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# Emerging Genetic Engineering Technologies and Minnesota Agriculture

## Stanley C. Stevens

New agricultural production technologies are inherently double-edged swords. The power of the genetic engineering technologies to fundamentally redesign a plant or animal by tinkering with its genetic core is almost mind-boggling, and the opportunities and threats it carries for agriculture are enormous. In this article I ponder the nature of the structural change that is likely to result from the inevitable onset of some of these technologies. I focus especially on the implications for traditional midwestern farming.

### Adapt or Fade

In the past, economic and political interests both throttled and filtered how new technologies ultimately unfolded into new realities. It wasn't always a rapid unfolding, of course. Some readers will remember the oleomargarine battles of the 1950s. Others are perhaps old enough to remember when threshing machines were still held to be the ultimate in harvest equipment. In the end, however, consumer and producer uncertainty, expressed in political terms, eventually yielded to stronger economic forces.

As this article was being written, a new wave of consumer and producer uncertainty is fueling a political resistance against genetic engineering. I believe, however, that this resistance will only temporarily delay the ultimate structural changes that will transform agriculture as we know it today. In this article, therefore, I focus on the emerging opportunities for those willing to adapt and on the serious threats to those who hold to the past.

### New Possibilities

The first wave of the new genetic engineering revolution has principally taken the form of Roundup Ready® soybeans (which are resistant to the herbicide Roundup) and Bt corn (which is resistant to attack by corn borer). A myriad of new products that have desirable qualities (such as high-oil corn and soybean oils low in saturated fat) are rapidly coming to market.

And this is only the beginning. Far more exotic products and procedures can be expected, given a little time. I'm told that it's now possible to move any gene from plant to plant, plant to animal, animal to plant, or animal to animal. Possibilities include non-legume crops that can fix nitrogen, crops that tolerate acid- and salt-laden soils, and even crops that can be irrigated with sea water. In addition, meat production will become

(See *Emerging Agriculture* page 2)

# The Big Shift from a Food Supply to a Food Demand Chain

## Jean D. Kinsey

The food and agriculture industry looms large in our national economy because it employs over 14 percent of all workers and accounts for 9 percent of the gross domestic product. Fully 71 percent of workers and 60 percent of the gross domestic product in this sector are devoted to wholesale/retail activities. Retail activities are especially important because retail food stores, restaurants, and bars sell over $890 billion of food and drink each year, which is more than any other retail sector—including automobiles.

The forces that shape the supply chain of the food and agriculture industry are shifting dramatically. Think of the supply chain as a set of railroad cars being pushed by a powerful locomotive called production agriculture. For decades, new agricultural techniques increased yields, so the train added cars to deliver goods to emerging world markets. As the train approached these new markets, the cars at the front of the train were pulled by even more powerful locomotives known as consumers—and their market representatives, retailers. These new consumer/retail engines pulled the train ever faster, but in more diverse directions than the original locomotive planned to go! Eventually, the train's managers had no choice but to stop the train and split it into several smaller ones, so the rear and front engines could move in the same direction, that is, toward new markets.

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University of Minnesota Extension Service

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more efficient with the introduction of correctly tailored feeds and animals designed to convert this feed more efficiently to meat.

It is now possible to redesign crops to produce fuels, fibers, plastics, and other industrial products and to use genetically engineered drugs to combat a wide variety of diseases. All of these projects and more become reasonable candidates for the input of large sums of research money because the potential benefits to society are enormous.

In the coming years, the rate of technological change resulting from these investments is likely to accelerate. What will this mean for Minnesota agriculture?

## Looking Forward by Looking Back

The production of hybrid seed corn can be reasonably viewed as a gene-manipulating technology and serves as a good, though slower-paced, example of what we can expect in the future as genetically altered plants and animals work their way through the agricultural system. A close study of the role of hybrid seed corn in producing structural changes in Minnesota agriculture during the past 60 years gives us some clues about where we are heading. The introduction of hybrid seed corn had a substantial impact on farm income, farm size, land use, land values, government farm policy, world food security, world trade, and the cost of food. Let's look at some of these effects.

The early—but slow—adoption of hybrid seed corn by farmers is summarized by one seed company (Pioneer) on its Web site (http://www.pioneer.com) as follows: "Our corn breeding program began in 1913. The first actual sales of seed were made in 1924 and the company was incorporated in 1926. Ten years later, sales were slightly more than 75,000 units. It was not until 1949 that annual sales passed the million-unit mark in North America, and 1981 before we passed 10 million units worldwide." Figure 1 shows that the nation's corn yield has increased approximately five-fold since the use of hybrid corn started to spread in the late 1930s.

Complementary technologies have also played a role in increasing corn yields. Commercial fertilizer was used more intensively after World War II, and chemical weed control was introduced in the late 1950s. Both have contributed to increased corn yields. In the 1970s, big machinery, and the prosperity that allowed farmers to buy it, improved the timeliness of many farming operations such as planting. Irrigation and improved drainage also contributed to higher corn yields from 1925 to the present day.

The quintupling of corn yields in 60 years caused an overwhelming surge in the supply of corn. Most of this corn was used (and continues to be used) to feed livestock, but corn production during these years tended to exceed demand, especially after the mid-1950s. Since the 1920s, the demand for corn has only increased fourfold—the population has nearly doubled, and per capita meat consumption has (almost) doubled from about 150 pounds in the 1920s to about 260 pounds today.

This failure of demand to keep up with increases in productivity meant that prices were kept lower than would otherwise have been the case. Until the 1950s this downward price pressure wasn't quite so visible because land that had been used for corn was shifted to the increasingly popular soybean (figure 2). In the 1960s and 1970s, expanded export markets also helped keep prices from dropping dramatically, as did the expansion of the corn sweetener and ethanol domestic markets in the 1980s and 1990s.

Even so, corn prices were lowered by 1) improved feed-conversion associated with the higher quality of corn/soybean meal rations, 2) improved feed-conversion rates that resulted from selective and cross-breeding of livestock, and 3) shifts in consumer demand for more poultry (figure 3), which are much more efficient than cattle at converting feed into meat.

Economic forces during 1925–95 were increasingly moderated by government action, especially after the mid-1950s, slowing the structural change that otherwise would have resulted. The government support price for corn, introduced during the Great Depression, was gradually increased. At first this had no major side effects on the market. The initial 34 cents ($5.69 in current dollars) per bushel in 1933 grew to a peak of $1.62 ($9.83 in current dollars) by 1954, as shown in figure 4.

By the late 1950s, higher and higher government payments began to make the government a market participant itself, rather than merely have it serve as a safety net for market participants. These high rates of support stimulated more corn production than was needed by the market. As a result, the government-managed corn inventory increased, as did the market's perception of a corn "surplus." Market prices had to drop.

The long-run downward pressure of hybrid-corn has been felt more intensely since the late 1950s, as shown in figure 4. Prices adjusted for inflation have never really recovered since the mid-1970s.

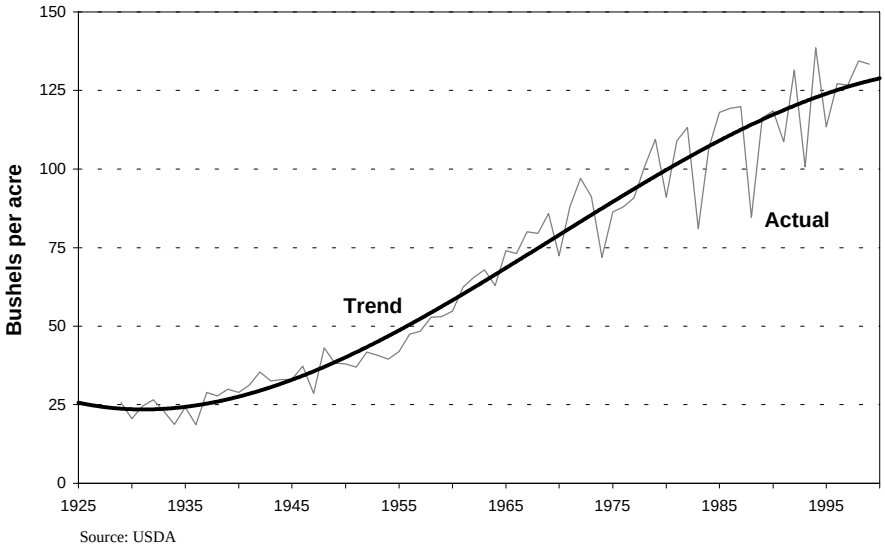
## Effects on Land Markets

Not all land suitable for growing corn is of the same quality. There are certain basic costs inherent in planting any crop, such as the cost of seed, weed control, fertilizer, fuel, and so on. Higher quality land means that a constant expenditure will result in higher yields than will lower quality land. Imagine a chart that shows the distribution of all corn land sorted from highest quality (on the left) to lowest quality (on the right). The cost per bushel of producing corn increases from left to right as land quality declines. At some point, it will cost more to grow the corn than the price it can be sold for.

Over time, if non-land costs are steady and prices fall proportionally by more than yields increase, farmers will remove lower quality land from corn production. Since the mid-1950s, however, legitimate market signals to reduce the amount of land planted to corn have not been heard. The government target prices and loan rates on corn and the array of related payments tied to the production history of the land meant that farmers found it profitable to continue to grow corn—even when there was no real demand for it, as shown in table 1.

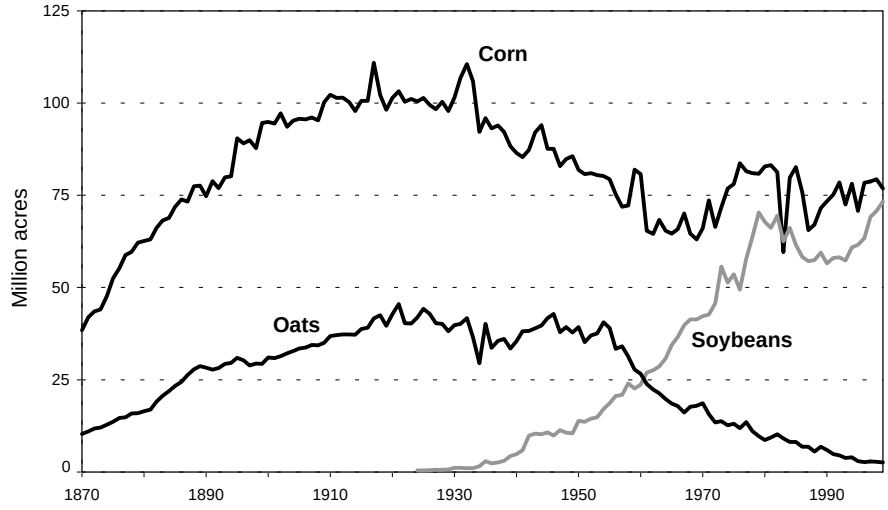
In the U.S. from 1925–95, the amount of land planted with corn has hovered around 75 million acres, as shown in figure 2. Federal farm policy

**Figure 1. U.S. corn yields from 1925 to present**



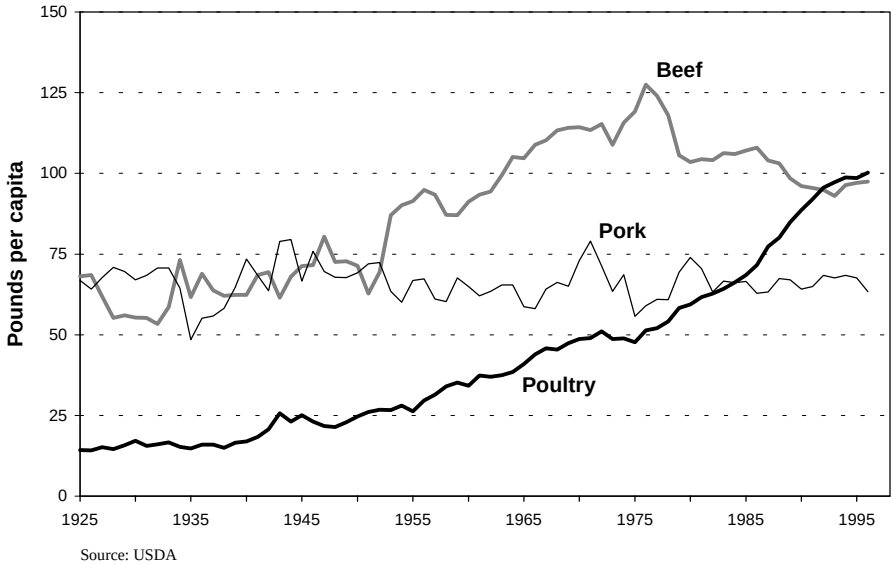

Source: USDA

**Figure 2. U.S. harvested cropland from 1870 to present**




Source: USDA

**Figure 3. U.S. per capita meat consumption from 1925 to present**




Source: USDA

has focused on maintaining the status quo and has thereby stabilized the amount of land planted with corn at around 75 million acres.

In recent decades, however, land values have stopped showing the steady, reliable advance of the 1940s and '50s, as shown vividly in figure 5—which tracks land values in Southwestern Minnesota. The figure shows a hint of a plateau in real land values (expressed in 1998 dollars) in the 1960s. This level was quickly revisited again in the mid-1980s when perceived surpluses once more led to drops in market prices.

This plateau in prices in the 1960s suggests that the 1970s were a temporary aberration amid long-term structural changes in the value of land. Since the 1970s, however, structural changes called for by the market were suppressed by federal farm programs that operated as if low prices were the aberrations.

Today, as new ways of farming emerge, the difference between what the market is calling for and what federal farm policies provide is likely to become even larger. It will take time but this difference will eventually affect the market price of land, just as it eventually did in the past. Despite government programs, Minnesota cropland values are likely to decline because less and less land is needed to grow the crops demanded by the market. The value of the land that remains in production will likely vary less from region to region because land quality influences will be overcome by science's increasing ability to incorporate just the right gene to maximize crop yields under a wide variety of soil, weather, and other conditions.

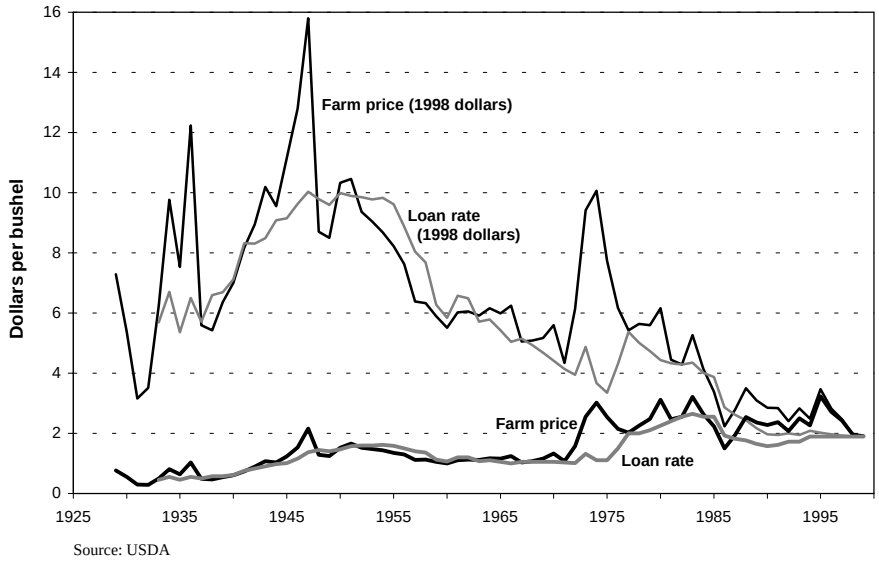
## Opportunities and Threats

The traditional food-production focus of crop and animal agriculture will be accomplished much more efficiently in the future by new agricultural structures that will make the old way of doing things obsolete. Moreover, crops and livestock that lack the specific qualities demanded by the market will sell at lower and lower prices.

In the future it will be important for farmers to organize themselves around very specific or unique products. Farmers who align with one or several of

(See *Emerging Agriculture* page 4)

**Figure 4. U.S. corn prices and loan rates from 1925 to present**

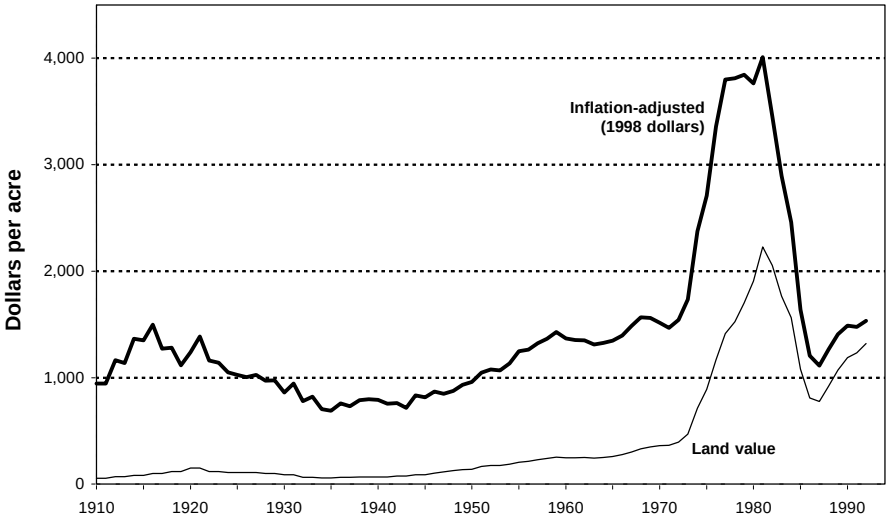



Source: USDA

**Table 1. U.S. corn target prices and loan rates in dollars per bushel for 1955–95**

| Year | Target price | Loan rate | Loan rate adjusted for inflation |
|---|---|---|---|
| 1955 | NA | 1.58 | 9.62 |
| 1960 | NA | 1.06 | 5.84 |
| 1965 | 1.25 | 1.05 | 5.42 |
| 1970 | 1.35 | 1.05 | 4.42 |
| 1975 | 1.38 | 1.10 | 3.35 |
| 1980 | 2.35 | 2.25 | 4.44 |
| 1985 | 3.03 | 2.55 | 3.87 |
| 1990 | 2.75 | 1.57 | 1.96 |
| 1995 | 2.75 | 1.89 | 2.02 |

**Figure 5. Southwestern Minnesota estimated land values from 1910 to present**




Source: University of Minnesota

*(Emerging Agriculture* from page 3)

these networks will be the ones who prosper in the new agriculture.

As the old methods become less and less profitable, traditional farming operations will eventually fade away. The pace of this exodus from farming will be influenced—but not stopped—by the generosity or austerity of government "farm programs" that respond to the stresses experienced by those who cling to the old structure.

In the coming decade, new industrially oriented crops (such as crops that produce fuel and construction materials) could keep the land that currently produces food-oriented crops in production. They could even stabilize or improve land prices if the new crops acquire strong consumer acceptance. Without new land-intensive crops, however, land values will likely decline.

Agricultural exports will decrease as importing nations seek greater self sufficiency in food and fiber production. Indeed, some of these nations will grow crops specifically engineered for their soil type and climate. In addition, importing nations may buy products from exporting nations that are either nearer at hand or currently converting unproductive land to useful production. Pharmaceutical crops, on the other hand, will probably be greenhouse crops, and won't require much traditional cropland.

The new agricultural structure of the future is certain to increase the welfare of people the world over, but the transition will be loaded with perpetual challenges to change and adapt—but will present enormous opportunities for the farmers and producers of Minnesota.

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(*Food Supply* from page 1)

Today, the food supply chain is being split up, moved faster toward a variety of markets, pushed by new science and technology, and pulled by consumer demand. How did this happen?

Six major factors have changed the face of the food supply industry during the past 20 years.

- Changing consumer tastes and demographics
- Widespread use of the Uniform Product Code (UPC)
- The rise of Wal-Mart as a dominant market force
- Introduction of the Efficient Consumer Response (ECR) system
- Company mergers
- The changing nature of wholesaler/retailer interactions

These six factors have led to a dramatic realignment of the food supply chain, to the point where we should probably now think of it as a food demand chain. Changes in production no longer drive the market. Most of the changes in this sector have been driven by new science and technology, new business management practices, and by people's evolving social and cultural attitudes. Some of these changes went largely unnoticed at first, but today have resulted in a fundamental change in the way the food industry does business.

## New Consumer Tastes and Characteristics

Many changes in consumer behavior and preferences are explained by demographics. Today, households are more heterogeneous than ever. They are smaller, richer, and more likely to have a female member in the labor force. Table 2 shows that only one-fourth of the nation's households are made up of married couples who have children present in the home. These households have the highest percent of women in the labor force (71 percent overall) and the highest median annual income ($51,768). In 64 percent of these families, both parents are employed.

These characteristics are interrelated. One of the most important demographic trends relating to food consumption is that women have entered the labor force in large numbers, thereby increasing household income. The fact that these women have less time to shop and cook and more money to buy ready-to-eat food means that we are seeing more calls for convenience, more purchases of food on the go, and a decline in home cooking.

**Table 2. Workforce and household characteristics of American women**

| Type of household | Total of all households % | Women in labor force % | Median income $ |
|---|---|---|---|
| Single | 30 | 68 | 16,398 |
| Single parent | 16 | 66 | 28,600 |
| Married, no children at home | 27 | 54 | 49,936 |
| Married, children at home aged: | 25 | | 51,768 |
| <6 | | 63 | |
| 6–12 | | 76 | |
| 12–17 | | 80 | |

Almost a third of the nation's households consist of only one person: 30 percent of these households are women over the age of 65, and 68 percent of the women in single households are in the labor force. As a result, the average woman seeks to reduce time spent shopping and preparing food. Studies show the time the typical woman spends at home preparing the evening meal decreased from two hours in 1967 to less than 45 minutes today. In addition, the typical woman today expects to devote only 15 minutes preparing a meal and spends over 20 percent of her food dollar on take-out food.

## Adoption of the Bar Code

The UPC bar code, born in 1972 at the Uniform Product Code Council, was designed to eliminate the paper price label. Under the original system, bar codes were scanned at the checkout counter, a computerized cash register displayed the price, and store managers were alerted when inventory was getting low. Today, UPC systems are also used to control inventory, order products automatically, and report (in great detail) exactly what types of products consumers are buying and at what time of the day, week, or year.

Bar codes now appear on cases of produce, trucks hauling goods, and shipping containers. Bar codes are used to pick foods in warehouses and drop them on the right pallets for delivery to the right stores at the right time. They are even used to track food through the grocery store so the vendor can bill the store only after the product has actually been sold (that is, scanned as sold at the checkout counter).

Retailers are just now beginning to use the large amount of consumer information stored in their computer systems. For example, approximately 50 percent of all retailers nationwide have implemented some type of frequent shopper or customer loyalty program, and a smaller number have figured out how to use their consumer data to reduce costs and increase sales.

## The Rise of Wal-Mart

Since the early 1980s, Wal-Mart has built its business on knowing exactly what its customers were purchasing on a daily basis and in asking its vendors to replenish shelves in a timely manner. This way, Wal-Mart avoided tying up cash in inventory and could work with vendors to drive down the cost of goods sold and the cost of moving them from manufacturer to consumer. This enabled

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(*Food Supply* from page 5)

Wal-Mart to offer lower prices and capture an ever-increasing share of the market.

Wal-Mart is now the largest retailer in the world with over 3,600 stores. It has captured 13 percent of all the sales in grocery, discount, and supercenter stores in the U.S. (Its nearest rival, Kroger, only has 6 percent of this market.) Wal-Mart accounts for about 5 percent of all food sales in the U.S., making it the third-largest food store in the nation. Because Wal-Mart is large and efficient, it has forced the rest of the industry to become more efficient and more organized.

## Introduction of the Efficient Consumer Response System

In 1992 the rest of the retail food industry woke up and realized it needed to copy the Wal-Mart model. Accordingly, the food supply industry developed the ECR system, which shares information between retailers and vendors. It allows for deliveries to be based on sales, lowering storage costs. The system has three main components.

### Electronic Data Interchange

A recent development is electronic data interchange (EDI). This allows businesses to order merchandise, slim down the offerings in each food category, streamline delivery, and reduce overall costs. EDI, however, requires that suppliers and retailers use compatible computer systems, which takes capital to install and skilled personnel to operate.

Sharing private sales data with vendors also requires a new level of trust among businesses in the food supply chain. This was asking a lot of an industry made up of 130,000 stores, all operating on thin margins and accustomed to treating suppliers as adversaries. Consequently, by 1998 only 7 percent of retail stores were using EDI.

### Collaborative Planning, Forecasting, and Replenishment

As usual, Wal-Mart was in the forefront when it came to developing new systems. In 1996, Wal-Mart (in conjunction with Warner Lambert) tested a new system of information exchange to study the effects on the sales of Listerine. This system, called Collaborative Planning, Forecasting, and Replenishment (CPFR), involves the manufacturer (Warner Lambert) and the retailer (Wal-Mart) separately forecasting future sales, sharing these forecasts, and tailoring their orders and deliveries accordingly.

Use of CPFR should allow the rest of the food supply industry to provide products that exactly meet consumers' preferences. Figure 6 illustrates this new way of thinking about the food supply chain.

In 1998 only 9 percent of food retailers and 26 percent of food wholesalers were using CPFR. By 1999, only one year later, 26 percent of retailers and 44 percent of wholesalers said they were planning to use it. In contrast, Wal-Mart is already using CPFR with over 7,000 of its suppliers.

### Scan-based Trading

A more recent development is scan-based trading (SBT), which is a part of CPFR and is moving rapidly into the industry. Using SBT, retailers are not billed for their inventory until after the goods are scanned and sold to the consumer. In addition, the retailer does not risk buying inventory that won't sell or moves slowly. As a result, a retailer improves cash flows, reduces the need for capital, and improves his or her return on assets.

Most manufacturers who use SBT do not bill retailers for 30 days and, in effect, extend a 30-day interest-free loan to the retailer. In return, the manufacturer learns in real time what is moving off the shelf and is able to promptly replenish the shelves. (This, course, also benefits retailers by reducing their labor costs.) A survey conducted in 1999 shows that only 59 percent of retailers and 16 percent of wholesalers plan to use SBT. Most current users of SBT are in the snacks and beverage industry.

## Mega Mergers in the Food Chain

Today, information technology matches supply and demand in ever smaller and more specialized niches in the food market. Because this is best done by large companies, mergers and acquisitions are commonplace. Efficiencies of scale—driven by information technology—are leading to vertical integration in all segments of the food supply industry. For example, in 1990 the four leading grocery chains accounted for only 16 percent of the nation's food sales. Today the market leaders—Kroger, Albertsons, Wal-Mart, Safeway, and Ahold—are responsible for fully 40 percent of all retail food sales.

Most mergers are motivated largely by the need to reduce delivery costs and lower the cost of goods sold. In other words, most mergers are designed to lead to economies of scale. Large corporations have greater bargaining power with manufacturers, use more efficient transportation and ordering systems, and utilize information technology effectively to manage inventory throughout the entire food-distribution chain. Industry estimates, for example, show that retail mergers can reduce the cost of goods by 0.5 percent and save another 2.5 percent in the cost of operating the food-distribution chain.

## The Changing Face of Wholesaler/Retailer Interactions

Traditional wholesalers buy food from a variety of producers, reorganize the produce for distribution to retailers, load it onto trucks, and deliver it to retailers. Today, wholesalers and retailers interact in three distinct ways—all of which are different from the traditional way of doing business.

### Self-Distributing Retailers

Self-distributing retailers own their own distribution centers (DCs). They buy directly from manufacturers and producers, who deliver food products to the DCs. About 35 percent of the nation's DCs are in this category, which includes market leaders (Kroger, Albertsons, Wal-Mart, Safeway, and Ahold) and a number of smaller grocery chains. The benefits of this arrangement are manifold. The labor expenses of self-distributing retailers as a proportion of sales at inventory costs are 0.9 percentage points lower than the costs of third-party wholesalers, and their nonlabor expenses are 1.3 percentage points lower. Moreover, because self-distributing retailers, as a general rule, move 39 more cases of produce per hour in their

warehouses than traditional wholesalers, their operating costs, as a proportion of sales, are 1 percentage point lower than traditional wholesalers.

#### Direct Store Delivery by Manufacturers

Direct store delivery is the system whereby manufacturers deliver their own products directly to individual stores and (usually) arrange it on shelves for retailers. Direct store delivery makes up 27 percent of the wholesale food market. Manufacturers in the direct-store-delivery segment of the market are usually strong proponents of SBT because it gives them direct access to information about what consumers are buying and when.

#### Third-Party Wholesalers

Third-party wholesalers are the traditional food assemblers and make up the remaining two-fifths of the wholesale industry. Third-party wholesalers buy food from manufacturers and resell it to retailers—making profits on the price spread and the services they provide. The traditional food-assembly-and-delivery business is shrinking while the other types are expanding. To survive, the larger traditional wholesalers are increasing the number of retailers they serve, and are forming what are known as "virtual chains," informal and shifting supply networks organized around contracts rather than ownership.

In the future, even more consolidation is likely in the food supply industry because retailers are in the driver's seat. The wealth of information they now possess about the buying habits of their customers permits retailers to bargain for the type of food their customers want and to obtain it at the lowest possible price.

## Conclusion

The six major factors outlined above have changed the food industry from a product-driven system to a *consumer-driven* system. To illustrate this point, here's a true story about Wheaties, "The Breakfast of Champions."

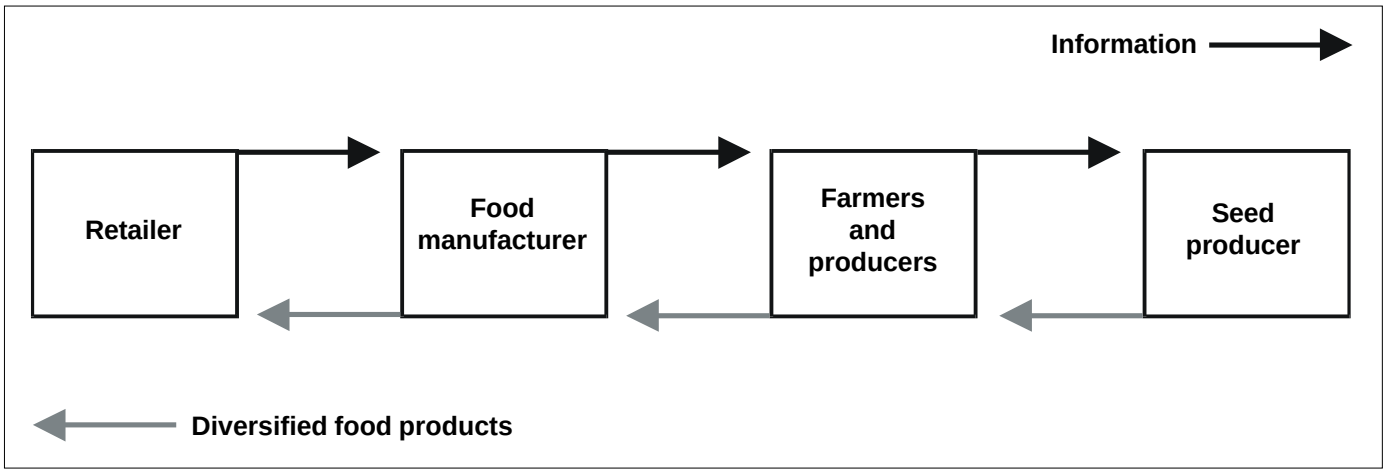
Until a few years ago, if you took the time to sort the flakes in a box of Wheaties, you would have noticed that some flakes were curly and some were flat. When consumers were asked whether they preferred flat or curly flakes, they told researchers they preferred the curly ones because curly flakes didn't crumble as much and tasted better. When this information was relayed to the manufacturer (General Mills), the company made the fortuitous discovery that curly flakes actually filled the box better, did not settle in the package, and were crunchier and tastier to boot.

Further investigation revealed that wheat flake curliness is a genetically determined feature of the wheat kernel itself. Today, General Mills pays more for this type of wheat, and farmers and grain handlers take care throughout the entire food distribution chain to produce, store, and ship "curly kernels" in separate containers.

This example demonstrates how consumers can motivate manufacturers to "pull" the right product from the farm to meet a specific, clearly identified consumer preference. As this story illustrates, the term "demand chain" best describes the food system of today—and tomorrow.

*Jean D. Kinsey is director of the Retail Food Industry Center and a professor in the Department of Applied Economics, University of Minnesota.*

**Figure 6. New partnerships and multiple markets in the food-delivery sector**



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