Economic Evaluation of Alternative Supply Chains For Soybean Peroxidase

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Soybean peroxidase is an enzyme derived from soybean hulls. Peroxidase has much commercial potential as an ingredient in the manufacturer of polymers and specialty chemicals, as a dough conditioner, and as a component in medical test kits. Commodity soybean cultivars contain various amounts of active peroxidase enzyme. This study evaluates alternative supply chain arrangements for moving soybean hulls containing peroxidase from producer to processor. Results suggest at current peroxidase levels in soybeans, supply chain arrangements involving soybean segregation offer cost advantages over the standard commodity supply chain. In addition, a supply chain involving high peroxidase cultivars may offer enough cost savings over the commodity supply chain to justify full identity preservation of the high peroxidase soybeans from producer to processor.

Much recent attention in the grain industry has been given to producing and marketing grains with specific characteristics which have added value. This recent development in grain production and marketing involves identifying specific needs of individual users and then selecting or developing appropriate genetics and production practices that will produce a product which meets those needs (Iowa State University, 1995). Evidence of this trend is the increase in the level of contract grain production for specific end-use products. In a 1992 survey of leading crop farmers, 15 percent of the acres farmed by the group were devoted to grain with a specific end-use such as seed corn, waxy maize, white corn, popcorn, tofu soybeans, etc. By the year 2000, these producers expected the proportion of their acreage devoted to grains with a specific end-use to double too more than 30 percent (Boehlje, 1994). Another independent study suggested that by the year 2000, seven percent of corn grown for hog feed and 15 percent of corn grown for poultry feed will be specialty cultivars grown on contract (*Feed and Grain*, 1993). The same study predicted that contract production of oilseeds such as soybeans will grow even more dramatically to support rapidly rising demand for grain derived vegetable oil – demand that is projected to grow from 200 million pounds in 1995 to 850 million pounds of grain derived oil in 2000.

Grain with specific quality characteristics or genetic attributes is sometimes known as "value added" grain because more value can be extracted from these grains relative to commodity grain in the same specific end use. The terms "identity preserved" and "segregated" have been used to describe grain which needs to be separated from commodity grain (co-mingling with commodity grains must be prevented) throughout the supply chain because it contains a specific characteristic.

Soybean Peroxidase

One new value added grain product which has demonstrated some initial commercial success and has shown indications of having large scale commercial potential is soybean peroxidase (Wick, 1996). Soybean peroxidase is an enzyme derived from soybean hulls. It has been known since the 1960s that soybeans contain various peroxidase isoenzymes. However, recent research has led to technological developments which allow peroxidase to be measured and extracted from soybean hulls (Vierling and Wilcox, 1996). With a potentially abundant supply of soybean peroxidase now available, many uses of peroxidase may become economically feasible. Soybean peroxidase also has the advantage that its activity is very stable compared to other enzymes and it has

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greater oxidating power compared to many industrial chemicals for which it can substitute.

Soybean peroxidase is concentrated in the soybean hull or seed coat. Specific soybean cultivars have been identified as being high in peroxidase enzyme activity. Initial research on these cultivars indicates that the level of peroxidase has no association with other soybean varietal characteristics such as yield, protein, or oil content. However, the quantity of peroxidase available in soybean hulls is affected by grain storage and handling procedures. Research has shown that the loss of peroxidase in stored soybeans is a function of time, temperature, and mechanical damage of the soybeans.

The technology associated with the extraction and processing of peroxidase has primarily been developed by private corporations including Mead Paper, Inc. and Enzymol International, Inc. (Wick, 1996). Peroxidase is extracted using a water solvent extraction process. The hulls are soaked in water for a predetermined amount of time, then the water solution and remaining hulls are separated. The water solution containing crude peroxidase goes through several purification steps to remove biological organic debris (B.O.D.), water, and other impurities.

Objectives

Large-scale efforts to commercialize new grain uses beyond the farm gate have been less than spectacular to date. Typically much research is devoted to development of seed genetics which provide the characteristic of interest. However, far less research addresses managing the supply chain in a way that will allow movement of the grain from the producer to the end-user in an efficient manner (Caswell, 1994). Specifically, there is a lack of information on what changes in traditional commodity marketing channels facilitate the economically successful introduction of new value added agricultural products for commercial uses.

The objectives of this study are to:

1) Identify the primary markets for peroxidase and estimate their size;
2) Estimate the costs associated with the existing soybean peroxidase supply chain; and
3) Evaluate the economic feasibility of alternative soybean supply chain arrangements.

Results from this study permit the construction of alternative scenarios under which different supply chains would be expected to emerge. In addition, the premiums above commodity grain prices that players in alternative supply chains will require to participate in the chain are explored.

Methods

The process of developing suitable business structures for marketing channels has been called "supply chain management." Agricultural supply chain management is defined as the planning and control of the flow of materials and information from agricultural producers to end-users (van der Vorst, 1996). Supply chain management has also been called integrated supply chain design, strategic network design (Iyer, 1996), and value-added chain management (Johnston and Lawrence, 1988). The purpose of supply chain management is to create an infrastructure that provides for efficient transfer of products and maximum capture and equitable distribution of added value.

The current situation in the commodity soybean supply chain is that hulls are being blended with soybean meal or sold as a fiber by-product with no consideration given to segregating cultivars that are high in peroxidase content. The existing peroxidase concentrations in commodity raw material supplies could be increased by developing a supply chain system which segregates soybeans that are high in peroxidase content, or by extracting peroxidase in a more timely fashion. Longer term, preliminary research has suggested that it is possible to develop soybean cultivars with higher yields of peroxidase relative to current commodity soybeans. Timely extraction is important because peroxidase activity declines in stored soybeans over time. These factors led to selection of three alternative supply chain arrangements involving segregation for analysis and comparison to the current commodity supply chain. A budget model is developed for each of the following supply chain arrangements:

- Commodity chain – the existing commodity supply chain (Figure 1),
- Sorting chain – a commodity sorting supply chain (Figure 2),
- IP chain – an identity preservation supply chain (Figure 3), and
- Enhanced IP chain – an identity preservation supply chain for enhanced soybean cultivars (Figure 4).

Figure 1. Commodity Supply Chain Diagram.

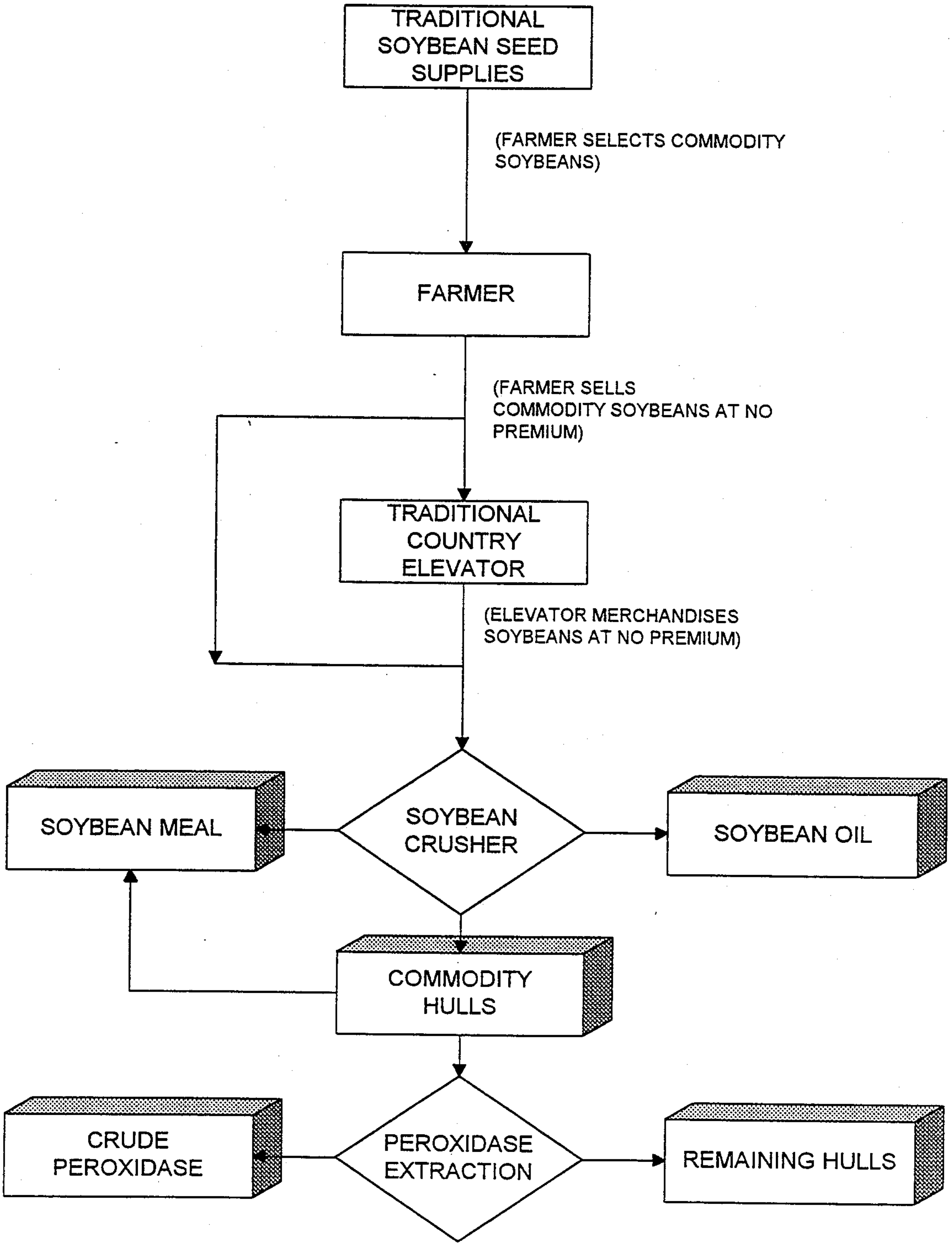


Figure 2. Sorting Supply Chain Diagram.

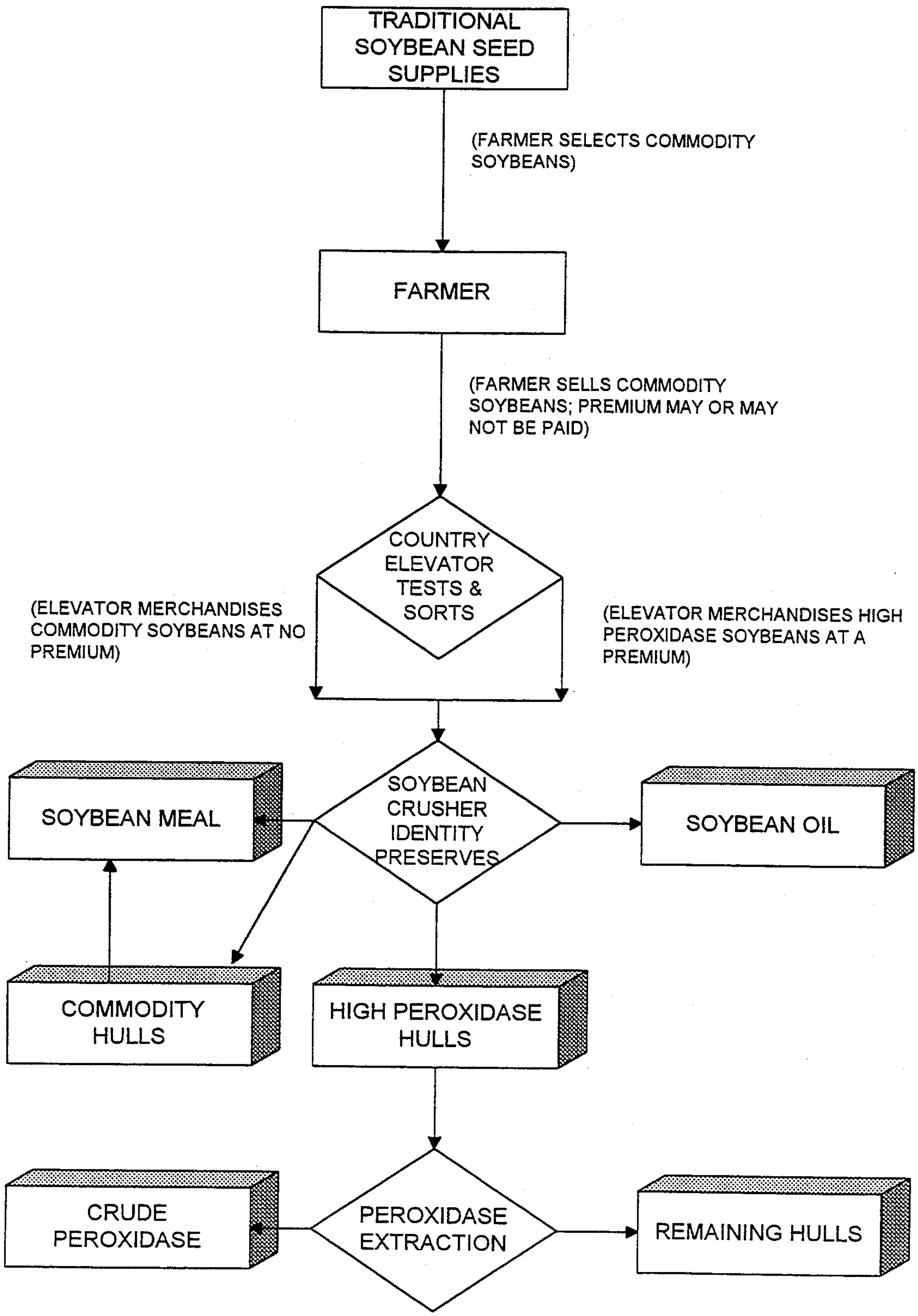


Figure 3. Identity Preservation (IP) Supply Chain Diagram.

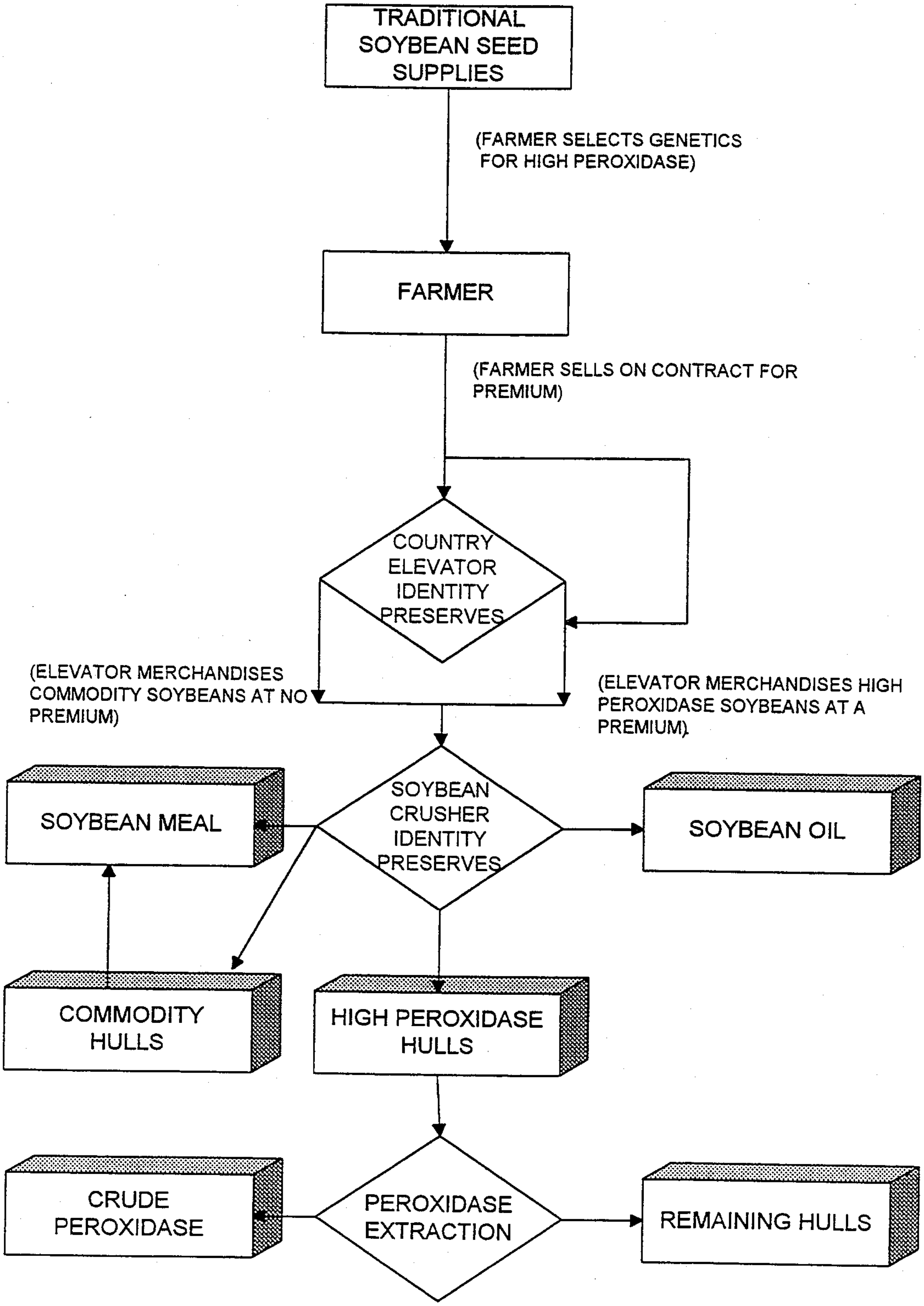
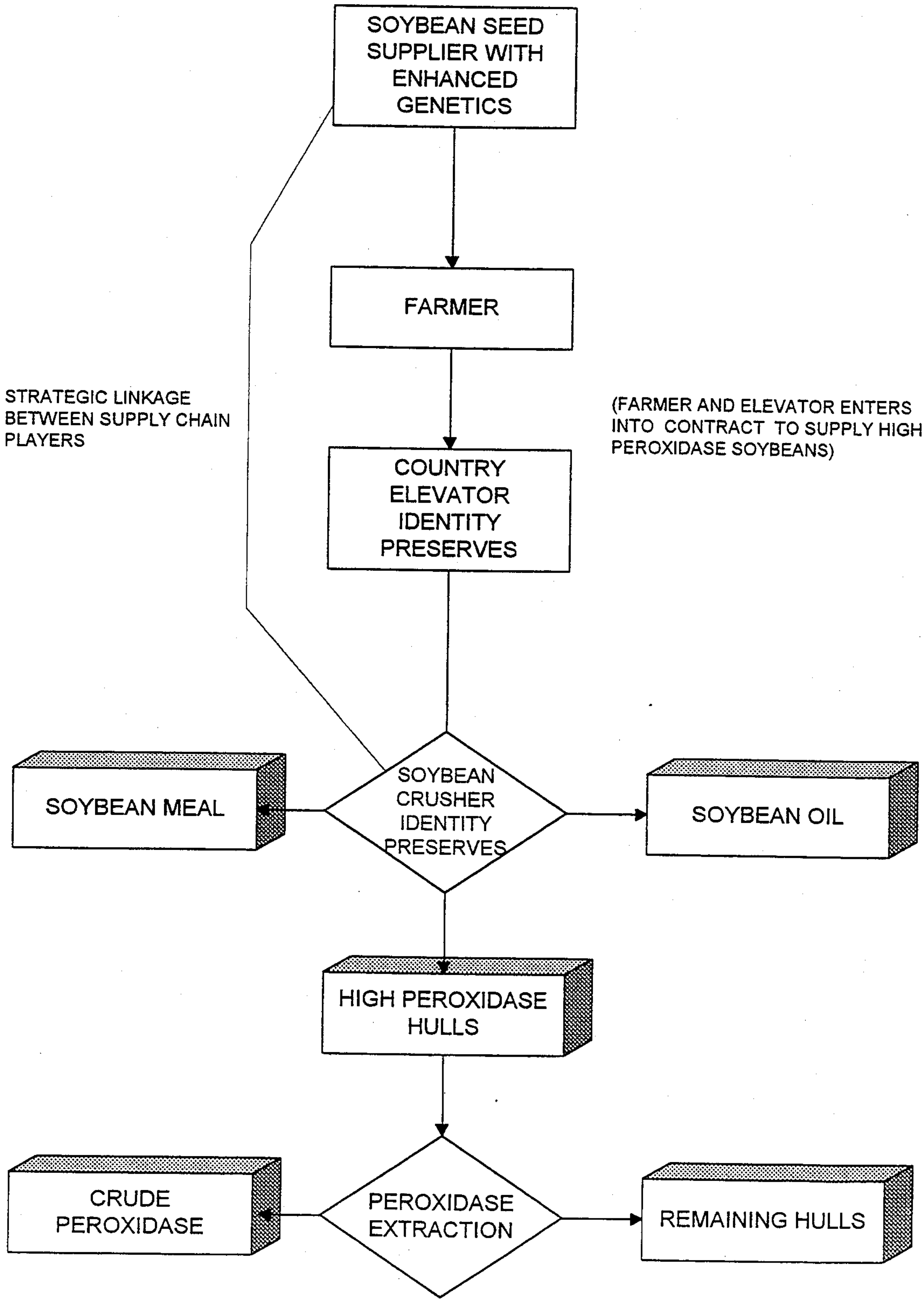


Figure 4. Enhanced Identity Preservation (Enhanced IP) Supply Chain Diagram.



The budget model has two key functions: the first is a function which calculates the amount of soybean hulls required to meet peroxidase demand:

$$(1) \qquad QH_i = (QE_i / f_v) * f_t * k_t$$

Variable descriptions and data sources for this equation are given in Table 1.

The second function calculates the added costs associated with soybean production, soybean movement and procurement, and other logistics in the supply chain. In the commodity supply chain, costs are based on historical market prices for soybean hulls (soybean mill run) and current transportation rates. In the supply chains involving segregation, handling and grading costs are developed from an economic engineering model constructed for country grain elevators (Hurburgh, 1994). All of these cost relationships are summarized in equation (2). The variables are defined in Table 2.[1]

(2)

$$C_{SC} \sum_{i=1}^{n} (XCE_i + (QH_i * PH_i)) + \sum_{i=1}^{n} (XCT_i + XCI_i) + \sum_{i=1}^{n} (CCH_i + CCG_i) + \sum_{i=1}^{n} (ECH_i + ECG_i) + \sum_{i=1}^{n} (FCH_i + FCG_i + FCP_i)$$

The goal of the budget model is to adequately capture the cost characteristics of the four supply chains, and specifically, to compare costs across the alternative supply chains (sorting, IP, and enhanced IP) relative to the commodity supply chain (commodity chain). As indicated earlier, the general structure of the cost relationships was derived from the work of Hurburgh (1994). Hurburgh developed an economic engineering model to estimate the costs of segregating grain by composition or unique characteristic. Operating inputs and coefficients in his work were derived from a three-year on-site test at one Iowa elevator, and a survey of 50 elevators in three Iowa counties. Operational and financial costs made up the largest portion of the total costs, suggesting that labor costs were more important than equipment costs, facility remodeling, or new facility purchases in segregating grain (Hurburgh).

There are two important sources of randomness in the supply chain: the quantity of peroxidase in soybean hulls and the price of soybean hulls. To capture the impacts of this randomness on the system, the budget model was cast in a simulation framework. Each of the four supply chain budget models was programmed as a computer simulation model. Extend Simulation and Decision Support software was used to construct the simulation models.

The simulation models were used to evaluate supply chain costs per pound of peroxidase produced. The amount of total added value in the supply chain is derived from the overall cost savings of any segregated supply chain arrangement compared to the commodity supply chain. Obviously, the amount of added value premium paid at any one level of the supply chain must equal or exceed the added segregation costs at that same level.

Information and data were collected from key industry contacts as well as from published literature. Little published economic information about peroxidase is available because it is a relatively new product and because the technology is proprietary. Therefore, primary data for the demand estimates, the model structure, and the cost equations were gathered by interviewing key industry players including seed suppliers, elevator organization managers, soybean processors, and peroxidase extractors.

Market Analysis

The current market for peroxidase is relatively small. The market has been largely confined to high value applications given the cost of extracting the enzyme from horseradish, the current primary source of supply. However, there are several markets that offer considerable potential for soybean peroxidase. One of the largest potential markets is the manufacturing of specialty polymers and phenolic resins. The advantages to polymer and resin manufacturers of the peroxi-

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[1] It is important to note that each of the variables in equation 2 represents the sum of a variety of fixed and variable costs. For example, the variable *ECH_i* (elevator handling costs) includes the cost of customer wait time, extra labor required at the dump pit, the cost of any new or modified facilities, the opportunity cost of underutilized storage, misgrading costs, and any relevant costs of contracting. For more detail on the specific equations used in the budget model, see Lentz.

Table 1. Key Variables in Function for Calculating Soybean Hull Requirements in Budget Model.

Variable Name	Description	Numerical Range	Source(s)
QH_i	Monthly requirement of soybean hulls to meet peroxidase demand (tons)	-------	Calculated in model based on equation (1)
QE_i	Monthly demand (lbs.) of active peroxidase enzyme	See Table 3	(Borovsky, 1996)
f_v	Peroxidase activity level measured immediately after harvest in:	All activity levels are normal distributions with:	(Vierling, 1996)
	• Commodity chain	• Mean=0.5 Std.Dev.=0.31	
	• Sorting chain	• Mean=0.888 Std.Dev.=0.08	
	• IP chain	• Mean=1.0 Std. Dev.=0.1	
	• Enhanced IP chain	• Mean=1.5 Std. Dev.=0.1	
f_t	Multiplier that reduces f_v as degradation occurs in stored soybeans	Lines fitted to functions for 10°C, 20°C, 30°C, 40°C over a period of 12 months.	(Vierling, 1996)
k_t	Conversion factor which converts measured activity level (f_v) to weight of active enzyme	1.0 measured activity level equates to 50 nanograms of active enzyme in an approximate 400,000 nanogram piece of tested soybean hull	(Vierling, 1996)

Table 2. Key Variables in Function for Calculating Total Supply Chain Added Cost in Budget Model.

Variable	Description	Source(s)
C_{sc}	Total Supply Chain added costs ($)	Calculated from equation 2
PH_i	Monthly historical soybean hull market prices ($/ton)	(Purdue, 1996)
XCE_i	Extraction costs associated with basic procurement, handling, extraction, and disposal ($/month)	(Pokora, 1996)
XCT_i	Transportation costs for moving soybean hulls from the soybean crusher to peroxidase extraction sites ($/month)	(Bratton, 1996) (Claycamp, 1996)
XCI_i	Inventory costs associated with soybean hull storage and lead time ($/month)	(Iyer, 1996)
CCH_i	Handling costs associated with segregation at the soybean crusher ($/month)	(Hurburgh, 1994)
CCG_i	Grading and testing costs associated with segregation at the soybean crusher ($/month)	(Hurburgh, 1994)
ECH_i	Handling costs associated with segregation at the elevator ($/month)	(Hurburgh, 1994)
ECG_i	Grading and testing costs associated with segregation at the elevator ($/month)	(Hurburgh, 1994)
FCH_i	Handling costs associated with segregation at the farm ($/month)	(Hurburgh, 1994)
FCG_i	Grading and testing costs associated with segregation at the farm ($/month)	(Hurburgh, 1994)
FCP_i	Production costs associated with identity preservation at the farm ($/month)	(Beck, 1996) (Purdue, 1996)
n	Number of months of processing	Simulated time

Table 3. Annual Soybean Peroxidase Demand Forecast for Year 2000.

End Use	Demand for Active Peroxidase Enzyme	Demand for Commodity Hulls	Demand for Commodity Soybeans
Polymers and Resins	3400 pounds	34860 tons	16.6 million bushels
Specialty Chemicals	3400 pounds	34860 tons	16.6 million bushels
Food and Medical	1700 pounds	17640 tons	8.4 million bushels
Biotreatment	0 pounds	0 tons	0 bushels
Totals	8500 pounds	87360 tons	41.6 million bushels

dase technology include the elimination of formaldehyde in the production process, the reduction of energy inputs, and the production of high purity products (Wick, 1996).

European companies are using soybean peroxidase as a dough conditioner in bakeries. Peroxidase replaces potassium bromate, which has been banned in all major markets outside the U.S. Potassium bromate is still allowed in the U.S., but this market also may open if concerns about this chemical persist (Wick, 1996).

Purified soybean peroxidase also has gained interest as a substitute for horseradish peroxidase in medical and diagnostic assays for medicine and research. Horseradish peroxidase is widely used as an enzyme label of antigens, antibodies, oligonucleotide probes, and other biological reagents in numerous diagnostic kits, research assays, tissue-staining techniques, and related applications. The keys to soybean peroxidase's superiority over horseradish peroxidase is its potentially vast availability, relatively low cost, stability over a wide range of temperatures, its long shelf life, and its overall performance (Vierling, 1996).

Another potential market for soybean peroxidase is in the treatment of waste streams, sludges, and soils contaminated with phenolics, aromatic amines, chlorinated organics, and heavy metals (Wick, 1996). These industrial wastes are produced during steel and iron manufacturing, ore mining, paper bleaching, and other industrial operations. Peroxidase would be used to polymerize pollutants, hopefully permanently immobilizing them so that they can be filtered out and disposed of. This technology was developed about 15 years ago, however, it had not been actively pursued because of the enormous cost of horseradish peroxidase and because polymerization immobilization techniques have not been promoted by EPA (*Resource*, 1995).

Most peroxidase extraction and purification technology is patented. In addition, soybean peroxidase is a new product for which no trend data exist. Given this situation, subjective estimates of peroxidase demand in the year 2000 were developed based on interviews with principals of Enzymol International, Inc. and a review of the literature on the chemicals peroxidase would replace. (Additional detail on potential markets for peroxidase is presented in Lentz. Other references discussing potential markets for peroxidase include *Chemical Week*; *Science News*; and Webb.) The projected demand for the enzyme, soybean hulls, and whole commodity soybeans is summarized in Table 3.

Results of the Supply Chain Analysis

Results for each supply chain were obtained by calculating the mean and standard deviation of 25 simulation replications, with each replication representing one year of supply chain operation. (The simulation model was also run for 100 replications for each supply chain, with no change in results.) The budget model first takes the total annual peroxidase demand forecast and divides it into 12 equal monthly peroxidase demand requirements. Turning then to supply, the model calculates the quantity of active peroxidase enzyme in each month's supply of soybean hulls based on the time and temperature degradation function and the distribution of peroxidase available in the soybean cultivar. The cultivar used depends on the supply chain under analysis. Figure 5 summarizes the monthly peroxidase activity levels used in the simulation model for each supply chain.

The activity levels shown in Figure 5 are used in the budget model to calculate the quantity of soybean hulls required to meet each month's peroxidase enzyme demand. The procurement, handling, and other logistics of this quantity of soybean hulls in the supply chain triggers the calculation of total added costs for the supply chain. The level of active peroxidase in the soybeans declines as the time from harvest increases, driving up the quantity of soybean hulls required to satisfy a given monthly demand. Monthly costs then increase for a given quantity of peroxidase as time from harvest increases. The (annual) soybean hull requirements, whole soybean requirements, total supply chain cost, and total cost per unit of extracted crude enzyme for the four supply chains are summarized in Table 4.

The results in Table 4 show that the commodity chain has a requirement of 99,951 tons of soybean hulls or 47,595,711 bushels of soybeans. The quantity of soybean hulls required to meet projected annual demand for peroxidase declines as the degree of segregation increases – the commodity channel has the highest hull requirements and the enhanced IP channel has the lowest requirements. The standard deviation of hull requirements is also significantly higher in the commodity chain relative to any other supply chain. This is primarily a function of the large variance in peroxidase activity in commodity soybean cultivars.

Figure 5. Peroxidase Activity Decline after Harvest in Each of Four Supply Chains.

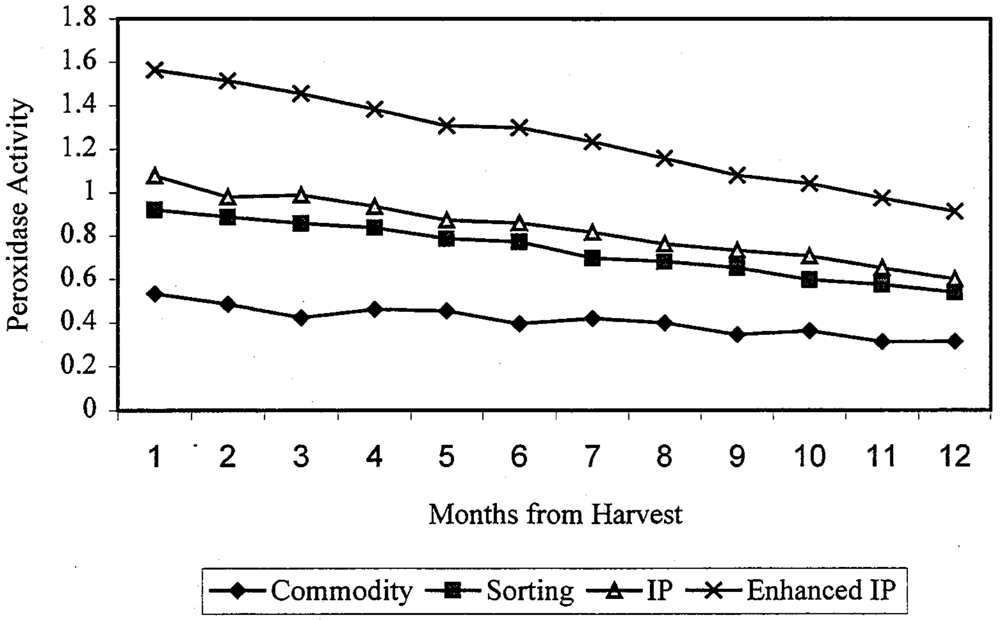

Table 4. Base Case Supply Chain Comparison.

	Supply Chain			
Results	Commodity	Sorting	IP	Enhanced IP
Soybean Hulls Required (tons/year)				
Mean	99,951	50,518	45,005	28,829
Standard Deviation	10,619	1,222	1,418	603
Soybeans Required (bushels/ year)				
Mean	47,595,711	24,056,424	21,431,252	14,204,254
Standard Deviation	5,056,880	581,866	675,471	168,500
Total Supply Chain Added Costs ($)				
Mean	$10,486,500	$6,844,145	$7,112,218	$5,296,475
Standard Deviation	$1,042,155	$225,129	$251,624	$168,500
Unit Cost ($) of One Pound of Peroxidase				
Mean	$1,234	$805	$837	$623
Standard Deviation	$590	$101	$102	$59

The supply chain costs follow a slightly different trend. The commodity chain has the highest total cost followed by the IP chain, the sorting chain, and the enhanced IP chain. This is a direct result of cost structure differences in the supply chains. The commodity chain requires a very large quantity of soybeans relative to the other three chains (Table 4). Hence, although the commodity chain involves no added segregation costs, the higher procurement, transportation, and inventory holding costs for this chain exceed the cost of segregation associated with the other chains. The IP chain is the first supply chain to add cost at the farm level of the chain. These farm level costs drive the cost per pound of peroxidase higher than in the sorting chain, which does not involve on-farm costs. The enhanced IP chain is the lowest cost supply chain as the greatly increased peroxidase activity in high-peroxidase cultivars more than offsets the higher cost of identity preservation for this chain.

Because the sorting and the IP supply chains had quite similar costs, a statistical test was used to compare the two means. A two sample t-test generated a t-value of 3.86 which indicates the difference in costs between the sorting and the IP supply chains is significant at the 0.99 confidence level (Moore and McCabe, 1989).

It is important to note that the costs in Table 4 assume no disposal value for the soybean hulls after peroxidase extraction – i.e., after extracting the peroxidase, the cost of disposing the hulls or preparing them for sale equals any revenue from the sale of the hulls. The other extreme would be the case where the hulls have full value after extraction and are sold to the market for the same price paid by the extractor. Under this assumption, the unit cost for peroxidase becomes $461 for the commodity chain, $419 for the sorting chain, $489 for the IP chain, and $392 per pound of enzyme for the enhanced IP chain. The hull disposal assumption has an important effect of the absolute level of cost, but not the ranking of the four chains. With the cost of drying the processed, wet hulls estimated at $30-$40 dollars per ton, the true costs of peroxidase would be closer to those shown in Table 4 and not the lower bounds given above.

It is also important to determine the costs incurred by individual players within the supply chain. Table 5 presents these costs as cost per unit of product handled for each player. These costs provide the break-even value each individual player must attain to just be compensated for the added costs of participating in a specific supply chain. Table 5 also gives the standard deviation of individual player costs for each base case simulation. This standard deviation can be viewed as the level of cost risk each player incurs.

In each supply chain, players have a different portion of the supply chain costs and cost risk. In the commodity chain, the extractor level has 100 percent of the total supply chain costs. The enhanced IP chain has the most rigid segregation standards and the most equal distribution of supply chain costs across players. This also leads to supply chain cost risk being the most evenly distributed of the four supply chains. In the sorting chain, all supply chain players except the farmer incur costs. In this supply chain arrangement, if the elevator paid the farmer a premium for peroxidase, this premium would be received without incurring any cost under the assumptions used in the base case model.

Using costs generated from the budget model, supply chain added value is calculated by taking the difference between costs in the more costly commodity supply chain and the supply chains involving segregation (sorting chain, IP chain, and enhanced IP chain). This added value was compared to a target premium above market prices that supply chain players indicated they needed to participate in a particular supply chain (Table 6).

In the sorting chain, supply chain players interviewed indicated that the target premium necessary to satisfy profit objectives and to pass premiums on to customers is $0.05 per bushel at the elevator and crusher. If it is assumed that the farmer will also receive $0.05 per bushel for soybeans meeting a minimum peroxidase standard, then the added value from cost savings in the sorting chain just matches the total target premium (Table 6).

In the IP chain, players interviewed indicated that the target premium to satisfy profit objectives and to pass premiums on to customers are $0.05 per bushel at the elevator and crusher and $0.10 per bushel at the farm. Here, the added value in the IP chain would not cover the total target premium for supply chain players (Table 6).

Table 5. Supply Chain Player Cost Analysis.

	Supply Chain			
	Commodity	Sorting	IP	Enhanced IP
Extractor Cost per Hull Ton				
Mean	$93	$96	$95	$95
Standard Deviation	$10	$15	$8	$12
Extractor Cost per Enzyme Pound				
Mean	$1055	$570	$504	$331
Standard Deviation	$351	$161	$104	$50
Logistics Cost per Hull Ton (Extractor Cost)				
Mean	$8.70	$8.70	$8.60	$8.70
Standard Deviation	$0.039	$0.084	$0.064	$0.042
Soybean Crusher Cost per Hull Ton				
Mean	$0	$23	$25	$35
Standard Deviation	$0.00	$1.40	$1.70	$1.58
Soybean Crusher Cost per Bushel				
Mean	$0.000	$0.048	$0.053	$0.074
Standard Deviation	$0.0000	$0.0029	$0.0036	$0.0033
Country Elevator Cost per Bushel				
Mean	$0.000	$0.020	$0.037	$0.038
Standard Deviation	$0.0000	$0.0007	$0.0026	$0.0016
Farm Cost per Bushel				
Mean	$0.000	$0.000	$0.025	$0.046
Standard Deviation	$0.00000	$0.00000	$0.00023	$0.00028

Table 6. Desired Premiums and Added Value for Supply Chains.

	Supply Chain			
Results	Commodity	Sorting	IP	Enhanced IP
Supply Chain Added Value from Cost Savings ($ per bushel soybeans)	0.00	0.15	0.15	0.36
Total Supply Chain Target Premium ($ per bushel soybeans)	0.00	0.15	0.20	0.30
Difference	0.00	0.00	(0.05)	0.06

In the enhanced IP chain, the supply chain players indicated that target premiums necessary to satisfy profit objectives and to pass premiums on to customers are $0.05 per bushel at the elevator and crusher and $0.20 per bushel at the farm. The added value from cost savings in the enhanced IP chain would more than cover the total target premium (Table 6).

An extensive sensitivity analysis was conducted on the variables of the model (Lentz). Sensitivity of the results to the following variables was explored: soybean genetic variation (peroxidase activity, minimum activity sort point, and soybean seed size); peroxidase demand and extraction capacity (monthly peroxidase demand and the extraction horizon); extraction cost variables (extraction costs, transportation load size); and crusher and elevator handling and storage costs (storage temperature, storage utilization, volume dedicated to segregation, customer wait time, value of customer wait time, truck unloading capacity, facility modification costs, peroxidase test price, and peroxidase kit accuracy).

This sensitivity analysis showed that variables related to the genetic peroxidase enzyme activity and variables related to degradation of peroxidase activity had the greatest proportional impact on total supply chain cost. These variables include: peroxidase activity, minimum activity sort point, and storage temperature. The results of the supply chain analysis did not prove to be nearly as sensitive to changes in the other variables evaluated.

As expected, costs in the commodity channel are quite sensitive to the genetic activity level in commodity soybeans. A 20 percent increase in the genetic activity level in this channel reduces the total cost of the commodity channel (per unit of enzyme) by 27 percent. Interestingly, increasing the minimum activity level for sorting in the sorting chain from 0.8 to 0.9 actually lowers the cost per unit of peroxidase in this channel by 5 percent. This occurs because the higher sorting standard (and resulting higher peroxidase soybeans) lead to much lower procurement and handling costs. Increasing storage temperatures cause more rapid degradation of peroxidase, leading to the need to process ever larger quantities of soybeans to meet a specific demand target. Increasing storage temperature from 10°C to 20°C increased the unit cost of peroxidase from 30 to 35 percent for the four supply chains. Clearly, storage temperature is an important handling variable to monitor.

Given the subjective nature of the peroxidase demand estimates, the impact of varying demand was also explored. The base case demand equates to roughly 700 pounds of peroxidase per month. The model results were replicated over a demand range from 100 to 1400 pounds of peroxidase per month. At quantities below 100 pounds per month the commodity chain has the lowest total cost. At this very low level of demand, the fixed costs associated with the other three channels are spread over few units, driving up average cost. While all chains showed some slight economies of scale, at demand levels greater than 300 pounds of peroxidase per month the rank order of the four chains in terms of cost did not change.

Summary and Conclusions

The results from the simulation analysis can be summarized as follows:

- A supply chain that uses cultivars enhanced with high peroxidase levels (if available) is the least cost arrangement assuming no yield drag is incurred.[2]
- If enhanced genetics are not available, the sorting supply chain followed by a supply chain which identity preserves currently available high peroxidase cultivars would be least cost.
- The traditional commodity supply chain has the highest costs. The cost relationships between the four alternatives hold over a wide range of possible situations.

For the immediate future, the commodity sorting supply chain would appear to be the most pragmatic alternative based on cost and the availability of seed genetics. In this supply chain, the farmer has no added costs, the elevator incurs $0.02 per bushel added cost, and the crusher incurs $0.048 per bushel added cost. If each supply chain player received full compensation for added costs plus a $0.05 per bushel premium, then total supply chain costs plus premium costs would be nearly equal to total costs of the commodity supply chain where no added value is created for supply chain players.

More broadly, it is expected that this type of analysis will find application as the economics of other new value added grain characteristics are explored.

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[2] As noted earlier, to date there has been no relationship documented between yield and peroxidase levels. However, such a relationship could conceivably exist in an enhanced peroxidase cultivar, depending on the base genetics carrying this trait.

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