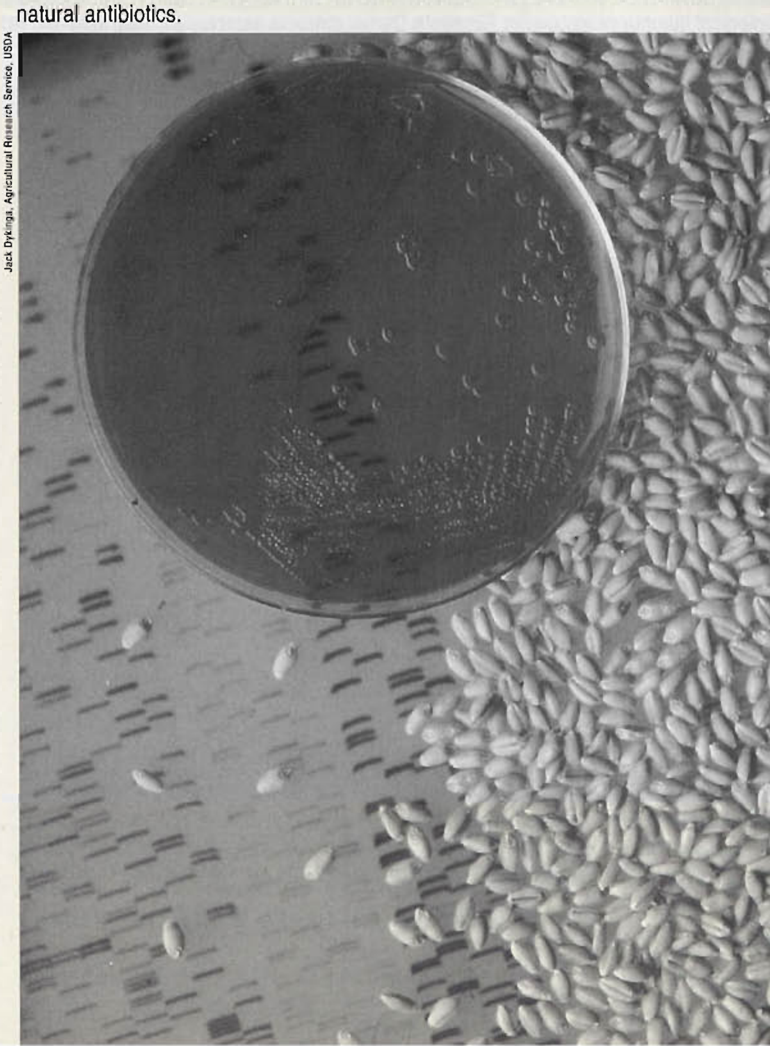
Source: OPTIMUM Quality Grains.

infractions. Then, by using both high- and low-quality loads of No. 2 yellow corn, the elevator "blends" No. 2 yellow corn of sufficient quality. By mixing scrap-quality with high-quality corn, the elevator can capture a profit which exceeds that from separate sales of high- and low-quality grain. Most IP systems would eliminate blending because each load must be segregated by its compositional factors.

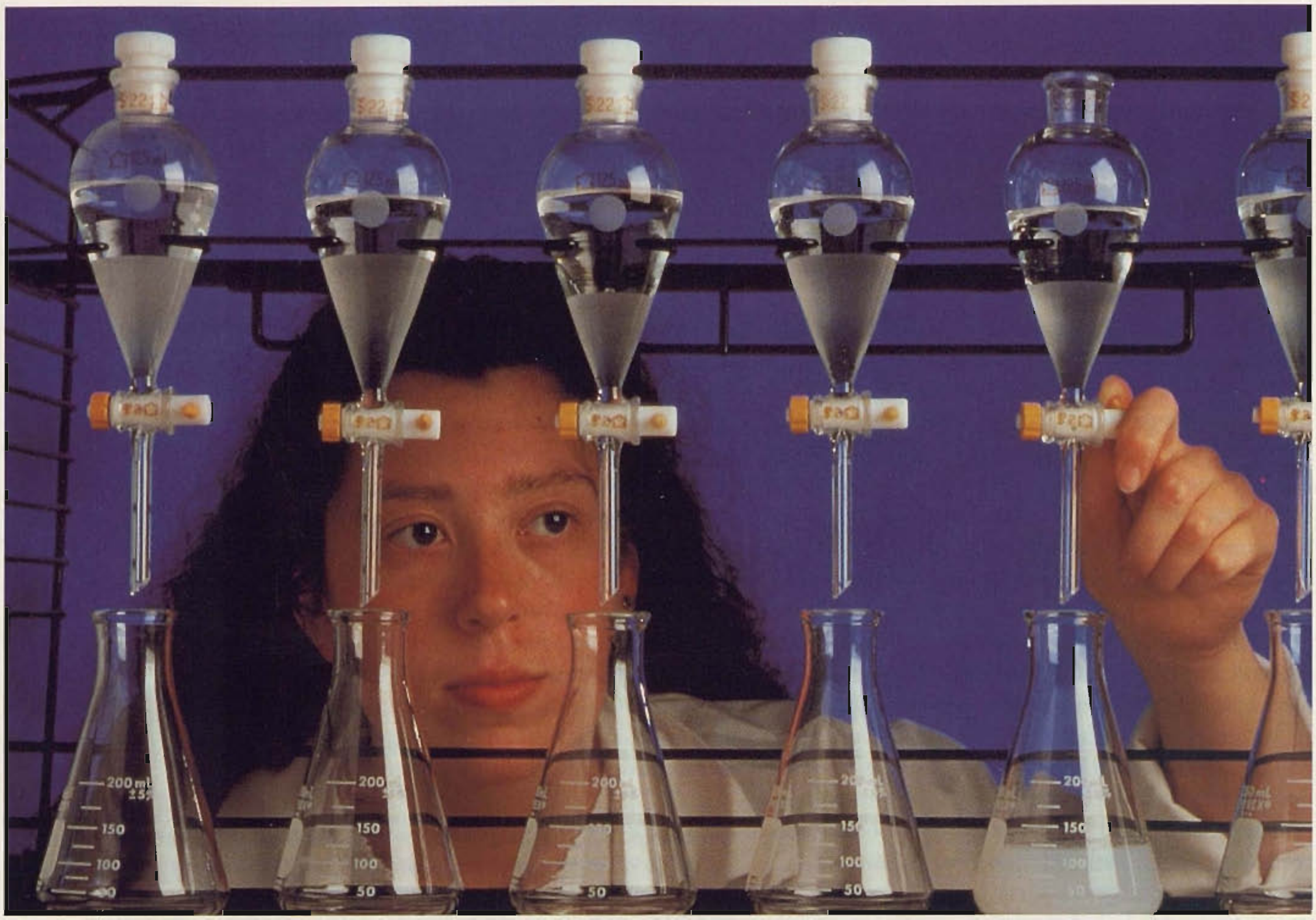
External factors may also affect participation in IP supply chains. For example, the recent reversal of long-standing government policies supporting certain crop commodities increased producer price

Wheat seeds treated with bacteria like those colonized in this petri dish are nearly immune to wheat take-all, a root-destroying fungal disease. The sequencing gel in the background bears the genetic code for bacterial enzymes that synthesize natural antibiotics.

Jack Dykinga, Agricultural Research Service, USDA



Scott Bauer; Agricultural Research Service, USDA



Biological laboratory technician Elizabeth Denvir extracts samples for total lipid and fatty acid composition.

risk. The added risk may encourage farmers to contract with companies offering set prices to grow their IP products.

IP chains in the long run

Eventually, a true IP crop merchandising system will likely emerge and operate in parallel with a diminished, traditional commodity system. Organizational innovation and investment in new assets will be important forces that mold the new IP system. The new IP crop merchandising system will not only distribute but it will also create *new* value through

- improved interface between the end user and technology originator so that less time is spent in the lab and more is spent in the market;
- expanded marketing of branded products;
- creation of new markets and/or new services (for example, food safety warranties and production practices labels);
- increased market segmentation; and
- improved logistics and supply chain management.

The ability to build effective IP chains could ultimately become a source of competitive advantage. Success will likely require effective use of technology, a superior network of partners, and a suitable geographic distribution of assets. Technology is not limited to biotechnology or proprietary germplasm, but will also include quality control and compositional measurement technology as well as logistical software. Logistical software includes financials, tracking, optimization of transportation and storage, system modeling to identify focal issues, and the ability to engage each participant in actively improving the chain. With incentives to innovate and share new technologies within tightly coordinated systems, closed membership supply chains or networks may emerge as the model of IP supply chain in the biotechnology industry. ■

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■ For more information

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