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Amino acid based soybean component pricing systems

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ABSTRACT

The history of soybean component pricing was first examined as a starting point. A theoretical basis for component pricing was then developed in a microeconomic context. Finally, a pricing system based upon the amino acid content of soybeans was built. To accomplish this, a data set of 268 soybean samples was used with animal feed diets from two species, broiler chickens and hogs. Diets were constructed at varying life cycle stages to create a total of seven diets. These diets were input into the Brill least cost livestock ration program to obtain variations in diet cost. The resulting variations were then translated into variations in marginal value product in order to price soybeans. This diet cost pricing system was then compared to two simpler pre-existing methods.

It was found that the amino acid based pricing system was more accurate had an effect on virtually all of the samples. Differences in pricing between systems were calculated and tested using non-parametric statistics. Protein was shown to have flaws as a proxy for price signal transmission, since a wide variety of protein percentages were observed at equal diet costs. Logistic regressions were calculated to approximate the probability that a soybean with a given protein content could outperform expectations based upon that protein content within an amino acid pricing system. These showed that lower protein beans are less likely to outperform protein based expectations, and probabilities improve for such an occurrence when protein levels are above average.

Finally, regression equations of the prices in each system versus protein were examined, to construct a method for estimating the difference in value of a soybean sample in any two given pricing systems. The paper then concludes by identifying areas of future research, and speculating on the future structure of the market for soybeans.

CHAPTER 1: INTRODUCTION AND LITERATURE REVIEW

A commodity price for soybeans is not based on end use quality. It does very little to accomplish the goals set out for pricing soybeans within the paper "Alternative Strategies For Pricing Soybeans Based on Components" by Roger Ginder and Mike Poray. These goals are as follows (Ginder, 1998, p.1):

1. The producer price is based on measured properties that add to the end use value of the soybeans.
2. The price accurately transmits price signals between farmers, elevators, and processors.
3. The price provides positive incentives to efficiently create maximum value for the crop through variety selection.
4. The price provides incentive for improvement in U.S. soybean quality through time.
5. The price promotes cooperation and discourages conflict among farmers, elevators, and processors.

The commodity price has very little to do with measured properties of the soybean. This leads to a potentially incorrect price signal, since there are known variations in the end use value of soybeans, and no resulting variations in price. Also, a commodity price does very little to encourage improvements in the quality of soybeans planted from year to year. Producers have nothing to gain from planting a higher quality soybean, since all profits are based upon weight, visual bean characteristics, and the amount of foreign matter. The main criteria used for variety selection by most farmers is then yield per acre. There is little incentive to consider the end use quality of the soybeans being produced. Ten years ago, few producers considered protein or oil content, and are just starting to do so now. Today, few producers consider the amino acid content of the soybeans they are producing, even though amino acid content is exactly what livestock feeders are seeking when they buy soybean meal. Just as soybeans are now selected and engineered to produce higher yields, and in some cases oil content, eventually they are likely to be selected and engineered to produce higher lysine or tryptophan content. A pricing system must be developed to accommodate and reward the efforts toward higher essential amino acid content.

Literature Review

Component pricing for soybeans was considered as early as 1976 by Nelson J. Updaw. In his paper "Pricing Soybeans on the Basis of Oil and Protein Content" (Updaw, 1976), Updaw set up the beginning framework of a pricing scheme based upon the oil and protein content of soybeans, as well as the prices of soybean oil and meal. The quantities of meal and oil were calculated from the oil and protein percentages of the soybeans by use of regression equations. These equations were based on varying oil and protein values, and yielded R-squared values of one. An average oil yield was chosen, which was subtracted from the sample oil yield to give an appropriate discount or premium.

Once the amount of meal was calculated, the protein percentage of the meal was calculated through the use of another regression equation. This equation used observations of meal including whole bean protein and oil content to calculate the pounds of protein content in the non-oil solids. An average value for soybean meal yield and protein percentage was then chosen, and again subtracted from the sample value to obtain a discount or premium. The oil and protein premiums and discounts were then summed for each sample to assign a total premium or discount.

The conclusion of this paper speculates on the effects to the market system of the component pricing of soybeans. While several points were made, including ideas about who stands to gain from such a system, and reactions by the producers to the change in pricing, the overall effect was left as an unknown.

In 1980, Updaw published "Social Costs and Benefits from Component Pricing of Soybeans in the United States" (Updaw, 1980), where he more closely addressed the questions left at the end of his 1976 study. In this paper, he developed an economic model based upon perfectly competitive markets for soybean meal and oil. First, Updaw established that grading procedures for soybean quality were sometimes inaccurate, and overlooked qualities valued by some end users. Also, it was established that proxies for actual characteristics that contribute to the marginal value product were sometimes necessary because of high measurement costs. The implication is that these proxies incorporate a degree of error into the valuation of the product. Component pricing was then the "logical refinement of grade determinant pricing", where the "price of an unprocessed commodity would be set according to point estimates of the values of all measured characteristics" (Updaw, 1980, p.648). The benefits of such a system are listed as a reduction in the possibility that a buyer over-pays for a commodity, and an incentive for producers to increase quality according to the characteristics that are most profitable.

Once the economic model was established, Updaw showed that the installation of a component pricing system would not have an effect on the overall protein and oil contents in soybeans. This conclusion hinged on the fact that elasticity of the marginal rate of substitution production possibilities frontier is one. If this is not true, the elasticity of transformation will not be infinite, and the realm of possible points along the production possibilities frontier will not be a single point, as Updaw concluded. This single point is, however, the point at which protein and oil production are equal to the pre-component pricing levels.

Updaw further concluded that without any changes in the protein and oil content of soybeans, the change in social benefits can only be zero when examined as the change in the sum of producers' and consumers' surpluses. Redistribution of wealth can take place, but the total effect will be zero without changes in the supply of either protein or oil. Of course, there are costs associated with testing and screening soybeans for protein and oil content, and these costs were tallied by Updaw to result in an exorbitant reduction in social welfare.

Within Updaw's study, a sensitivity analysis was constructed, wherein the elasticity of the marginal rate of substitution was allowed to vary to negative one and negative infinity. However, Updaw still assumed a marginal rate of substitution of one between protein and oil, which may have been an inaccurate assumption. These other iterations were shown to provide for surpluses in producer welfare that still did not outweigh the costs of soybean testing. Based upon his evidence, Updaw concluded that under the then current conditions, soybean component pricing provided for a decrease in social welfare.

Six years after the study by Updaw that found soybean pricing to be socially detrimental, R.C. Leffel took up the topic again in his paper "High Protein Lines and Chemical Constituent Pricing in Soybeans" (Leffel, 1988). In this paper, the author first gave a brief history of attempts at improvements in soybean quality. This lead into a review of the pricing system developed in Updaw's first paper, and the use of premiums and discounts in this manner to analyze recent attempts at improvements in soybean quality.

The tradeoffs between protein and oil were examined in a soybean value setting, and soybean oil was valued at both \$0.15 and \$0.25. Leffel examined the possibility of an upper bound on the possible range of protein values, which was undertaken due to the meal price driven value of soybeans at the time of the paper. In conclusion, Leffel determined that high protein soybean varieties did not give higher monetary returns than average varieties, because of the decreases in both yield per acre and oil content.

In 1990, Thomas J. Brumm and Charles R. Hurburgh, Jr. refined the process for valuing soybeans based upon protein and oil content, and presented it in "Estimating the Processed Value of Soybeans" (Brumm, 1990). This new process replaced the regression equations developed by Updaw with material balances to model the entire processing of soybeans, including "dehulling, addition of hulls to the meal to control protein content, changes in processing efficiency among different plants…and effects of soybean meal marketing practices, such as limitations on fiber content" (Brumm, 1990, p.302). To accomplish this, a three stage model was developed. The first stage dehulled the soybeans, the second extracted the soybean oil, and the third separated the meal into 44% and high protein meal, and added back in hulls as necessary. The estimated processed value was calculated as follows (Brumm, 1990, p.303):

$$EPV = (Pm)(Wm)/2000 + (Po)(Wo) + (Ph)(Whn)/2000$$

where EPV is the estimated processed value in dollars per bushel, Pm is the meal price after discounts from trading rules in dollars per ton, Po is the oil price in dollars per pound, Ph is the hull price in dollars per ton, Wm is the weight of soybean meal in pounds per bushel, and Whn is the weight of hulls in pounds per bushel, which can be either positive or negative for removal or addition. Several examples were then developed using ten different soybean samples. The EPV was calculated for each, and these values were compared with samples from Updaw's study.

Not only was the EPV model shown to be more accurate, but it was also more flexible. With the ability to add hulls back into the meal, the protein content can be varied, and high protein meal can be simulated. National Oilseed Processors Association (NOPA) trading rules for fiber, fat, and protein restrictions can be used within the EPV model. Also, assumptions in the Updaw model, such as residual oil content in the meal, can be varied within the EPV model to simulate results from different processing plants. The paper concluded with figures showing the estimation of EPV for both high and low protein meal from varying bean protein and oil contents.

Within R.C. Leffel's next paper, "Economic Models and Breeding Strategies for Soybean Improvement" (Leffel, 1990), the EPV model was compared to Updaw's valuing system from 1976 and a simple model by W.D. Hanson from 1989, where the Approximate Processed Value (APV) was calculated as a simple function of prices and soybean characteristics as follows (Leffel, 1990, p583):

$$APV = [P_0X + (P_{44}/0.44)\ Y]$$

In this equation, P_0 is the oil price in dollars per pound, P_{44} is the 44% protein meal price in dollars per pound, X is the oil content of the soybean sample, and Y is the protein content of the soybean sample, both at 13% moisture. As in Brumm and Hurburgh's study, Leffel used a lot of ten soybeans and valued them according to each strategy. Also, a hypothetical set of soybeans was constructed that used a 1.5:1 ratio of protein to oil gains and losses, starting from Updaw's 35.9% protein and 18% oil averages. Using figures of sample number versus value, Leffel showed that all three methods provided approximately the same valuation, with the exception of EPV with the use of NOPA's trading rules.

In conclusion, Leffel endorsed the development of high oil soybeans with high yield characteristics, at a minimum loss of protein content. These soybeans would, according to Leffel, fare better under circumstances where the soybean price is less meal driven and more oil driven. Instead of establishing minimum requirements on bean protein, Leffel suggested minimum requirements on meal protein, and a possible restructuring of trading rules.

T.C. Helms and David L. Watt undertook a project in 1991 designed to analyze the differences in yield, protein and oil contents of several common soybean varieties. The resulting publication was titled "Protein and Oil Discount/Premium Price Structure and Soybean Cultivar Selection Criteria" (Helms, 1991). Three different sets of prices were used in the analysis: 1989 prices, a high meal to oil price ratio, and a low meal to oil price ratio. They first described the previous work done by Updaw, Brumm, Hurbrugh, and Leffel for valuation of soybeans.

The constituent yield index (CONY) was also introduced within this paper, which is equal to protein percent plus oil percent times grain yield. This was used as a possible method for variety selection that was independent of price considerations, since producers may lack the information to accurately predict changes in the meal to oil price ratio. Within the limited protein and oil values used in this study, CONY was shown to be a reasonably accurate predictor for ranking the value of soybeans. While it was not as accurate as the premiums and discounts method developed by Updaw or the EPV system developed by Brumm and Hurburgh, it was shown to be a better predictor than yield per acre.

The authors did admit, however, that a wider range of protein and oil contents should be examined before the CONY is used in variety selection. At the time of publication, the high oil and high protein soybean varieties were shown to not provide more value than the high yield varieties, although the authors allowed for the fact that future technological improvements could result in tradeoffs between value in terms of yield and value in terms of high oil or protein.

In 1994, "The Market Valuation of Soybean Quality Characteristics" (Hyberg, 1994) was published by Bengt Hyberg *et al.* Within this study, it was shown that the U.S. grades and standards for soybeans are not statistically significant when examining the price of U.S. soybeans exported to several different countries. Log linear regressions were run on a set of 213 shiploads of U.S. soybeans exported to five different countries from January 1990 to October 1991. These regressions included dependent variables such oil content, meal value, percentages of split and damaged kernels, and processing margin. The oil and meal value coefficients were found to be statistically significant and positive. This was interpreted as a sign "the soybean, soybean meal, and soybean oil markets are all linked and efficient" (Hyberg, 1994, p. 77). The damaged kernels and foreign materials coefficients were found to be not statistically significant, which led to the conclusion that the U.S. grades did not convey value.

Another paper was published three years later by the same group titled "Quality Pricing in U.S. Soybean Exports" (Lyford, 1997). Essentially the same data set was used, and this time the results showed that the protein and oil content of soybeans were not used to price U.S. exports. Instead, the coefficients that return statistically significant values at the 10% level were for damaged kernels, foreign material, moisture content, and a variable for marketing year. This lead to the conclusion that "while buyers may attach a positive value to the protein and oil yields of soybeans, the current marketing system does not value protein and oil content" (Lyford, 1997, p.61). Therefore, the demand for higher protein and oil contents of soybeans produced in the U.S. was not obvious.

The coefficients that did come out positive were linked to the factors that were included in the U.S. grades and standards, which were found to not convey value in the previous paper. In essence, the 1997 paper seemed to refute the findings of the 1994 paper, and stated that the explicit inclusion of protein and oil percentages in pricing would be an improvement to the efficiency of the soybean export market. It was speculated that this would lead to incentives for soybean quality improvements over time that would improve the standing of U.S. soybeans in the foreign market over time.

In 1998, Paul Gallagher published "Some Productivity-Increasing and Quality Changing Technology for the Soybean Complex: Market and Welfare Effects" (Gallagher, 1998). This study considered essentially the same topic as Updaw's 1980 paper on welfare. The analysis was much more rigorous, using 54 equations to model the markets for foreign and U. S. soybeans, corn, fishmeal, and livestock. The fishmeal and corn markets were modeled as competition for soybean meal, and the livestock market was modeled as the main end use of soybean meal.

With the model in place, normal values were calculated for the market state, including meal and oil prices, demands, and supplies on both the foreign and U.S. sides. Then two other soybean varieties were considered: one with higher oil, lowered protein, and no yield change, and one with higher oil, lowered protein, and a yield increase. The relationship between oil and protein was 0.5:1 for increases in oil and decreases in protein, and essential amino acid contents were assumed to decrease with protein. The same market status values were then calculated and compared to the normal market state values to acquire welfare measures for the producers and consumers of soybean meal and oil, beef, chicken, pork, milk, and corn.

Through this analysis, Gallagher showed that with a yield increase and an oil increase, overall welfare in the U.S. would increase by about $684 million. There would also be a redistribution of wealth, so that there would be losers of welfare, such as soybean and corn producers. These were accounted for by the increase in soybean and corn production that would occur with an increase in yield and oil content. All other agents were shown to receive increases in welfare, causing a total welfare surplus. The simulation without a yield increase resulted in a welfare decrease of $43 million. Soybean and corn producers were shown to gain, while most other agents were shown to lose in this case, resulting in a total welfare decline. New uses for soybean oil were also considered in the case of a high oil soybean with yield increase, because of the decline anticipated in the soybean oil price. These results motivated the author to advocate research in soybean oil processing, in the hope of creating new markets for oil in the future.

According to the article "Another Step Toward Possible Component-Based Pricing" by Barb Baylor Anderson (Anderson, 1997), the pricing of oil and protein actually began at test sites in 1997. Estimates by Charles Hurburgh at that time stated that the high quality end of soybean varieties that were being produced could be worth $0.10 to $0.30 above commodity price. However, several test elevators had been monitoring protein and oil content for three years prior to 1997 using near-infrared (NIR) testing. The results of these tests are described in the article "Experiences with Value-Added Grains: Testing and Handling" (Hurburgh, 1997).

This paper identified several "niche products" that are produced for a very specific end use. Examples included were soybeans for tofu production, clear hilum soybeans, waxy corn, and white corn. The article "Niche Market Soybeans – Opportunity for Some Soybean Growers in Illinois" (Pepper, 1995) examined this topic within the realm of soybeans for food production. Many examples of food products were given, including soy milk, yuba, sprouts, flour, and others.

These grains were sold based upon a contract with the producer and were therefore not subject to regular pricing schemes. The key to these types of products is not necessarily the pricing, but the handling, according to Hurburgh. The buyers of these grains need to be assured that mixing has not taken place. Unfortunately, this comes with an added cost, and Hurburgh found that for the test elevators handling soybeans were subject to human errors in the testing, data transcription, and pit assignment.

Producer responses to pit assignment were also identified as a problem, with a 30% error rate in where the grain was actually dumped (Hurburgh, 1997, p.3). He also noted that the time required for analysis of oil and protein content caused some producers to refuse testing. The main conclusion of this paper was that automation, quality control, and training are required to make value-added grains a source of profit for producers and handlers.

In the internal discussion paper "Localized Impacts of Component Pricing for Soybeans" (Hurburgh, 1998) by Charles Hurburgh Jr., geographical considerations for protein and oil content were undertaken. Estimates of the amount that soybean value can be increased through variety selection were provided, under the assumption that the lower third of all soybeans produced in 1997 were those selected for improvement. These estimates were along the lines of $0.25 for the lower third, to produce an average of $0.12 overall. Another result was that meal quality was attributed mainly to regional characteristics, while meal quantity was within the control of the producer. In other words, the farthest northwest soybeans produced would always be lower in protein content, but the producers in states such as North and South Dakota could improve their standing through selection of varieties with higher yields.

The internal discussion paper titled "Using Protein and Oil in Soybean Variety Selection" (Hurbrugh, 1997) by Charles Hurburgh Jr. examined the topic of variety selection more closely. The problem identified by this study was that of the selection process faced by producers. Without compensation for soybean composition, producers have no reason to include protein and oil considerations in variety selection. Also, there is risk inherent with including composition into variety selection because there are probably tradeoffs between composition and yield. To compound the problem, fluctuations in the protein and oil components mean there is no assurance that planting high quality varieties will result in high quality soybeans.

Hurburgh's study therefore attempted to develop a method for variety selection that included compositional considerations, in order to begin to build a database of higher quality soybean varieties. The possible methods examined were the EPV per bushel (EPVB), the sum of protein and oil percentages, the meal protein percentage potential, expected EPV, and a system that simply puts minimums on soybean values or compositional percentages.

Regressions were run for three separate geographical regions against EPVB, which was used as the benchmark. The sum of protein and oil, the meal protein, and meal yield all showed correlation coefficients higher than 0.5, while the regression of yield on EPV did not. As expected, yield did show a high correlation to EPV per acre, however, returning correlation coefficients of 0.962 to 0.997. The relationship between protein and oil was examined, and determined to be much more variable than expected due to weather and variety considerations.

EPVB required price inputs that change over time, as did expected EPV. The meal protein percentage potential did not include considerations for improvements in oil, and the system with minimum values or compositions did not take into account geographical disadvantages. The sum of protein and oil was also shown to mirror EPV closely for the assumed prices within this study. For these reasons, the sum of protein and oil was decided on by Hurburgh to develop a high quality soybean variety database. The high quality varieties were established, and this group showed an average difference in value of $0.16 from the mean value. It was also established that these compositional considerations can not come at a sacrifice of yield, since value differences in yield were shown to be five times as great as value differences in protein and oil.

The final relevant paper was from Dr. Hyesun S. Park and Dr. Charles R. Hurburgh, Jr., and was titled "Improving the U.S. Position in World Soybean Meal Trade" (Park, 1998), which was again an internal discussion paper from the Iowa State Grain Quality Laboratory. Within this paper, the beginnings of amino acid considerations were developed. The objectives of Park's paper were to "compile a world and U.S. soybean meal quality database, estimate the accuracy with which near-infrared technology can measure soybean meal quality, begin an assessment of amino acid and protein digestibility as related to meal value and measurement, define additional research needed, and summarize available data relating meal quantity and quality to soybean composition, and project availability of higher quality meals" (Park, 1998, p.3).

The objective most relevant to the current study was that involving the amino acids.

Within this analysis, amino acid values were presented for soybean meal from several different countries. The point to note from this study is that the protein content did not necessarily imply the amino acid content. Assuming that the differences in amino acids values within the soybean meal were a result of differences in the amino acid values within the bean, the implication made was that the low protein beans of the northwest may not warrant lower values, as prescribed by protein content. The preliminary assumption is a valid one, since the extraction of oil does not influence amino acid values. Park and Hurburgh then concluded that the value should depend on the livestock being fed, and not the protein value, which is precisely the topic of the current study.

CHAPTER 2: THEORETICAL FRAMEWORK

The theoretical foundation for this work is based on the marginal product of soybeans in livestock production. The marginal product of any input is defined as the extra amount of output that can be gained by an incremental increase in that input. Starting with an objective function as follows,

$$\Pi = P * Q(B_1, B_2) - (P_1 * B_1 + P_2 * B_2)$$

where Π is profit, P is the price of the output, which in this case is livestock, B_1 and B_2 are two separate types of soybeans, P_1 and P_2 are the associated soybean prices, and $Q(B_1, B_2)$ is the production function for livestock. The first order conditions that result are

$$P * \frac{\partial Q}{\partial B_1} = P_1 \qquad\qquad P * \frac{\partial Q}{\partial B_2} = P_2$$

It is assumed here for simplicity that soybeans are the only input, and that livestock can represent any species. Dividing the first order conditions, the following equation is derived:

$$\frac{MP_1}{MP_2} = \frac{P_1}{P_2}$$

If the two types of soybeans are identical, both sides of the equation must equal one. Assuming the two soybeans are not identical, the marginal products must be different. However, under a commodity pricing system where price is given by P = f(weight), the prices would be the same, and the equality would not hold. This leaves the market with a theoretical flaw that should be corrected.

The first attempt to correct this discrepancy was through the use of protein and oil premiums and discounts. This system used protein and oil as a proxy for the actual marginal product of each bean, and assigned premiums and discounts accordingly. Essentially, a price equation of the form P = f(Pr,O), where Pr is protein and O is oil, was established to convey the relationship between price and physical characteristics. For the use of comparison to later systems, protein and oil premiums can be summarized by

$$\Delta MP \rightarrow \Delta[\Pr, O] \rightarrow \Delta P$$

which says that the changes in price reflect changes in protein and oil, that are assumed to reflect changes in the marginal product. However, the relationship between the protein and oil components and the marginal product is indirect and depends on several intermediate functional relationships.

The problem with these systems is that while protein and oil do give an idea of the quality of the bean, they do not relate directly to the marginal product in terms of end use. These systems do give a better idea of the marginal product than a commodity price, because they price soybeans based upon characteristics that are assumed to convey the marginal product. This assumption was questioned, and a more accurate method of measuring the marginal product was developed through a modeling process that turns soybeans into meal and oil. This model assigns values based upon the theoretical amounts and quality of products that would result when the beans have been processed using a hexane extraction process.

The Soybean Processing (SPROC) program, version 2.42, was used to calculate the estimated processed value (EPV) based upon soybean percentages of protein, oil, and output prices for meal, soybean oil, and mill feed. In functional form, EPV = f(Pr, O, P_m, P_o, P_h), where P_m is the price of soybean meal, P_o is the price of soybean oil, and P_h is the price of mill feed, or soybean hulls. The EPV that was calculated was broken down into four components: meal value, oil value, mill feed value, and a "make allowance", reflecting the margin taken by a processor. In all the components except the make allowance, a marginal product was found by SPROC. As an example, the marginal product for meal was in the form pounds of meal per bushel of soybeans. These marginal products were multiplied by the appropriate price to calculate the value of the marginal product according to the following identity:

$$VMP = P * MP$$

The price was then set to mirror the value of the marginal product to complete the following relation:

$$\Delta[\Pr, O] \rightarrow \Delta MP \rightarrow \Delta VMP \rightarrow \Delta P$$

This relationship states that changes in price reflect changes in the value of the marginal product. These changes reflect changes in the marginal product, as calculated from changes in the end products of protein and oil.

Although this method was an improvement over the protein and oil premiums and discounts system, it did not draw upon the actual end use of the soybean meal, which is feed for livestock. As an even more accurate method of obtaining the marginal product of each soybean sample, diets were developed for swine and poultry. The marginal product of each soybean was determined through the observation of changes in a least cost diet ration from one soybean sample to the next. To determine the value of the marginal product, the diet was fixed, and the marginal product was multiplied by an appropriate price ratio:

$$\frac{livestock}{\Delta meal} * \frac{\$}{livestock} = \Delta VMP$$

where the term *livestock* represents one unit of any animal species. The variable $\Delta meal$

refers to the amount of soybean meal that is required in one unit livestock diet, which changes with differences in amino acid content of the beans in each sample. The marginal product is the first term, and is intended to capture the changes in performance relative to changes in soybean quality.

This system then assigns a price based upon the differences in the value of marginal product that results in the following:

$$\Delta soybean \rightarrow \Delta MP \rightarrow \Delta VMP \rightarrow \Delta P$$

This expression does not use any proxy for the marginal product, and therefore accurately relates soybean quality to the final end use value. In functional form, $P = f(AA_i, P_{AAi})$ where AA_i represent the amino acids that vary from one soybean sample to the next, and P_{AAi} is the set of prices for synthetic amino acids.

Each system attempts to price soybeans based upon a more accurate measure of the value of marginal product, and therefore marginal product. The higher quality soybean samples are shown to give either more of a product, as in the case of soybean oil, or a higher quality product, as in the case of soybean meal. The soybean prices assigned by each system attempt to capture this quality difference and reflect it in a price. By connecting the value of the marginal product with a pricing system at the very beginning of the market chain, this method provides the market with a more accurate method of pricing soybeans.

CHAPTER 3: PROCEDURES

In order to analyze the different pricing systems available for soybeans, two different data sets were used. The first spanned the years 1992-1999, and was provided by the Iowa Grain Quality Initiative. It included only protein and oil values consistently, with occasional fiber values. The fiber values were not used in any analysis, since they could not be universally included. Data points with missing values for oil and/or protein were also omitted. The second data set used was from the Iowa Grain Quality Laboratory at Iowa State University. It included wet chemistry analysis that provided values for oil, protein, and fiber, as well as for amino acid content.

Summary statistics for these data sets are shown in table 1, with the second data set referred to as "amino acid" (AA). The average soybean in the United States has 35% protein and 18.5% oil. The data used here roughly follows that average, although the protein tends to be slightly higher than average, and the oil tends to be slightly lower. The amino acid data

Table 1: Summary values for sample data.

	1992	1993	1994	1995	1996	1997	1998	1999	AA
Maximum Protein	40.4	39.9	40.2	40.4	40.7	41.7	40.8	40.9	47.51
Minimum Protein	28.4	31.3	30.6	30.3	30.3	29	29.6	25.3	25.08
Average Protein	35.2	35.6	35.5	35.4	35.5	34.6	36.1	34.6	36.93
Protein Std. Deviation	1.34	1.20	1.34	1.34	1.16	1.53	1.50	1.88	4.00
Maximum Oil	20.8	21	21.4	21.4	21.1	22.4	22.2	23.9	23.20
Minimum Oil	14.1	12.8	15	14.6	15.2	15	16	15	12.91
Average Oil	17.4	17.9	18.2	18.2	18.0	18.5	19.1	18.6	18.25
Oil Std. Deviation	0.87	0.84	0.92	0.84	0.86	0.96	0.81	1.05	2.00
Observations	2286	1957	1551	1951	1528	2611	2035	1059	268

set is from a much larger area, including at least 22 states and several provinces of Canada. The geographic information associated with this data set is incomplete, so the number of states could actually be higher. This range in source geography causes a noticeable difference in protein and oil values. The maximums are generally higher, and the minimums are generally lower.

For instance, the highest protein bean in the amino acid data set has a protein percentage of 47.51%, while the next highest in any other year is 41.7%. The protein minimum is also lower than any other observed, at 25.08% while the next lowest is 25.3%. The same is true of the oil values, where the maximum is higher than other oil maximums in seven of the eight years of data, and the minimum is lower than other oil minimums in seven of the eight years of data. This range translates through to the standard deviations, which are fairly low in the 1992-1999 data, but are at least twice as high in all cases for protein and oil, with the exception of the 1999 oil values.

This data was used to analyze the effectiveness of several soybean pricing systems. The first was a system developed by Ag Processors Incorporated (AGP) that pays premiums per bushel for oil content according to the following scale shown in table 2. The performance of this system was analyzed and compared to the next most accurate system, which included oil and protein premiums of a different nature.

Table 2: AGP oil premium scale.

Oil Content	19.6-19.7	19.8-19.9	20-20.1	20.2-20.3	20.4-20.5	20.6-20.7	20.8-20.9	21-21.1	21.2-21.3
Premium ($/bu)	$0.02	$0.03	$0.04	$0.05	$0.055	$0.06	$0.065	$0.07	$0.075
Oil Yield (lbs/bu)	11.51	11.63	11.75	11.87	11.99	12.11	12.23	12.35	12.47

Instead of only establishing premiums, the next system used discounts as well to pay for the use of premiums. At first, only oil premiums were used this way, in order to provide a direct comparison to the AGP system. In subsequent analysis, protein premiums were included to provide a more accurate method of pricing soybeans. These premiums and discounts were also ascribed on a less arbitrary basis then in the AGP system. The general format used was to give the average bean a long term commodity price of $5.15 per bushel, and then to pay a set amount per unit deviation from the average within the sample. For instance, in the first oil premium system, it was decided that a .1% deviation in oil content would warrant a $0.01 premium or discount. In other words, with an average oil content from 1992 of roughly 17.4%, a bean with an oil content of 17.5% would receive a $0.01 premium.

The same would hold true for the discount given to a bean with 17.3%. Protein premiums were examined in the same way. A deviation of 0.1% from the mean protein value was given a $0.01 premium or discount. However, neither protein or oil premiums by themselves are completely accurate. It is well known that an inverse relationship exists between protein and oil content. This relationship is not captured by either protein or oil premiums by themselves, which led to the inclusion of both protein and oil in later systems.

When both protein and oil premiums and discounts were included, they were allocated in the same way and added together. Continuing with the previous example, if a soybean with 17.5% oil had 35.1% protein when the average was 35.2%, the oil premium and the protein premium would cancel out, leaving simply the commodity price. This assumes that deviations of .1% in protein were actually worth $0.01, which is the same scale set up for oil content.

The sample data was then priced using the estimated processed value (EPV) method. This was accomplished through the use of the program SPROC, developed by T.J. Brumm and Dr. Charles Hurburgh. SPROC essentially models the industry processes that separate soybeans into meal and oil, and then uses prices for each to obtain a price for the soybean. It allows for fiber inputs with each sample, although they were not available in the 1992-1999 data. Instead, a constant 4.4% fiber content was assumed and imposed. Long term prices were needed for soybean meal and oil, so ratios from "Soybean Price Adjustments Based on Protein and Oil Variations" (Huck, 1997) were used to obtain the necessary prices. In this paper, a value of 2.32 was calculated as the average ratio of soybean oil price to soybean meal price in Decatur, Illinois over the span 1987-1996.

Averages of 42.8 lbs. meal per bushel and 11.1 lbs. of oil per bushel were also given. Assuming that the long term price for soybean meal is $180 per ton, and using the average value of 42.8 lbs. meal per bushel of beans, the average value of meal from a bushel of soybeans is $3.852. With the ratio of 2.32 and the $180 per ton meal price, a soybean oil price of $0.209 results. This price was reduced slightly to a value of $0.20, in part to accommodate for recent trends in oil as well as soybean prices. Using the 11.1 lbs. of oil per bushel average, this gives an average oil value of $2.22 per bushel. The value given by the sum of the parts is $6.07. The difference between this price and the long term assumed commodity price of $5.15 is defined as the make allowance.

In each and every transaction that takes place, the producer will receive a lower amount than the processor, to cover the cost of adding value to the product. In this case, the make allowance is the difference between $6.07 and $5.15, or $0.72. In order to compare across systems later in the paper, $5.15 was subtracted from the average sample EPV in each data set. This gave the make allowance used for that year, and equalized the means across samples. While the make allowance could have been set at essentially any price between observed values of $0.58 and $1.71 from Huck's analysis, it was useful to set the allowance at a value that permitted comparison across systems. The values for oil, meal, and commodity soybeans remained set, and were used consistently throughout the rest of the paper.

Since the only sample inputs used were bean protein and oil, it was expected that not much difference would be seen in the structure of premiums and discounts given. The nominal value of premiums and discounts for individual bean varieties would be different, though, because the beans were being priced based upon end use value, rather than arbitrarily on content. It should be noted that the protein content of the meal produced in SPROC was allowed to vary, as opposed to being held to the 48% constraint that currently exists. This was necessary for comparability with analysis done later in the paper.

The next system considered was an attempt to bridge the gap between the previous system and the most specific analyzed here. This system used regressions run on the amino acid data set to provide coefficients for each amino acid against protein. These coefficients were then used to predict amino acid values for each of the soybean samples for the 1992-1999 and amino acid data sets. While it is impossible to know if the predictions are accurate for the data sets without actual measured amino acid values, they can be judged within the amino acid data set.

Differences between the predicted and actual values were calculated for these predictions. From the differences, sums, averages, maximums, and minimums were calculated for each of the five essential amino acids (threonine, cystine, methionine, lysine, and tryptophan). Averages, maximums and minimums were also calculated for amino acid values in the other 8 data sets. If this system is found to be reasonably accurate, it could provide an intermediate step for pricing until wet chemistry that provides amino acid data can be made cheaper and easier.

The final system analyzed used end use value as a method of pricing soybeans. This was accomplished with the help of the Brill Agri-Business software. Brill is essentially a program that calculates least cost feed rations based upon user supplied data, including species specific feed and nutrient requirements. First, diets were developed in consultation with Dr. Jerry Sell and Dr. Dean Zimmerman from the Animal Science department for seven types of animal. Three were for broiler chicks, aged 0-3 weeks, 3-6 weeks, and 6-8 weeks. The other four were for pigs, representing average grower and finisher pigs, lactating sows, and gestating sows. These diets included a list of possible feed sources, including soybean meal, corn, animal fat, salt, and synthetic amino acids, among others. Each of these feed sources were associated with a price and list of nutrient values to be gained by use in the diet. The diets also included a set of animal requirements obtained from the appropriate National Research Council Nutrient Requirements book (NRC) (National Research Council, 1994, 1998). The poultry and swine NRC's also were the source for the nutrient composition of each feed.

Before the actual analysis within Brill was conducted, several steps were taken to prepare the data for entry into the program. It was first necessary to determine what effect the process that turns soybeans into meal would have on the amino acid content of the end product. Since the protein levels increase from the bean to the meal, there should be a higher concentration of amino acids in the meal than in the original soybean. For simplicity, it was assumed that any hulls added back into the meal contained no amino acids. While this is not strictly true, the amount of error incorporated with this assumption is very low. Hulls were added back in on a varying basis, to equalize the fiber content at 3.5% for each sample.

It was also assumed that there were no losses of amino acids during processing, from such sources as break down of amino acids or loss of total mass during processing. This left the change in amino acid to be equal to the percentage change in protein value. Generally, the calculation takes the form

$$AA * (MP/BP) = MAA$$

where AA is the amino acid percentage, MP is the meal protein, BP is the bean protein, and MAA is the meal amino acid percentage. For instance, if a 35% protein bean was found to produce 48% meal, and the original soybean contained 2.8% lysine, then the lysine content within the meal would be 2.8*(48/35) = 3.84%.

The second necessary step was to understand the nature of digestion in swine, and to choose the appropriate basis for calculation of amino acids. In determining the amino acid requirements of swine, there are three bases that can be used: apparent ileal digestible basis, true ileal digestible basis, and total basis. The apparent ileal digestible basis measures the difference between the amount of amino acids fed to the pig and the amount of amino acids found at the end of the ileum. This value is by definition lower than the true ileal digestible basis, which takes into account the addition of amino acids through digestive secretions, and the loss of amino acids that are absorbed in forms that are not completely metabolizable. In effect, the apparent ileal digestible basis is simply a mass balance on the digestive system of the pig, while the true ileal digestible basis includes a correction for the addition of amino acids from digestion and the disappearance of amino acids that are not metabolized.

The total basis expresses requirements as a percentage of the total amount of nutrients fed. For this study, the true ileal digestible basis was used, since it includes the corrections previously mentioned and most accurately expresses amino acid requirements. As an example, take a 35 kilogram growing pig. The requirement listed in the swine NRC for lysine is 1.34% of the diet, on a true ileal digestible basis. Also in the NRC, the lysine percentages for corn and 47.5 % soybean meal are .26 and 3.02, respectively. To accurately represent the amount of lysine that can be digested and metabolized, these values must be multiplied by the true ileal digestibilities for each, 78% and 90%, respectively. The equation takes the form

$$AA * ID = NAA$$

where AA is the feed amino acid content, ID is the ileal digestibility, and NAA is the new amino acid contest. This means that only 78% of the lysine in corn and 90% soybean meal will be digested, so the values entered into Brill are .26*.78 = .2028 for corn, and 3.02*.90 = 2.718 for soybean meal.

Once all seven diets were entered into Brill, the next step was to enter amino acid and crude protein values for each of the 268 data points in the amino acid data set. The difference in method of calculation between swine and chickens meant that each data point had to be entered twice, once with the amino acid values for chickens, and once on the true ileal digestible basis for pigs. The other values for each soybean sample were left at their average values. This was done because the largest change in value was expected to be a result of variations in amino acids. The time consuming nature of data entry with little potential benefit was also a factor in the decision. From here, the seven diets were analyzed in Brill with each of the soybean samples. This produced 268 sets of seven diet costs for the two species to be analyzed.

To translate these diet costs into a soybean price, the same method of assigning premiums that had been used in other systems was used for simplicity. The average soybean meal was assumed to have the values listed in the respective NRC for swine and poultry. These averages were associated with the assumed long term price of \$5.15, and deviations from the mean diet cost were given premiums or discounts at a rate of \$0.01 per \$0.01 deviation from the average based upon 100 lbs. of feed. The choice of rates was somewhat arbitrary, as before, but this was only a first step.

Regardless of the rate selected for giving premiums and discounts, this system is more accurate because of the increased level of specificity that is used to determine the premiums and discounts. Later, a more accurate method of pricing the soybean samples was developed that related the changes in diet cost directly back through the market system to a change in soybean value. This was done through the following equation:

$$\left(DC_i - DC_{avg}\right) * \frac{1}{meal_i} * mealyeild_i = pod_i$$

where $(DC_i\text{-}DC_{avg})$ is the deviation from the average diet cost, $meal_i$ is the percentage of meal in the total diet, $mealyield_i$ is the theoretical amount of meal produced per bushel of soybeans from SPROC, and pod_i is the premium or discount given by the new system. Since this method relates directly the changes in diet cost to changes in soybean price, and does not rely upon an arbitrary scale for establishing premiums and discounts, it was used for the analysis that follows.

To accurately compare across systems, the value of soybean oil was subtracted from the price of each bean. Since the last system considers only the end use value of the soybean meal, and since soybean oil really has no qualitative differences across beans, this process of standardizing each bean based on protein seemed appropriate. In other words, soybean oil from one bean is essentially the same as soybean oil from another bean, so that the only question from bean to bean is how much soybean oil can be derived from each sample. The quantity of oil is derived within SPROC when it simulates the processing that extracts oil.

To properly analyze the results obtained from running each of the soybean samples through Brill, it was useful to understand the kind of distribution each of the systems produced. This helped to determine whether or not it was reasonable to assume that all of the systems produced the same type of distribution, and could be easily transformed and compared. The software Best Fit was used to examine the distributions. Best Fit was used to analyze the price data and choose which of approximately 30 alternative distributions most closely represented the distribution of prices. When it was found that the seven species, EPV, and protein premium systems produced four different distributions, other methods for analyzing the results were deemed necessary.

Non-parametric statistics basically attempt to "forgo the traditional assumption that the underlying populations are normal" (Hollander, 1999, p.1). To that end, the prices obtained from each of the three systems and seven species were ranked in order from cheapest to most expensive. Then three statistical methods were used to analyze whether or not the nine systems of pricing soybeans were statistically different: Pearson's product moment correlation coefficient, Spearman's Rho, and Kendall's Tau. Pearson's product moment correlation basically gives the amount by which two sets of data are linearly correlated. The data need not be ranked for this analysis, as in the other two methods.

In equation form, Pearson's product moment correlation is given by (Conover, 1999)

$$r = \frac{\sum_{i=1}^{n}\left(X_i - \overline{X}\right)\left(Y_i - \overline{Y}\right)}{\left[\sum_{i=1}^{n}\left(X_i - \overline{X}\right)^2 \sum_{i=1}^{n}\left(Y_i - \overline{Y}\right)^2\right]^{1/2}}$$

where X_i and Y_i are specific points within data sets X and Y. An r value of one would show an exact linear relationship between two pricing systems. An r value of negative 1 would show an exactly inverse linear relationship between two pricing systems. As values get closer to zero, they get closer to showing independence between the two systems. Hypothesis tests are possible with Pearson's product moment correlation coefficient if the bivariate distribution between the two data sets is known. For the pricing data, several different univariate distributions were observed, making a correlation statistic that is independent of distribution necessary.

Spearman's Rho and Kendall's Tau are two such statistics. Since they are independent of distribution they can be used in hypothesis testing. Spearman's Rho is essentially the same as Pearson's product moment correlation, except it is computed on the ranks and average ranks in case of ties. The equation for Spearman's Rho is as follows (Conover, 1999):

$$\rho = \frac{\sum_{i=1}^{n} R(X_i)R(Y_i) - n\left(\frac{n+1}{2}\right)^2}{\left(\sum_{i=1}^{n} R(X_i)^2 - n\left(\frac{n+1}{2}\right)^2\right)^{1/2}\left(\sum_{i=1}^{n} R(Y_i)^2 - n\left(\frac{n+1}{2}\right)^2\right)^{1/2}}$$

where $R(X_i)$ and $R(Y_i)$ are the ranks of each data point in the data sets X and Y, and n is the total number of data points. The interpretation of this is essentially the same as with

Pearson's coefficient, where the values range from negative one to one, with zero being statistical independence. The difference is that hypothesis tests can be run to determine whether or not two data sets are independent. In this case, a degree of dependence is expected, so hypothesis testing to determine independence at a significance level is not appropriate. As a result, Spearman's Rho is not the preferred statistic in this situation.

Another statistic used to describe the amount of dependence between each of the pricing systems was Kendall's Tau. This statistic is essentially a measure of how many concordant and discordant pairs exist between two sets of data. Concordant pairs are defined as pairs of samples that differ by the same sign, such as (4,6) and (6,8). Since both samples increase from observation one to observation two, they are considered concordant. In the same way, discordant pairs of samples are those which have opposite signs from one observation to the next, such as (4,6) and (8,6).

Kendall's Tau uses these ideas in the following way (Conover, 1999):

$$\tau = \frac{N_c - N_d}{n(n-1)/2}$$

where N_c is the number of concordant pairs, and N_d is the number of discordant pairs. The denominator is equal to the number of pairs that can be chosen within a data set that has n samples. This means that if every pair observable is concordant τ will be equal to one, and if every pair is discordant τ will be negative one.

While Kendall's Tau is also used to test for independence, it does not look for the linear relationship between sets of data, which is something that is expected here. Kendall's Tau is more likely show the effects of many small changes between data, whereas Spearman's Rho is more likey to display major changes from one data set to the next.

For this reason, Kendall's Tau seems more appropriate in this situation.

The last method used to assess differences between pricing systems was a logit model. To do this, values of zero or one were assigned to each sample, based upon whether or not the sample outperformed expectations based upon protein content. The determination of outperforming protein was made by normalizing each of the prices according to the following standard equation:

$$P_N = \frac{P - \mu}{\sigma}$$

where P_N denotes the normalized price, μ denotes the mean price, and σ is the standard deviation of the prices. The normalized values were then compared to the values from the protein premium system to see if they fell closer or farther from the mean in terms of standard deviations.

The ones and zeros were used in the logit model with the response variable as protein. With only one response variable, the coefficients B_0 and B_1 in the equation (Conover, 1999)

$$\Pr_i = \frac{1}{1 + e^{\mathrm{B}_1 * P_i + \mathrm{B}_0}}$$

were estimated, where $\Pr_i$ is the probability of outperforming protein, and P_i is the bean protein. This provided a rudimentary prediction equation for determining the likelihood of a bean being worth more under an amino acid system than under a protein premium system, at a given protein value.

In order to estimate how much a soybean might be worth under a given amino acid system, regressions were run in the form

$$system_j = \mathrm{B}_0 + \mathrm{B}_1 * P_i$$

where $system_j$ was the price under any given system, and P_i referred to the soybean protein percentage. Once B_0 and B_1 were calculated from an OLS regression, the price of any soybean at a given protein could be estimated. This allowed differences in value between systems to be estimated for any given protein content. From here, conclusions were drawn from the study and sources for more analysis were examined.

CHAPTER 4: RESULTS AND DISCUSSION

As a first step, a data set was acquired from Dr. Charles Hurburgh and the Iowa Grain Quality Initiative that contained protein, oil, fiber, and amino acid contents of 268 sample soybeans. The samples were drawn from at least 22 states and several provinces of Canada, giving a wide range of qualities for use in developing an amino acid pricing system. Before any pricing of these soybeans was examined, a fairly extensive study into the nature of relationships between protein and essential amino acids was undertaken. The first step was simply to regress what are considered the essential amino acids (cystine, lysine, methionine, threonine, and tryptophan) on protein content, to see how each amino acid contributed to the overall protein value. The results of this regression were less than clear, and are shown below in equation form.

$$\underset{(-9.10)}{Prot = -7.856} - \underset{(-1.15)}{1.755*Cys} + \underset{(18.08)}{17.603*Lys} - \underset{(-2.40)}{5.904*Met} + \underset{(3.21)}{5.506*Thr} + \underset{(1.06)}{1.384*Try}$$

The numbers in parenthesis are t-values, which show that only the intercept and lysine coefficient can be considered statistically significant. Also puzzling was the fact that two of the coefficients on the essential amino acids were negative, implying that higher bean protein contents could actually be associated with lower cystine and methionine levels. This could not be said with any level of confidence because of the t-values, but is interesting as a preliminary result regardless.

The next step taken was to regress the essential amino acids individually on protein, in order to see if the negative coefficients were valid, or only a factor of interference from the other variables included. The regressions took the form

$$PROT = \beta_1 + \beta_2*AA$$

where AA is the amino acid in question. The results of this are shown in table 3. All of the

Table 3: Results from individual amino acid regressions against protein.

	Intercept (β_1)	Coefficient (β_2)	T-value	R-squared
Cystine	14.94	35.80	8.82	0.226
Lysine	-8.61	19.68	58.86	0.929
Methionine	7.99	54.83	15.31	0.468
Threonine	-5.11	30.22	37.36	0.840
Tryptophan	24.19	30.44	8.90	0.229

regressions provided high T-values, which is in contrast to the regressions done with multiple amino acids against protein. Also, all the relationships seem to be positive which again differs from previous regressions. Another interesting fact to note is the strength of the relationship between lysine, threonine and protein. Considering that regressions of all the essential amino acids only produced an R-squared value of .9328, these can be considered significant. Therefore, lysine appears to be the main contributor to variations in protein.

In an attempt to examine the nature of the high R-squared values obtained in this regression for lysine and threonine, these amino acids were regressed on protein in the form

$$PROT = \beta_1 + \beta_2*Lysine + \beta_3*Threonine$$

This regression yielded an R-squared of only .9300, which is a gain of only .0013 over the regression with only lysine. Another interesting facet to this regression is that it returned a coefficient that was statistically insignificant for threonine. This led to the hypothesis that lysine and threonine were accounting for the same types of variation in protein values, and thus would show a high amounts of collinearity. The hypothesis was examined using a regression with the following equation:

$$Threonine = \beta_1 + \beta_2*Lysine$$

A high degree of collinearity was found, since the R-squared value obtained was 0.8794. These results only re-affirmed the suspicion that lysine was the main contributor to protein, and that without values to weight the cost and necessity of individual amino acids, other amino acids have very little effect on measured protein values.

At this point it was still uncertain whether or not the same was true for amino acid content within soybean meal, compared to the raw soybeans themselves. This was also examined, and the process used is described later in this section. Essentially, it consisted of simulating the process that makes meal from soybeans, and carrying the amino acid content through the process. This resulted in amino acid contents for soybean meal theoretically made from each of the 268 samples within the amino acid data set. The same types of regressions were run in the following form,

$$AA = \beta_1 + \beta_2 * PROT$$

where AA is the amino acid content, and PROT is the meal protein percentage. This time other sources from literature were available to compare and validate the results. The first source of regression values was a study done by the Degussa Corporation (Heimbeck, 1990) that contained 277 samples from at least 8 different countries and both 44% and 48% meal. The second source of regression coefficients was the Nutrient Requirements of Swine (NRC) (National Research Council, 1998), which gave an average protein value of 45.6%, and did not report the number of samples used. The comparison of these two, along with the sample values from this study are shown in table 4. While most of the values for both the protein coefficient and the intercept are of the same order of magnitude, the values are far from being consistent. Part of this discrepancy could be because the sample meal values are only simulated meal and not actual measurements. Even the two literature sources do not agree, however, on many of the intercepts. For instance, the intercepts for methionine differ by a factor of 10. Most of the protein coefficients were in close agreement, with the two

Table 4: Regression results of protein against amino acids from several sources.

Lysine			
	β_1	β_2	R-squared
Degussa	-0.252	0.0665	0.70
NRC	-0.081	0.0644	0.78
sample	0.152	0.0439	0.85

Tryptophan			
	β_1	β_2	R-squared
Degussa	-0.041	0.0144	0.62
NRC	0.058	0.0118	0.59
sample	0.035	0.0078	0.26

Threonine			
	β_1	β_2	R-squared
Degussa	0.203	0.0344	0.66
NRC	0.081	0.0381	0.81
sample	0.118	0.0258	0.77

Methionine			
	β_1	β_2	R-squared
Degussa	0.127	0.0111	0.44
NRC	0.017	0.0141	0.65
sample	0.106	0.0086	0.50

Methionine + Cystine			
	β_1	β_2	R-squared
Degussa	0.157	0.0255	0.52
NRC	0.147	0.0263	0.57
sample	0.418	0.0147	0.44

literature sources not varying by more than a few thousandths. The sample coefficients tend to be somewhat lower, but this was somewhat offset by the fact that many of the sample intercepts tend to be slightly higher. Regardless, the strongest correlation for all three data sets were those for threonine and lysine, which reaffirm the previous conclusions that lysine and threonine accounted for most of the variations in protein.

One final method was used to determine the order of importance of the essential amino acids within the sample data set. This consisted of a stepwise regression that started with no variables, and first included the most statistically significant of the five essential amino acids. The process was repeated, subject to the constraint that any variable entered had to show a 0.5 significance level before it was entered into the model. The results are shown in the table 5. The first variable that entered the model was again lysine. One surprising result was that threonine did not pass the 0.5 significance level constraint and was never entered into the model. This is likely due to the fact that threonine and lysine account

Table 5: Summary of stepwise regression of amino acids.

Step	Variable Entered	Number Vars In	Partial R-Square	Model R-Square	C(p)	F Value	Pr > F
1	lysine	1	0.8511	0.8511	7.938	1520.65	<.0001
2	tryptophan	2	0.0038	0.8549	3.035	6.9	0.0091
3	methionine	3	0.0009	0.8558	3.457	1.58	0.2096
4	cystine	4	0.0006	0.8564	4.315	1.14	0.2857

for much of the same type of variance in protein. Once lysine entered the model, adding threonine appears to have accounted for very little of the remaining variance. As can be seen in table 5, both methionine and cystine did not seem to add much to the model once lysine and tryptophan had already been included. They were also much closer to failing the 0.5 significance constraint than were lysine and tryptophan. Again, the hypothesis that lysine accounted for much of the variability in protein was confirmed. Also, it was shown that the contributions of the other essential amino acids to protein values were either very small, or at least vastly outweighed by lysine.

AGP Oil Premiums

The AGP premium system awarded premiums based only upon oil content, according to the schedule in table 5. A moisture adjustment was made to the data by multiplying the original oil percentage by (100-11.5)/(100-13), to account for the increase in oil percentage associated with a decrease in moisture percentage. Using the 1992-1999 and amino acid data, the following values were obtained and are shown in table 6.

Most samples were unaffected by this premium system. It should be noted that the average premiums are calculated only for those samples that received a premium. This was done because so many samples received no premium that including them in the average would cause the value to be extremely low and difficult to interpret. Both 1997 and 1998 were particularly good weather years for producers, which explained the larger number of premiums. The maximum percentage of samples that received a premium was in 1998 when about 40% of the samples received an average of more than $0.04 per bushel.

There are several problems with this system. First, the magnitude of the premiums involved are probably not enough to encourage much improvement in soybeans over time. Second, this system does very little to approximate the actual value of the soybean. Not only

Table 6: Data analysis of the AGP Oil Premiums System.

	1992	1993	1994	1995	1996	1997	1998	1999	AA
Average Premium	$0.032	$0.036	$0.038	$0.036	$0.036	$0.039	$0.042	$0.042	$0.051
Maximum Premium	$0.070	$0.075	$0.075	$0.075	$0.075	$0.075	$0.075	$0.075	$0.075
Total Premium Value	$1.46	$3.93	$6.09	$7.05	$3.36	$21.34	$35.46	$11.29	$4.81
Number of Premiums	45	108	162	197	93	541	844	270	95
Total number	2286	1957	1551	1951	1528	1528	2035	1059	268

is protein, and therefore meal, not accounted for, but even the premiums for oil are vastly under-valued. As can be seen in table 2, oil yields are associated with each premium. The changes in yield from one premium level to the next are consistently 0.12 pounds per bushel, which translate to a difference in value of $0.024 from one premium level to the next using a price of $0.20 per pound of oil. However, the changes in premiums are only one cent, and in some cases, only half a cent. Even when using a price of $0.16 per pound of oil, the difference in value is almost $0.02 from one premium level to the next.

Added to this problem, the premiums do not even begin until a bean is a full 1.0% above the national average. This translates to an extra $0.08 of value that is unrewarded if the national average oil yield is assumed to be 11.1 pounds per bushel. A final problem with

this system is the processing fee on all deliveries to cover testing and handling costs. A processing fee was assessed at a flat rate of $4.00 per load. As an alternative, AGP could include discounts with their premiums, as a means to offset the cost of NIR equipment and handling costs. Discounts would provide further incentive for improvement in soybean quality, and would reduce or eliminate the amount of processing fee necessary. Overall, this system leaves much to be desired in terms of the goals set at the beginning of this analysis, even for one that only uses oil to
assign premiums for soybeans.

Protein and Oil Premiums and Discounts

In comparison, a zero sum premium system, as developed by Dr. Roger Ginder and Mike Poray (Ginder, 1998), not only provides for a consistently higher level of premiums, but also provides greater incentives for soybean quality improvements. The first system examined used a somewhat arbitrary premium of $0.01 per 0.1% deviation from the sample oil mean, which was assessed for variations from the $5.15 long term average price. Tables 7 and 8 show sample statistics from such a strategy. Despite the fact that this system does not include any premiums or discounts for protein, it does have several advantages over the AGP oil system. First, much higher incentives are provided for increases in soybean quality, because of the higher premiums and discounts. The maximum premium observed was almost $0.53 per bushel, and the maximum discount observed was $0.51 per bushel. While these values are probably unreasonable to levy, they do show that large premiums and discounts are possible as a result of variations in the beans. To narrow the range of discounts and premiums, the rate at which premiums and discounts are applied could be changed. The average premiums and discounts tended to vary around six or seven cents, which is approximately the highest valued premium included in the AGP system. As expected, the total value of all premiums and discounts is zero, and the number of premiums and discounts tend to be fairly even. However, this system still falls short of conveying the true value of soybeans based on protein and oil, the estimated processed value (EPV). The values showing deviations between the oil premium system and EPV are shown in tables 7 and 8.

Table 7: Data analysis of a zero sum oil premiums and discounts system.

	1992	1993	1994	1995	1996	1997	1998	1999
Avg Discount	-$0.071	-$0.062	-$0.074	-$0.062	-$0.068	-$0.078	-$0.059	-$0.079
Avg Premium	$0.067	$0.068	$0.071	$0.070	$0.067	$0.074	$0.067	$0.083
Max Discount	-$0.327	-$0.512	-$0.316	-$0.360	-$0.277	-$0.348	-$0.314	-$0.361
Max Premium	$0.343	$0.309	$0.324	$0.320	$0.314	$0.392	$0.306	$0.529
Total Discount Value	-$78.68	-$63.43	-$56.42	-$63.74	-$51.70	-$99.49	-$63.56	-$42.81
Total Premium Value	$78.68	$63.43	$56.42	$63.74	$51.70	$99.49	$63.56	$42.81
Total Value	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Number of Discounts	1109	1020	759	1035	758	1273	1086	544
Number of Premiums	1177	937	792	916	770	1338	949	515
Total Number	2286	1957	1551	1951	1528	2611	2035	1059

Table 8: Deviations from EPV in an zero sum oil premiums and discounts system.

	1992	1993	1994	1995	1996	1997	1998	1999	AA
Number of deviations<0	1256	1022	845	1049	830	1482	1066	637	140
Number of deviations>0	1030	935	706	902	698	1129	969	422	128
Average deviation	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000
Maximum negative deviation	-$0.610	-$0.440	-$0.527	-$0.537	-$0.567	-$0.777	-$0.494	-$0.743	-$1.166
Maximum positive deviation	$1.400	$0.839	$0.836	$0.917	$0.876	$1.110	$1.081	$1.563	$2.023
Total deviation	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000

While the differences between EPV and an oil premium system are fairly reasonable, there are still a consistently larger number of negative deviations than positive deviations in each of the years analyzed. The maximum deviations may seem unreasonably large , but when the fact that no protein premiums were used in the first system is considered, they appear more reasonable. In other words, soybeans that are extremely high in protein, but low in oil would have a much higher value than what is assigned by an oil only premium.

Next, premiums for protein were added as well as the oil premiums to the $5.15 average long term price. This could be done one of two equally valid ways, through use of individual premiums or through use of the sum of protein and oil. The results are the same, regardless of which method is used. The calculations are as follows, with the individual premiums method on the left side of the equation:

$$\text{prot\%} - (\Sigma\ \text{prot\%} / k) + \text{oil\%} - (\Sigma\ \text{oil\%} / k) = (\text{prot\%} + \text{oil\%}) - \{ (\Sigma\ \text{prot\%} / k) + (\Sigma\ \text{oil\%} / k)\}$$

where k is the number of samples used. Since the terms cancel out, the two strategies are shown to be the same. The results for this strategy are shown in table 9.

Again, much higher premiums and discounts were provided by this strategy than for the AGP oil premium system. This pricing system does not have the problem of ignoring value in protein. The trade-off between protein and oil can be captured in these prices. However, prices assigned by this system still depend on the arbitrary application of premiums and discounts at a rate of $0.01 per 0.1% deviation from the mean in protein and oil, or some other arbitrary rate. This is another serious shortcoming for this system. No matter what market value exists for either component of soybeans, the rate at which premiums and discounts are allocated is equal. This could be changed by adjusting the scale to reflect the price ratio between protein and oil, which was one of the benefits to using EPV.

Table 9: Data analysis on a protein and oil premiums and discounts system.

	1992	1993	1994	1995	1996	1997	1998	1999
Average Discount	-\$0.090	-\$0.100	-\$0.075	-\$0.091	-\$0.070	-\$0.090	-\$0.094	-\$0.126
Average Premium	\$0.083	\$0.114	\$0.077	\$0.088	\$0.081	\$0.099	\$0.090	\$0.124
Maximum Discount	-\$0.589	-\$0.513	-\$0.442	-\$0.484	-\$0.481	-\$0.455	-\$0.497	-\$0.556
Maximum Premium	\$0.442	\$0.417	\$0.358	\$0.376	\$0.429	\$0.655	\$0.413	\$0.594
Total Discount Value	-\$99.00	-\$103.89	-\$58.80	-\$87.32	-\$57.12	-\$122.82	-\$93.57	-\$66.11
Total Premium Value	\$99.00	\$103.89	\$58.80	\$87.32	\$57.12	\$122.82	\$93.57	\$66.11
Total Value	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00
Number of Discounts	1098	1044	789	959	819	1370	994	525
Number of Premiums	1188	913	762	992	709	1241	1041	534
Total Number	2286	1957	1551	1951	1528	2611	2035	1059

This is done automatically in EPV through the use of soybean meal and oil market prices, and an assumption that every bushel of soybeans weighs 60 pounds. The other main differences between this system and EPV is that EPV is based upon the end use value of the soybeans, and incorporates a manufacturing make allowance to cover the cost of processing. For these reasons, differences between a protein and oil system and EPV were calculated, and can be seen in table 10.

Again, this strategy underestimates the value of soybeans for every sample used, as evidenced by the number of deviations less than zero. It was observed that the average deviations and the total value of all deviations were exactly the same as under the system that used only premiums on oil. Although this may seem counter-intuitive, the following series of equations illustrate that it is true.

(1) $$\Sigma\ \{\text{commodity} + (\text{oil\%}+\text{prot\%}) - \Sigma(\text{oil}+\text{prot})/k - \text{EPV}\}/k =$$

$$\Sigma\ \{\text{commodity} + \text{oil\%} - \Sigma(\text{oil\%})/k - \text{EPV}\}/k$$

Table 10: Deviations from EPV of a protein and oil premiums and discounts system.

	1992	1993	1994	1995	1996	1997	1998	1999	AA
Number of deviations<0	1730	1216	1029	1308	937	1927	1247	758	222
Number of deviations>0	556	741	522	643	591	684	788	301	46
Average deviation	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000
Maximum Negative Deviation	-$0.106	-$0.085	-$0.076	-$0.075	-$0.085	-$0.143	-$0.071	-$0.156	-$0.146
Maximum Positive Deviation	$0.719	$0.468	$0.430	$0.412	$0.461	$0.552	$0.428	$0.660	$0.866
Total deviation	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000

The left side of equation (1) is the average deviation from EPV in a system that pays based on protein and oil values. The right side is the average deviation from EPV in a system that pays on only oil.

(2) $$\Sigma(\text{commodity}) + \Sigma(\text{oil\%}) + \Sigma(\text{prot\%}) - \Sigma(\text{oil\%})/k - \Sigma(\text{prot})/k - \Sigma(\text{EPV}) =$$

$$\Sigma(\text{commodity}) + \Sigma(\text{oil\%}) - \Sigma(\text{oil\%}) - \Sigma(\text{EPV})$$

(3) $$\Sigma\ \{\text{prot\%} - \Sigma(\text{prot\%})/k\} = 0$$

Once the summation is carried through each term, equation (2) results. From here, terms cancel to give equation (3). Equation (3) is true, since deviations from the average protein value must be zero be definition, so equation (1) must be true.

One implication of this is that from the processor's point of view, it doesn't matter whether or not protein premiums are included in the system, because the average deviation is the same either way. Also, the total sum of deviations from EPV are the same, since the first equation, representing the average deviation, is the same as the equation would be for the total deviation with out dividing by the number of samples. The analysis would be the same otherwise. Therefore, from the processor's point of view, it appears that the extra effort of including protein premiums does not bring the soybean value any closer to the true value.

However, further examination indicates this is not true from the producer's perspective. For instance, consider a sample that has an extremely low oil value and an extremely high protein value. The value of this sample would only be increased by the protein premium, although the value of the soybean would have remained low under an oil only premium system. Thus, the addition of protein premiums does serve to re-order the premiums paid out in a beneficial manner. It is especially beneficial in creating proper incentives at the producer level. As a result, there is shown to be a value to this step in increased specificity.

Predicted Amino Acid Contents Based On Protein

The next most specific method of pricing soybeans involves predicting soybean amino acid contents based upon regressions from protein. In order to do this, regressions of the form Protein% = $\beta_1 + \beta_2$*amino were constructed. The coefficients β_1 and β_2 were then used to estimate amino acid contents of soybeans where real amino acid values were already known. Table 11 shows the error between the estimated values and the measured values, where amino acids with a * denote estimated values. The R-squared terms are from the regressions mentioned earlier. As expected, the largest errors were seen in the estimation of amino acids having the smallest R-squared values. The average deviation from predicted values was near zero for all amino acids. The most accurate predictions were in the middle range of protein contents. This appears to warrant separation of the amino acid data into groups based upon protein content if some kind of premium system employing predicted values is used.

The regression coefficients were then used to estimate amino acid values in data

Table 11: Differences between measured and predicted amino acid values

	threonine-threonine*	cystine-cystine*	methionine-methionine*	lysine-lysine*	tryptophan-tryptophan*
Sum	-0.0111	-0.0627	-0.0319	-0.0199	0.0785
Average	-0.0001	-0.0004	-0.0002	-0.0001	0.0005
Maximum	0.1153	0.5559	0.1739	0.1149	0.3532
Minimum	-0.1296	-0.3436	-0.1577	-0.1589	-0.3939
R-squared	0.8266	0.1193	0.3554	0.9299	0.1947

*denotes estimated values

where the true amino acid content was not known. It should be noted here that many of the protein values were in the middle range that was found earlier to yield the most accurate predictions. The results of this analysis are shown in table 12.

It can never be known how accurate these predictions are without wet chemistry

Table 12: Summary statistics for amino acid predictions.

Threonine								
	1992	1993	1994	1995	1996	1997	1998	1999
Average	1.333	1.345	1.340	1.340	1.343	1.313	1.361	1.312
Max	1.493	1.477	1.487	1.493	1.502	1.533	1.505	1.508
Min	1.123	1.212	1.191	1.181	1.342	1.141	1.160	1.027
Cystine								
	1992	1993	1994	1995	1996	1997	1998	1999
Average	0.555	0.574	0.567	0.566	0.570	0.526	0.597	0.525
Max	0.793	0.770	0.784	0.793	0.807	0.853	0.812	0.816
Min	0.243	0.376	0.344	0.330	0.569	0.270	0.298	0.100
Methionine								
	1992	1993	1994	1995	1996	1997	1998	1999
Average	0.494	0.503	0.500	0.499	0.502	0.479	0.516	0.478
Max	0.617	0.605	0.612	0.617	0.624	0.648	0.626	0.629
Min	0.332	0.401	0.385	0.377	0.501	0.347	0.361	0.259
Lysine								
	1992	1993	1994	1995	1996	1997	1998	1999
Average	2.235	2.255	2.247	2.246	2.251	2.203	2.280	2.202
Max	2.492	2.467	2.482	2.492	2.507	2.557	2.512	2.517
Min	1.897	2.041	2.006	1.991	2.249	1.926	1.956	1.743
Tryptophan								
	1992	1993	1994	1995	1996	1997	1998	1999
Average	0.363	0.379	0.373	0.372	0.376	0.337	0.400	0.336
Max	0.574	0.553	0.566	0.574	0.586	0.626	0.590	0.594
Min	0.086	0.204	0.175	0.163	0.374	0.110	0.135	-0.040

values for amino acids, although the predicted values could be used to assign a price in the same manner as the next system, based upon amino acid content. This was not considered practical in this study due to the size of the data sets from 1992-1999. The time consuming nature of the amino acid diet cost analysis in the next section precluded it from a time and cost perspective.

Amino Acid Pricing System

The final system was developed using the following theoretical relationship from chapter 2:

$$\Delta meal \rightarrow \Delta MP \rightarrow \Delta VMP \rightarrow \Delta P$$

where the symbol Δ refers to changes in each variable, *meal* represents the characteristics of soybean meal, *MP* is marginal product, *VMP* is the value of the marginal product, and *P* is the price of the soybean. The changes in soybean meal are assumed to be limited to changes in amino acid content. This was assumed because it was expected that most of the changes in soybean quality that could not be accounted for by previous methods were in the resulting soybean meal. For instance, soybean oil has one general quality; when it is sold at a commodity price the buyer knows how much oil they are getting. In soybean meal, crude protein content is purchased, but amino acid content represents the true value. Therefore, a new method for pricing soybeans based upon amino acid content was examined.

The first step in developing this pricing system was to examine feed for livestock, the most common end use of the soybean meal. To accurately model this end use, seven diets were constructed in cooperation with Dr. Jerry Sell and Dr. Dean Zimmerman in the Animal Science department. Examples of these diets can be found in the appendix. They are based on dietary suggestions from the National Research Council's (NRC) "Nutrient Requirements of Swine" and "Nutrient Requirements of Poultry" (National Research Council, 1994, 1998) for amino acid content, as well as for mineral and vitamin contents. The contents of other common feed ingredients were also obtained from this source. The diets were then input into the Brill Agri-Business software. Before the soybean samples could be input into Brill, they had to be adjusted, as was described earlier in the Procedures section. These adjustments amounted to standardizing the fiber content at 3.5%, adjusting for the processing of soybeans in to meal, and setting the amino acid values for swine to the true ileal digestibility basis. Once these adjustments were made, the soybean data was entered into Brill.

The input of the soybean sample data was done by entering their amino acid values. All other contents of the soybeans were left at the average value obtained from the NRC. This was considered viable because the minerals, trace elements and digestible energy are generally obtained from sources other than soybean meal. Therefore, the amount of soybean meal used within a given diet will mainly depend on the amino acid and crude protein requirements. The crude protein requirements were also lifted, since it was desirable to only include soybean meal to the extent that the amino acids were needed. In other words, it was intended that Brill not include soybean meal simply to raise the crude protein content. Since crude protein is generally just a proxy for many amino acid contents and accurate measurements for amino acids were available, crude protein was not allowed to have any influence.

Once the 268 soybean samples were entered into Brill, the least cost ration was found using each of the samples. This resulted in a set of 268 diet costs for each species that were ordered from least expensive to most expensive. Summary statistics from these results are shown in table 13. It should be noted that these diet costs are on a per ton of feed basis. The largest ranges between the maximum and minimum diet costs were found in the chicken diets, since chicken diets inherently include more soybean meal than swine diets. Therefore, the differences in amino acid contents across soybean samples are magnified. Also, the diets for young chicks and grower pigs showed higher costs and standard deviations than any others within the species. The younger animals typically require more amino acids for building muscle and tissue mass. This leads to the same effect, since the higher amino acids requirements in the diet mean higher percentages of soybean meal in the diet.

Table 13: Summary of diet cost results

	0-3 Week Chickens	3-6 Week Chickens	6-8 Week Chickens	Grower pig diet cost	Finisher pig diet cost	Gestating sow diet cost	Lactating Sow diet cost
Average	$131.18	$122.85	$115.52	$104.70	$91.65	$92.15	$104.39
Maximum	$145.56	$136.56	$127.11	$112.05	$94.45	$95.46	$110.76
Minimum	$121.86	$114.50	$108.66	$100.18	$89.88	$90.11	$99.95
Standard Deviation	$4.72	$4.23	$3.60	$2.17	$0.86	$0.98	$2.05

The ordered dietary costs were then translated into soybean prices. To do this, a method similar to methods used in previous systems was employed. The long term price of $5.15 was assigned to the diet cost that resulted from the average beans given in the NRC. As a preliminary method of valuation, premiums and discounts were assigned based on deviations from the NRC average at a rate of $0.01 per $0.01 deviation in diet cost on a 100 pound basis. This rate was arbitrary, though less arbitrary than previous systems because the premiums and discounts were based on differences in amino acids, rather than a proxy for the end-use components. Summary statistics for the prices that resulted are shown in table 14.

The rate chosen for assigning premiums and discounts resulted in fairly wide spreads

Table 14: Summary statistics for prices in the preliminary amino acid pricing system.

	0-3 Week Chickens	3-6 Week Chickens	6-8 Week Chickens	Grower pig diet cost	Finisher pig diet cost	Gestating sow diet cost	Lactating sow diet cost
Average	$5.12	$4.98	$4.99	$5.11	$5.13	$5.14	$5.13
Maximum	$5.59	$5.39	$5.33	$5.34	$5.21	$5.25	$5.35
Minimum	$4.40	$4.29	$4.41	$4.74	$4.99	$4.98	$4.81
Std Dev.	$0.24	$0.21	$0.18	$0.11	$0.04	$0.05	$0.10

between the maximum and minimum values for those based on chicken diets. The variation within prices based upon swine diets was much lower. This is again a result of the fact that swine diets use lower amounts of soybean meal than chicken diets. The averages were consistently below the long term price of $5.15, which shows that the amino acid values in the data set were generally lower than the averages provided by the NRC.

As a more accurate method of pricing the differences observed within diet costs, the variations in diet cost were related back through the market system to the bean directly through the following relation:

$$(DC_i - DC_{avg}) * \frac{1}{meal_i} * mealyeild_i = pod_i$$

where $(DC_i\text{-}DC_{avg})$ is the deviation from the average diet cost, $meal_i$ is the percentage of meal in the total diet, $mealyield_i$ is the theoretical amount of meal produced per bushel of soybeans from SPROC, and pod_i is the premium or discount given by the new system. This resulted in a new set of prices that were even more accurate because they did not rely upon the arbitrary rate for establishing premiums and discounts. Instead, the deviation in diet cost was transferred first to the meal within the diet, and then from the meal to the soybean at the beginning of the market system. Table 15 shows summary statistics for the improved pricing system.

These prices more accurately captured the fact that the data set had amino acid

Table 15: Summary statistics for soybean prices in the final amino acid pricing system.

	0-3 Week Chickens	3-6 Week Chickens	6-8 Week Chickens	Grower diet cost	Finisher diet cost	Gestating diet cost	Lactating diet cost
Average	$5.15	$4.92	$4.92	$5.10	$5.04	$5.14	$5.13
Maximum	$5.88	$5.51	$5.55	$5.63	$5.48	$5.67	$5.72
Minimum	$4.49	$4.21	$4.33	$4.61	$4.56	$4.64	$4.56
Std Dev.	$0.279	$0.262	$0.241	$0.191	$0.195	$0.195	$0.197

contents that were below those found in the NRC. This is shown by the fact that most average prices are lower than those generated using the previous method. Also, the premiums and discounts are less closely concentrated around zero, as indicated by the significantly higher standard deviations. The higher maximums and lower minimums also point to the idea that the more accurate pricing system provides for a wider spread in the sample prices. Some of this wider range can certainly be attributed to the fact that two new variables have been introduced: meal yield and percentage soybean meal in the diet . Values for the meal yield show little variance, so most of the changes can be attributed to the same meal in diet percentage. This is not surprising, since the amount of meal in the total diet ranged from 26% to almost 44% in 0 to 3 week chickens. The improvements provided by this method are used throughout the remaining analyses.

To explore the results provided by this new pricing method, scatter plots were constructed, showing bean protein and amino acids versus diet cost for each species. Several examples are shown in Figures 1, 2, and 3. The remainder can be found in the appendix.

These scatter plots are representative of the others that were produced in that all showed a negative slope, implying that higher bean protein and amino acid values do generally provide for lower diet costs. However, it is easy to see without any complex calculation that a great degree of variation does exist. For instance, at a constant diet cost of $130/ton, there are soybeans with protein percentages from approximately 34-41% that

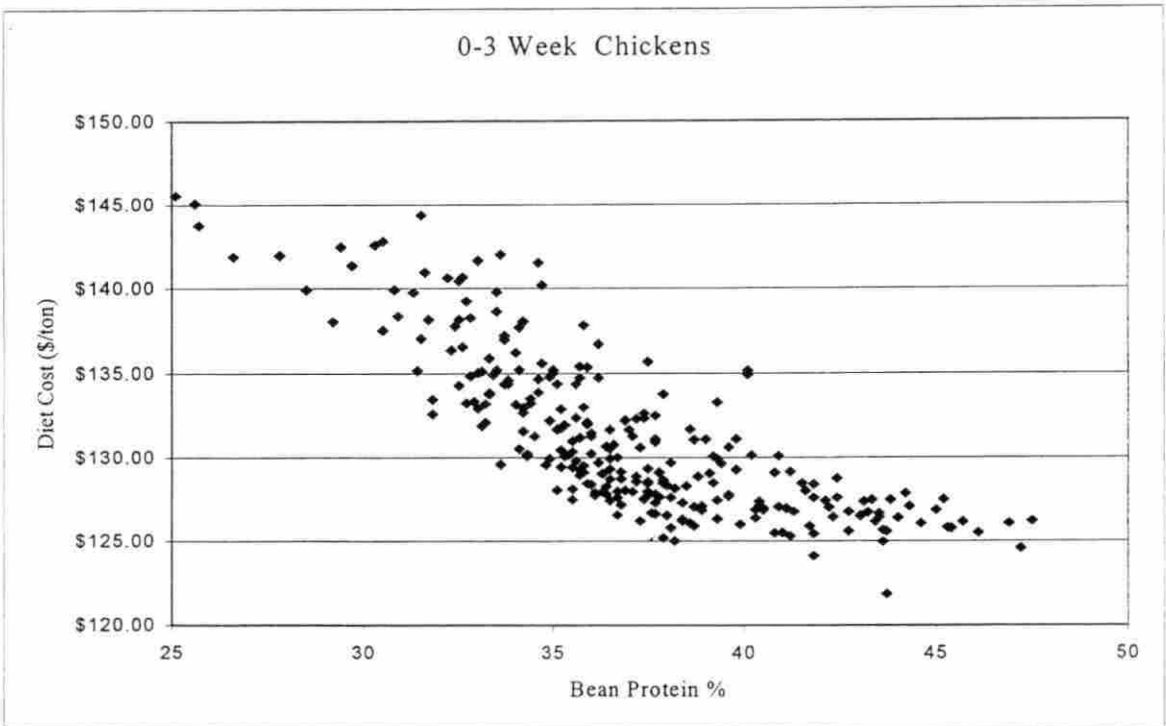


Figure 1: Bean protein versus diet cost for 0-3 week chicken diets.

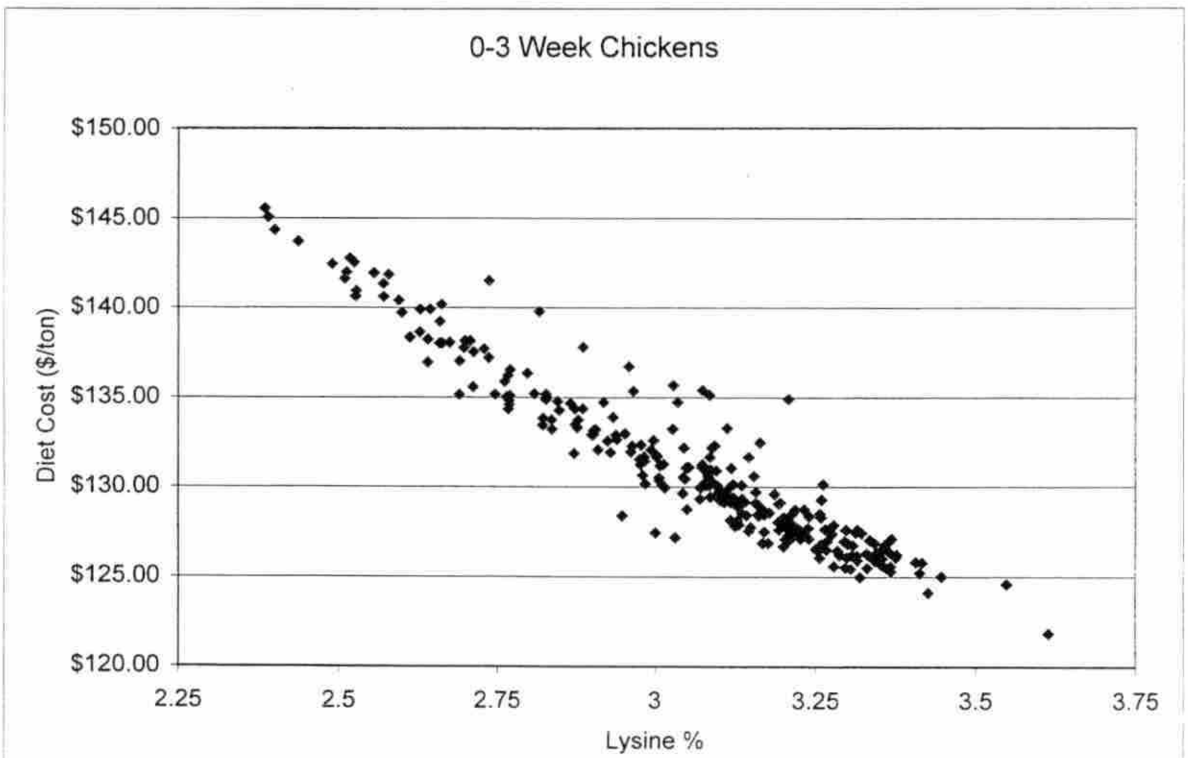


Figure 2: Lysine versus diet cost for 0-3 week chicken

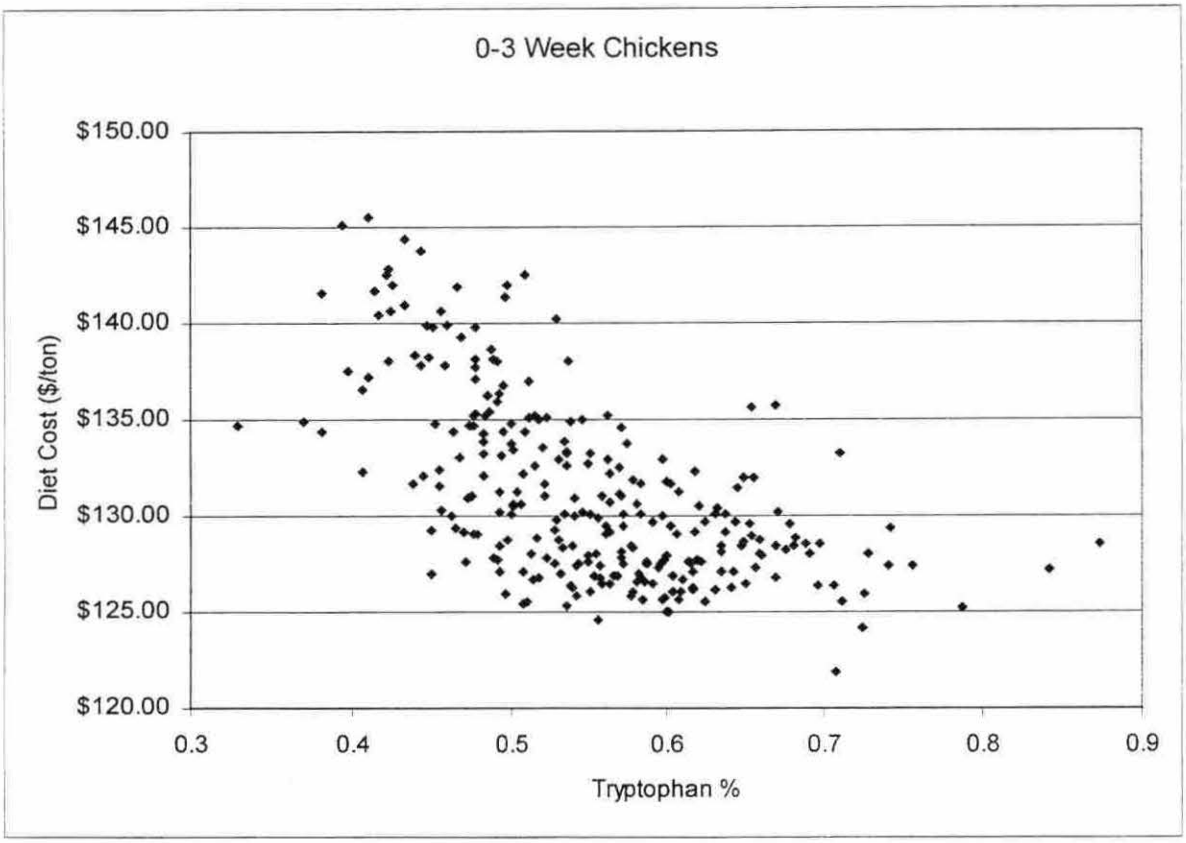


Figure 3: Tryptophan versus diet cost for 0-3 week chickens.

satisfy the dietary requirements of 0-3 week chickens. Despite the fact that they show widely varying protein values, all these beans are priced the same. Under every other pricing system examined, this would not be the case. As an even more obvious example of this effect, at a diet cost of $126, the protein content of the soybeans fell in a range from approximately 36-47%. These are also priced the same under this pricing system.

In order to accurately compare this system to the others presented earlier, it was deemed necessary to subtract off the value of the soybean oil derived in SPROC from each sample. This was done because the diets developed for the amino acid pricing system only included differences in soybean meal, not soybean oil. The most accurate method currently for pricing soybean oil is using SPROC, since it provides the amount of oil derived per bushel of soybeans. There are generally no quality differences in soybean oil, so this method of pricing oil is adequate. The values provided by SPROC were the values used in subtracting oil value to get the value of the resulting meal. The make allowance also had to be accounted for in the EPV. Since the price ratio of oil to meal was 2.22, the make allowance used this ratio so the cost would be distributed between oil and meal proportionally. Therefore, the make allowance was calculated as being 1/3.22 from the meal, and 2.22/3.22 from the oil. Once the make allowance was subtracted from the oil value, and the oil value was subtracted from the amino acid based soybean price, the remaining value was that of the meal only. This was done for all of the systems, in an attempt to compare across systems.

In comparing across systems, the expectation was that it would be reasonable to assume normal distributions for each of the pricing systems. To assess the validity of this assumption, the software Best Fit was used to fit the prices to 30 available distributions. There were a total of nine different sets of prices (7 amino acids, EPV, protein premiums). Best Fit indicated that four different statistical distributions represented these nine price variables, and these distributions are shown in the appendix. Several sets of prices were shown to fit three or four distributions better than a normal distribution. Therefore, the means of the prices could not be adjusted to one common mean, and the normalized values would not be comparable.

Because the distributions were not common, other methods for examining the data had to be pursued. Non-parametric methods are designed specifically to not include the assumption of normality, and therefore could be used to analyze the data. The soybean data were ordered first by diet cost, then by bean protein percentage, and ranked within each

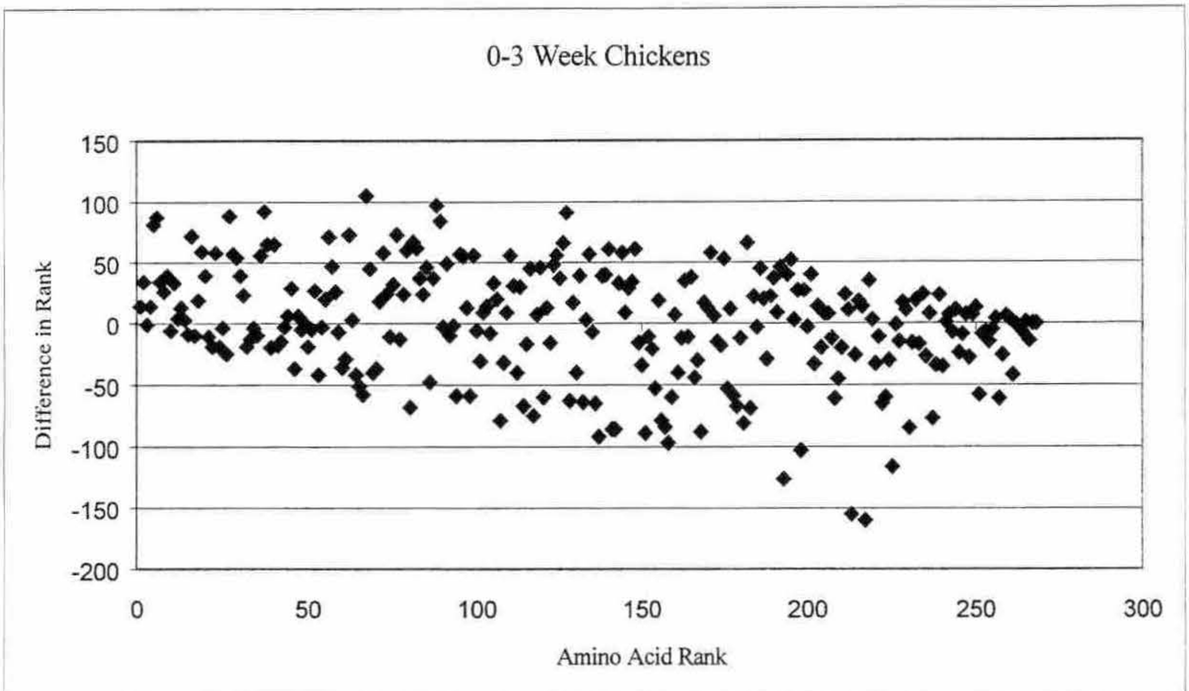


Figure 4: Difference in rank versus amino acid rank based upon 0-3 week chicken diets.

ordering. A ranking of 1 was given to the highest protein soybean, as well as the lowest diet cost. The differences between these rankings were calculated as protein rank minus diet cost rank, and plotted against the amino acid rank. One such plot is shown in Figure 4, with the rest in the appendix.

This plot indicates that there was a large amount of re-ordering within the data set. For example, several soybeans showed a change in rank of −100 or more. This result occurred when a high protein bean did not perform as well under the amino acid pricing system as it would under a protein premium system. The same is true on the positive side. Several soybeans performed much better than protein would have indicated. If no re-ordering existed, all points would lie along the zero line in the middle of the plot. This did not occur, however. The general slope of the plot is negative, which can be interpreted in several different ways.

First, the data points toward the top of the amino acid ranking showed higher changes in rank, indicating that they were not necessarily the soybeans with the highest protein rankings. Second, the beans at the bottom of the amino acid ranking tend to show negative or small positive changes. This means that they are not necessarily the soybeans with the lowest protein rankings. Third, it is difficult to make any generalizations about the middle portion of the plot. From amino acid rankings of 100-175, there is considerable scatter among the data points on both sides of the zero mark. All of these points indicate that protein does not necessarily predict the true performance of soybeans in an amino acid pricing system. Summary statistics for this analysis are shown in table 16.

Table 16: Summary statistics for preliminary non-parametric analysis.

	0-3 Week Chickens	3-6 Week Chickens	6-8 Week Chickens	Grower diet cost	Finisher diet cost	Gestating diet cost	Lactating diet cost
Maximum positive rank change	105	91	87	152	182	124	116
Maximum negative rank change	-160	-113	-115	-131	-133	-124	-159
Standard Deviation	45.36	39.65	37.91	48.34	55.47	41.36	42.99

The maximum positive and negative rank changes were generally above 100, indicating a move of over 30%. The standard deviation can be interpreted as meaning that approximately 68% of the changes in rank are less than ± 45 for prices determined by 0-3 week chicken diets. This is surprising, because a change in rank of 45 places in a 268 observation sample is fairly sizeable. The initial expectation was that this number would be much lower, meaning less reorganization of the data. This expectation is also discounted by the maximum positive and negative changes in rank, which are sometimes greater than half the sample population. This is true in the prices determined by finisher pig diet cost, which showed a maximum positive rank change of +182. The maximum positive and negative rank changes are always greater than a third of the sample population. The smallest rank change given is +87, as the largest positive rank change for prices determined by 6-8 week chicken diets. It is also interesting to note that the diets for hogs showed a much larger amount of re-ordering, as evidenced by the considerably higher maximum positive and negative rank changes and higher standard deviations.

In order to further explain the graphs of diet cost versus bean protein and individual amino acids, regressions were run for individual amino acids versus diet cost for all 7 different diets. The form used was: (diet cost) = $\beta_1 + \beta_2$*(amino acids). The R-squared values and b coefficients are shown in tables 17 and 18. The intercepts (a) are really of no consequence because they correspond to diet costs containing soybean meal with no amino acid content.

Table 17: R-Squared values for regressions on diet cost.

	0-3 Week Chickens	3-6 Week Chickens	6-8 Week Chickens	Grower Pigs	Finisher Pigs	Gestating Pigs	Lactating Pigs
Bean Prot	0.6346	0.6881	0.7018	0.6127	0.5447	0.6712	0.6345
Tryptophan	0.3087	0.2650	0.2488	0.4446	0.5703	0.3069	0.3059
Threonine	0.6714	0.6919	0.6819	0.6694	0.6246	0.7337	0.5958
Lysine	0.7063	0.7451	0.7424	0.6920	0.6429	0.7328	0.6987
TSAA	0.5376	0.4211	0.3930	0.4880	0.4816	0.4739	0.3718

Table 18: Slope values for regressions against diet cost.

	0-3 Week Chickens	3-6 Week Chickens	6-8 Week Chickens	Grower Pigs	Finisher Pigs	Gestating Sows	Lactating Sows
Bean Prot	-0.9406	-0.8780	-0.7549	-0.4251	-0.1589	-0.2015	-0.4094
Tryptophan	-30.6317	-25.4416	-20.9888	-18.7885	-8.4355	-7.0705	-14.7491
Threonine	-25.2363	-22.9657	-19.4103	-13.3220	-5.1014	-6.3174	-11.8939
Lysine	-16.2034	-14.9181	-12.6785	-8.1960	-3.1319	-3.8203	-7.7936
TSAA	-26.9647	-21.3928	-17.5957	-13.2862	-5.2322	-5.9299	-10.9737

As expected, diets with higher soybean content such as those for young chickens and grower pigs are more dependent on amino acids. This is shown by the more negative values for slope coefficients in these diets consistently observed in the amino acid versus diet cost regressions. It is also evidenced by the fact that each R-squared is lower in these diets, meaning that more of other amino acids were being used. The other interesting point to note is that the R-squared for lysine was higher in every diet than the R-squared for bean protein. This means that it would be more accurate, on average, to price soybeans based upon lysine content than on bean protein. However, the R-squared values for lysine were lower than was expected from first viewing of the scatter plots of diet cost versus lysine content.

Since a great deal of re-ordering took place between the simple protein premium system and the amino acid system, differences between all of the pricing systems presented were examined. To accomplish this task, several statistical methods were used. As developed in the procedures section, Pearson's product moment correlation coefficient, Spearman's Rho, and Kendall's Tau were calculated for the nine different pricing systems (protein premiums, EPV, and seven amino acid based systems). The results of these calculations are shown in table 20 for Kendall's Tau. Tables 21 and 22 in the appendix show the results for Pearson's product moment correlation coefficient and Spearman's Rho. Each method resulted in a nine by nine symmetric matrix of values ranging from approximately .65 to 1. In theory, each statistic can actually take values from negative one to positive one, but the nature of the data provided a much smaller range.

The values shown in table 19 for Kendall's Tau are calculated by comparing every possible pair of data samples, and determining the number of concordant and discordant pairs. Concordant pairs are defined as those which move in the same direction between

Table 19: Kendall's Tau results.

	Protein Premium	EPV	0-3 Week Chic Price	3-6 Week Chic Price	6-8 Week Chic Price	Grower Pig Price	Finisher Pig Price	Gestating Sow Price	Lactating Sow Price
Protein Premium	1	0.797	0.79063	0.81419	0.82859	0.80524	0.76946	0.83272	0.81662
EPV	0.797	1	0.7076	0.71623	0.72089	0.67843	0.65114	0.69606	0.67755
0-3 Week Chic Price	0.79063	0.7076	1	0.91186	0.90478	0.84662	0.81598	0.85396	0.84144
3-6 Week Chic Price	0.81419	0.71623	0.91186	1	0.95422	0.84781	0.81225	0.86544	0.85242
6-8 Week Chic Price	0.82859	0.72089	0.90478	0.95422	1	0.84381	0.80456	0.86653	0.85395
Grower Pig Price	0.80524	0.67843	0.84662	0.84781	0.84381	1	0.93759	0.91514	0.92011
Finisher Pig Price	0.76946	0.65114	0.81598	0.81225	0.80456	0.93759	1	0.8561	0.87327
Gestating Sow Price	0.83272	0.69606	0.85396	0.86544	0.86653	0.91514	0.8561	1	0.90096
Lactating Sow Price	0.81662	0.67755	0.84144	0.85242	0.85395	0.92011	0.87327	0.90096	1

systems, such as the data points (2.75, 3.05) and (4.85, 4.92). Discordant pairs are then defined as those which move in opposite directions between systems, such as the points (3.45, 3.25) and (4.65,4.80). Kendall's Tau is then given by the difference between the number of concordant and discordant pairs divided by the total number of observable pairs.

The interpretation of Kendall's Tau at a value of one is that all pairs are concordant. At zero there are equal portions concordant pairs and discordant pairs, and at negative one all pairs are discordant. Therefore, the value of Kendall's Tau can be used to calculate the probability of observing a concordant pair, given a random selection of two data samples. From table 19, the values for a protein premium system are generally around 0.8, meaning that the numerator N_c-N_d results in 80% of the sample. Therefore, about 90% of the possible pairs are concordant, but 10% are discordant.

For amino acid based systems, higher percentages of concordance are shown within species, for instance between 0-3 week chickens, 3-6 week chickens, and 6-8 week chickens. These values are generally around 0.9, and range as high as 0.95 for the comparison between 3-6 and 6-8 week chickens. This makes sense because the major differences in amino acid requirements are between 0-3 week chickens and all others. Across species, the values are generally higher than those comparing amino acid systems and a protein premium system, but lower than within their own species. Most of these values are between 0.84 and 0.86. The values for EPV versus other systems are considerably lower than those for any other system. This may be because of the meal to oil price ratio that was used, or possibly because of the system within SPROC that assigns premiums and discounts for high and low protein meal production. Another consideration is that SPROC assumes that a certain amount of oil remains in the meal during processing, so that simply subtracting off the oil value does not completely account for the oil within the beans. This would cause a discrepancy between EPV and other systems that might have led to the low Kendall's Tau values.

While the data set used is from a fairly broad cross-section of geography, the previous results should generalize well to the set of all U.S. soybeans. If the current data set is a subset of all soybeans produced in a year, then at least the amount of re-organization found within the subset will be found within the larger set. It is possible that the amount of re-organization in this data set is not representative of the larger data set, but this is not likely considering the fact that there are samples from at least 22 states and several provinces of Canada.

To apply these results to the larger set of all soybeans produced, a logit model was used, as described in the procedures section. The results were values of B_0 and B_1 that provided a general equation for determining the probability that an individual bean would

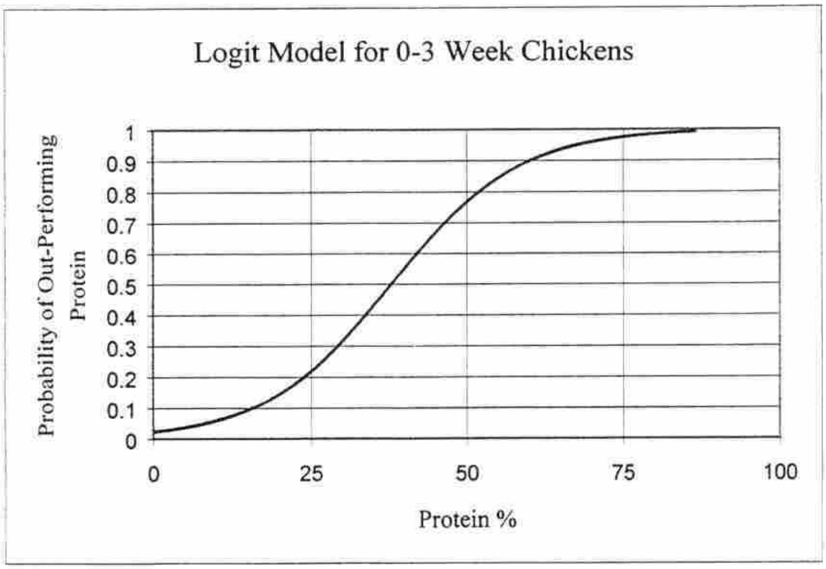


Figure 5: Logit model based on 0-3 week chicken diets.

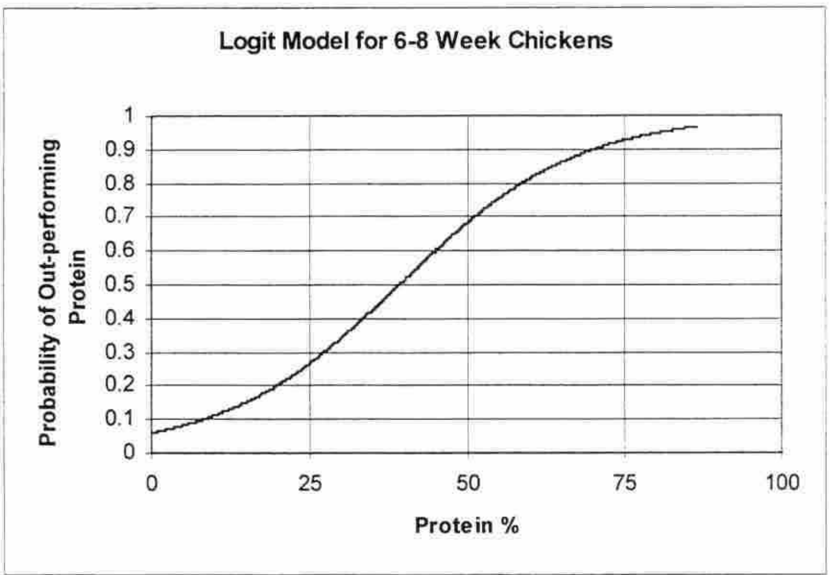


Figure 6: Logit model based on 6-8 week chicken diets.

outperform the expectations based upon protein, at a given protein content. The graph for two such equations are shown in Figures 5 and 6.

Not all the values shown in the figure were observed in the data set. Bean protein levels outside of the 25-50% range are shown simply to relate the shape of the equation.

Logit figures based upon other pricing systems are available in the appendix. The general interpretation of these figures is that protein becomes a more reliable predictor of value at lower levels. For instance, at a bean protein of 25%, there is only a 20% chance that the soybean price based upon 0-3 week chicken diets will be relatively higher than the soybean price for a protein premium system. These graphs show that there is a relatively small chance that a low protein soybean will turn out to be more valuable than protein would suggest. The odds are against such an occurrence, but it is possible. It is, however, much more likely for a higher protein bean to out-perform expectations based upon protein. In the middle of the range of observed protein percentages, the odds are just as good that the bean will under-perform protein expectations as out-perform protein expectations. This reaffirms and quantifies the results found within the scatter plots of changes in rank versus amino acid rank.

As a final method of quantifying the results, regressions were run in the form

$$system_1 = B_0 + B_1 * prot$$

in an attempt to predict the price of a soybean in a given pricing system at a given protein content. With these regressions, estimated prices could be compared across systems to predict the change in value from one system to the next. The results from these regressions are shown in table 20.

Table 20: Summary statistics from price prediction regressions of soybean price on protein.

	Protein Premium	EPV	0-3 Week Chicks	3-6 Week Chicks	6-8 Week Chicks	Grower Pigs	Finisher Pigs	Gestating Sows	Lactating Sows
Intercept (B_0)	-1.301	-1.419	0.089	-0.024	0.081	0.748	0.780	0.676	0.692
Coefficient (B_1)	0.142	0.139	0.099	0.096	0.093	0.080	0.077	0.083	0.082
R-Squared	0.913	0.958	0.802	0.800	0.819	0.756	0.728	0.768	0.748

The R-squared values are generally quite high, ranging from .7279 to .9575. One interesting point to note is that the R-squared for protein versus EPV is actually higher than for protein versus the protein premium system. This is due to the fact that oil values from the EPV estimation were subtracted from all samples before the regressions. Regardless, estimation of prices can then be done from the values in the previous table. For instance, to estimate the difference in price from a protein premium system to an amino acid system based upon finisher pig diets for a 36% protein bean, the prices would equal $3.80 (-1.3014 + .1417*36), and $3.56, respectively. Therefore, a decrease of $0.24 in value could be expected.

CHAPTER 5: CONCLUSIONS AND AREAS FOR FURTHER RESEARCH

Several significant conclusions can be drawn from the work that has been done. First, the amino acid system developed here is more accurate and affects all samples to some extent. The scatter plots comparing the change in rank to the amino acid rank show that most of the soybean samples do not lie along the zero median line.

Second, protein does not necessarily predict amino acid content. As shown by Hyberg *et al.* (Hyberg, 1994) that the US grades and standards on test weight, moisture content, split beans, damaged kernels, and oddly colored soybeans did not convey value, it is shown here that protein does not accurately convey the true marginal value product of soybeans in end use. It has been found that lower protein beans are less likely to outperform expectations based upon their protein contents than higher protein beans. Some of the low protein beans compared favorably to beans of average, and in some cases even above average protein content. It was shown that there are 26-28% protein beans that perform as well as some 35% beans in a livestock diet. This was even more true for soybeans in the middle range of protein contents. One diet cost for 0-3 week chickens had beans with protein values ranging from 34-41%.

Third, Errors associated with a protein premium system are less pronounced at lower protein levels than at higher protein levels. Logit graphs showed that the likelihood of outperforming protein is lower at lower protein levels, and higher at higher protein levels. Therefore, a system based on protein is likely to be closer to accurate at these lower protein levels.

Fourth, even within currently available soybean varieties, there exist varieties that are better suited for some animal species. This is shown by the fact that some soybeans showed a large change in rank from one amino acid system to the next. These beans can be considered more useful when fed to one animal species than another, even without variety breeding or genetic engineering.

Fifth, varieties that are better suited for one animal species are not necessarily better for another. Values obtained for Kendall's Tau show that within swine and chickens, the ordering of samples is much closer than across species. Therefore, the beans that performed well when fed to chickens are not necessarily the beans that perform well when fed to swine.

Sixth, lysine is a better measure of value than protein. Scatter plots of bean protein and lysine content versus diet cost showed that lysine is more highly correlated with diet cost than bean protein. This conclusion may hold the most interest for further research, since the cost of full wet chemistry results are currently so high. If lysine content can be measured at a lower cost than the full range of amino acids, it could provide a very good proxy for the value of a soybean without having to do the diet cost simulation detailed in this study.

Areas For Further Research

Pricing systems based upon amino acids are likely several years away, due to the current costs involved with the wet chemistry analysis required to obtain amino acid values. With future improvements in technology the costs should decrease, and these systems may become more reasonable. The situation is much like the one faced by Nelson Updaw in the late 1970's and early 1980's. His studies showed that at the time, the price ratios and costs of technology made component pricing systems decrease total social welfare. It is likely that such an analysis on amino acid based systems would yield the same results. However, a study similar to Updaw's that included a sensitvity analysis on technology costs would provide the point at which amino acid systems would provide positive changes in social welfare. Also, the addition of more data would give a better idea of the benefits available under such systems.

In the article "New Opportunities for Farmers In Value-Added Grains" by Roger Ginder (Ginder, 1998), the author states that "the level of precision has been blunted by the variability in specific traits contained in commodity grain and meal". With the use of amino acid pricing systems and improved testing, this no longer needs to be the case. The logical result is then traditionally bred or genetically engineered grains that can provide very specific amounts of dietary requirements that vary from one animal species to the next.

In other words, as traditional breeding or genetic technology improves, soybeans will probably be adjusted to provide different dietary needs to different animals throughout the different stages in their life. Chickens in the beginning of their life cycle will not consume the same soybean varieties as hogs in the beginning of their life cycle, or even chickens at the end of their life cycle. As these type of improvements occur, amino acid pricing systems will only become more valuable. Therefore, a study using data on such genetically tailored engineered soybean samples would probably provide a more accurate vision of the effects on social welfare.

Along the same lines, in order to develop soybean varieties for animals beyond those included within this analysis, diets will have to built and analyzed in the same manner. For instance, no research has been done into the effects that variations in even the existing soybean varieties would have on the performance of dairy cattle or types of foul other than broiler chickens. A study of this nature will need to be developed to build prices based upon amino acids for these types of animals.

The most significant research that remains to be done is probably in the area of making the whole process of pricing soybean based upon amino acids more efficient. In this study, the amino acid values were input manually into Brill and optimized for each diet and soybean sample. Overall, approximately 40,000 keystrokes were needed just to input the amino acid values for the 268 soybean samples. This is simply not practical for an elevator where many more than 268 samples are conducted in a year. Once the process for optimizing the least cost rationing is developed, the estimations of amino acid content based upon protein values could provide an important intermediate step between pricing based upon protein and oil, and pricing based upon amino acids. However, it was already established that regressions of individual amino acids on protein vary from source to source, so the accuracy of such a method would need to be analyzed as well. The possibility also exists for pricing systems based solely on lysine content, as was discussed earlier in this paper.

APPENDIX A: ADDITIONAL FIGURES

Figure 7: Bean protein v. diet cost for 3-6 week chick diets.

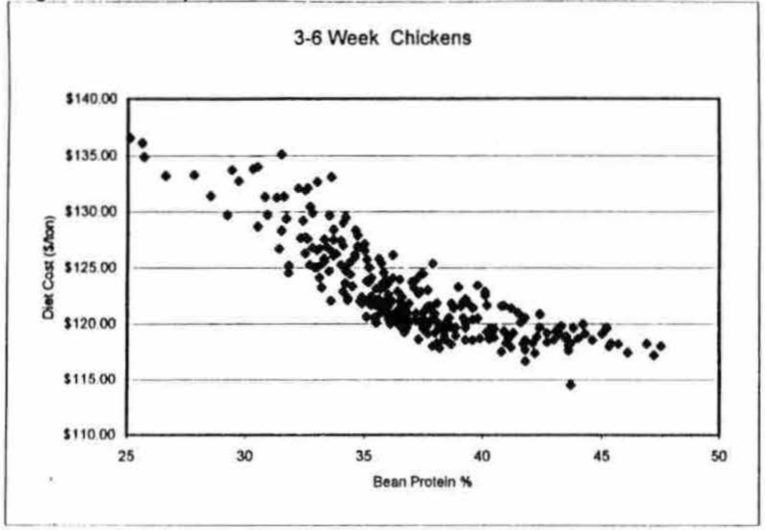


Figure 9: Bean protein v. diet cost for 6-8 week chick diets.

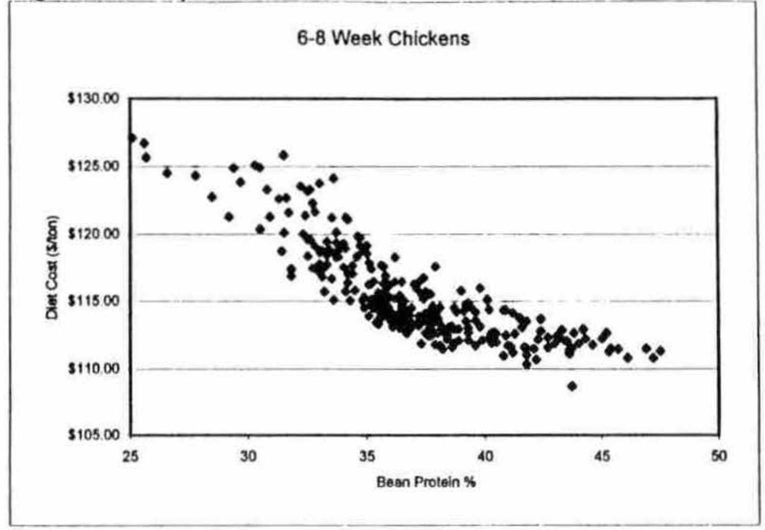


Figure 8: Bean protein v. diet cost for grower pig diets.

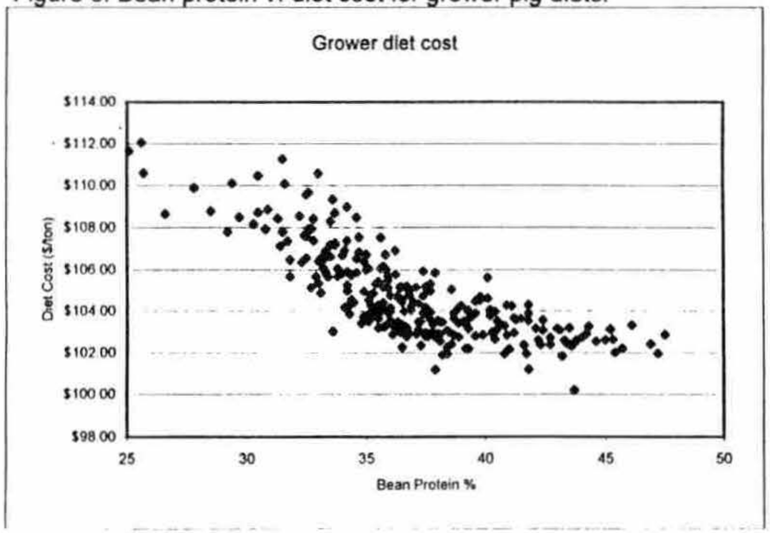


Figure 10: Bean protein v. diet cost for finisher pig diets.

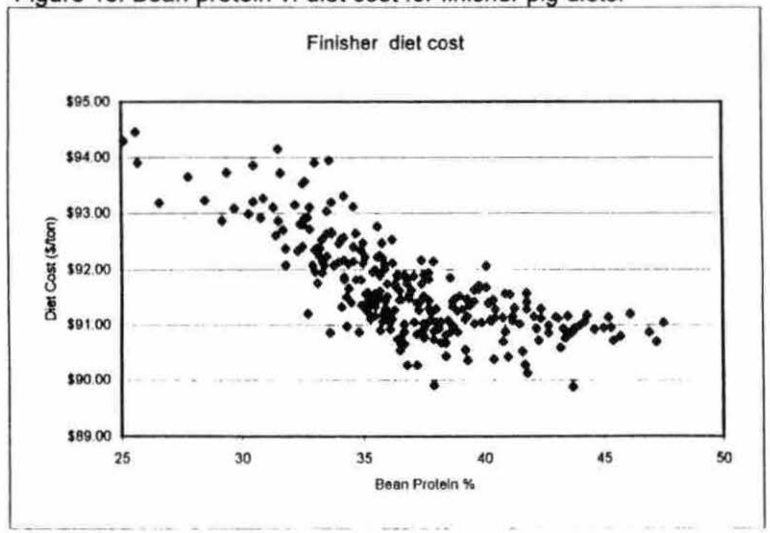


Figure 11: Bean protein v. diet cost for gestating sow diets.

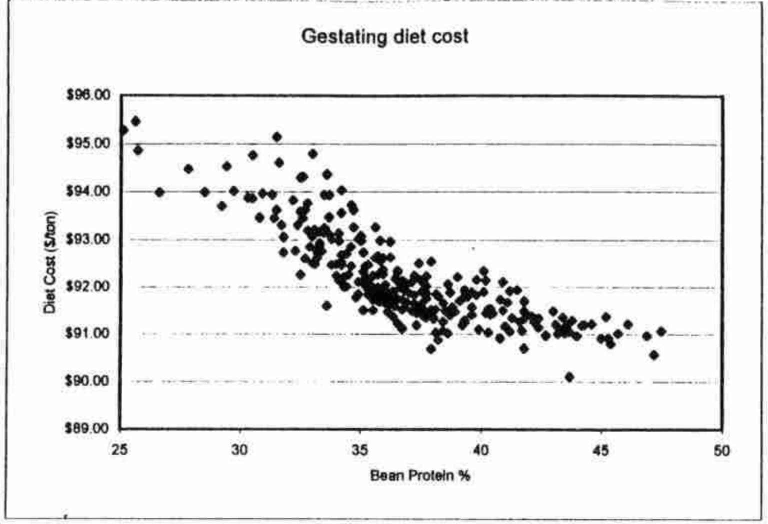


Figure 13: Bean protein v. diet cost for lactating sow diets.

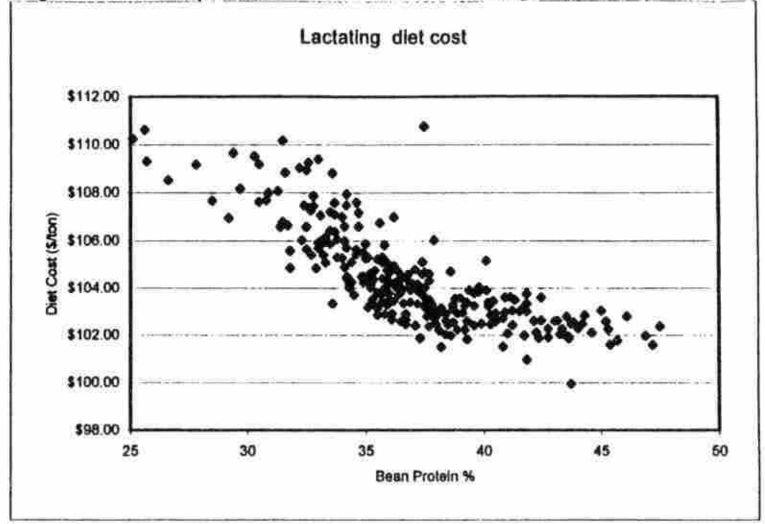


Figure 12: Total sulphur AA's v. diet cost for 0-3 week chick diets.

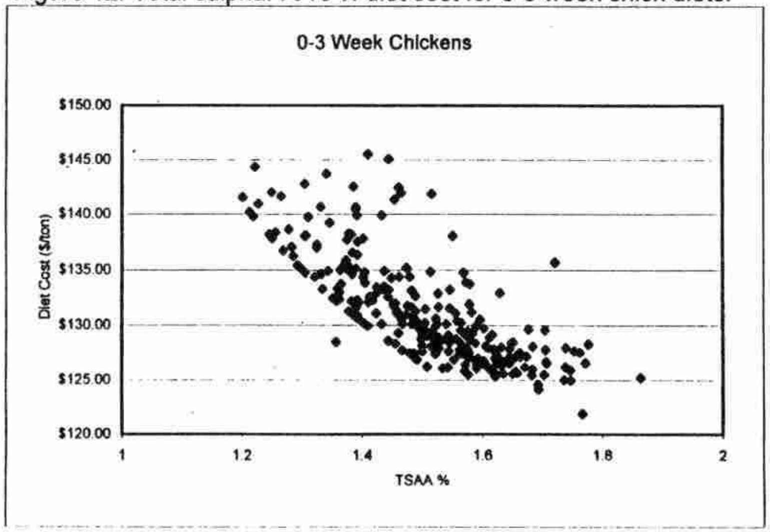
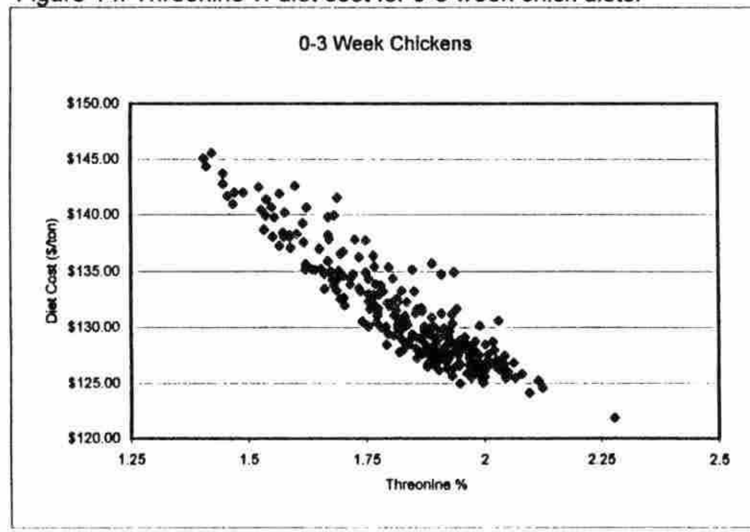


Figure 14: Threonine v. diet cost for 0-3 week chick diets.



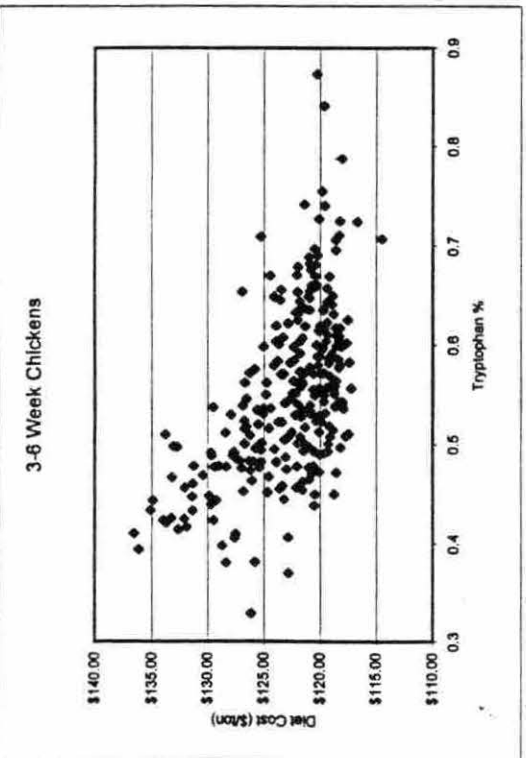


Figure 15: Tryptophan v. diet cost for 3-6 week chick diets.

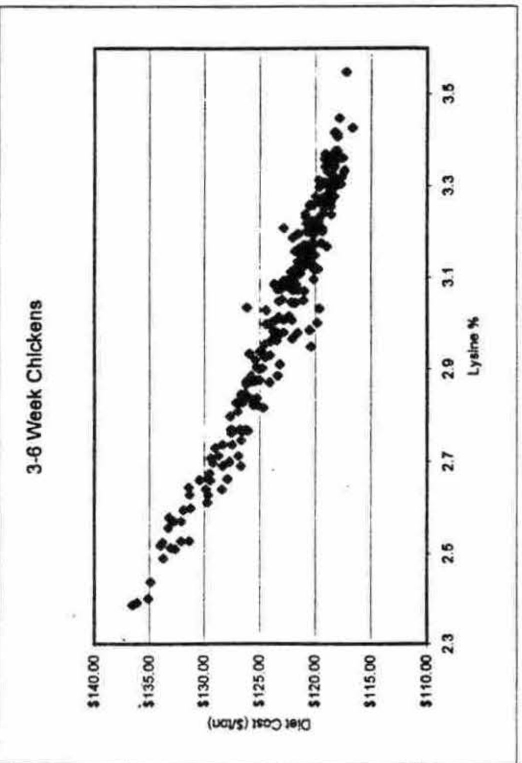


Figure 16: Lysine v. diet cost for 3-6 week chick diets.

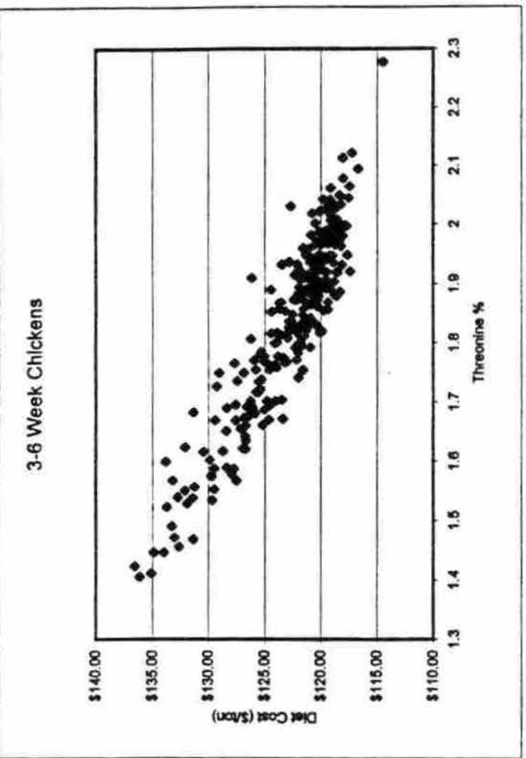


Figure 17: Threonine v. diet cost for 3-6 week chick diets.

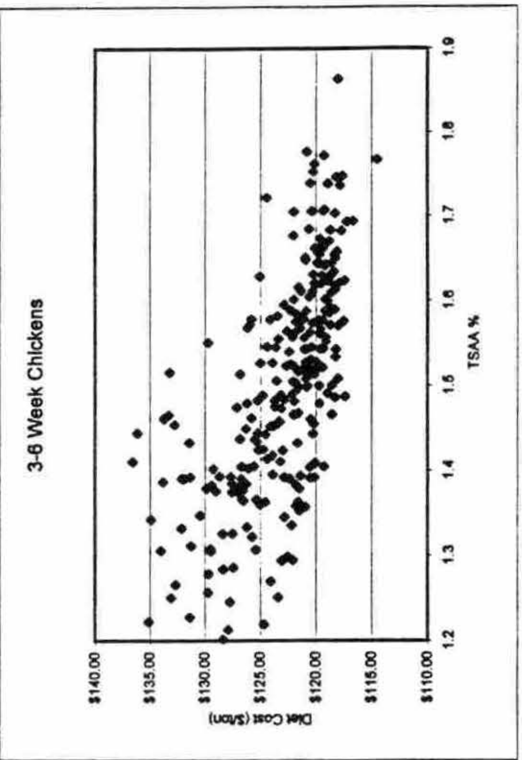


Figure 18: Total sulphur AA's v. diet cost for 3-6 week chick diets.

Figure 19: Lysine v. diet cost for grower pig diets.

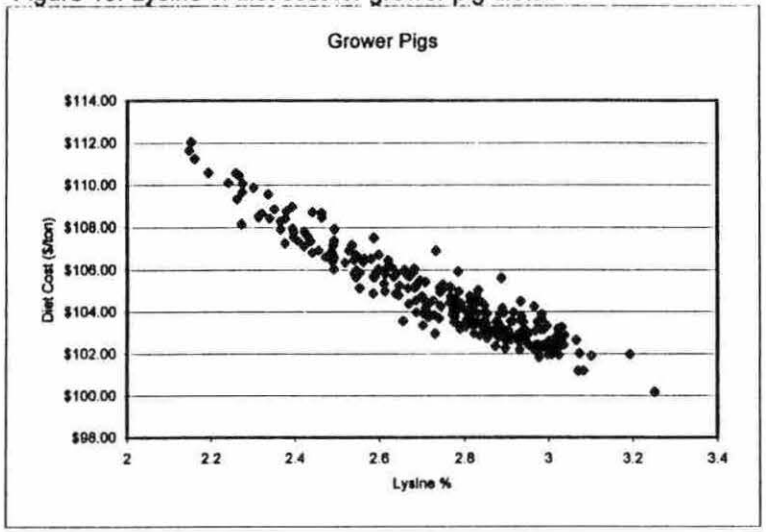


Figure 20: Threonine v. diet cost for grower pig diets.

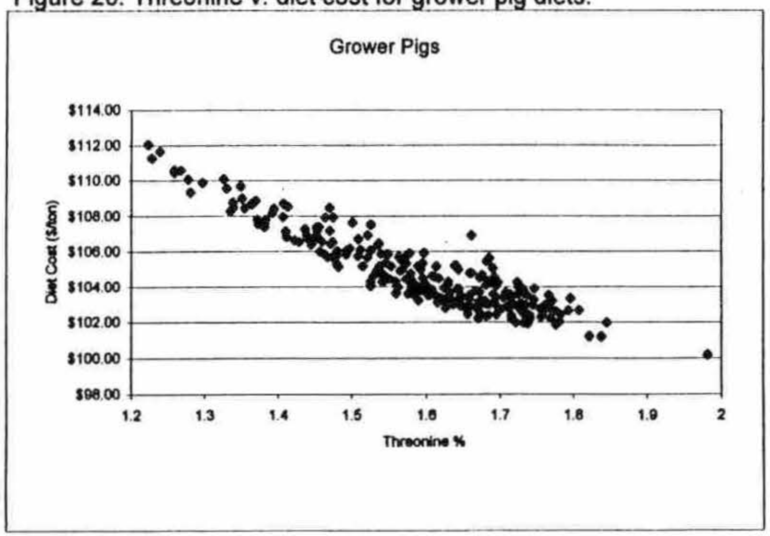


Figure 21: Total sulphur AA's v. diet cost for grower pig diets.

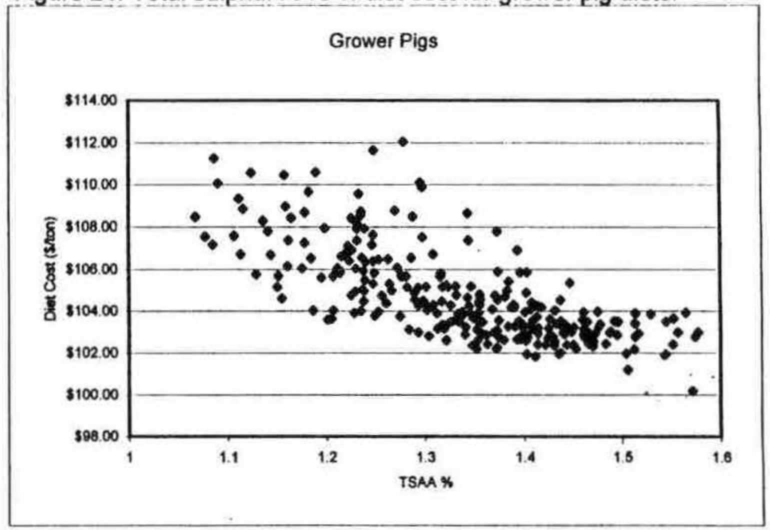


Figure 22: Tryptophan v. diet cost for grower pig diets.

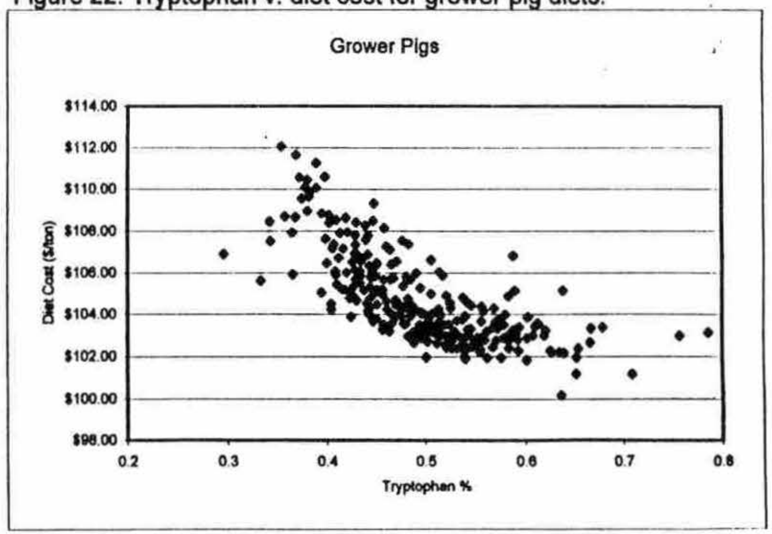


Figure 23: Lysine v. diet cost for finisher pig diets.

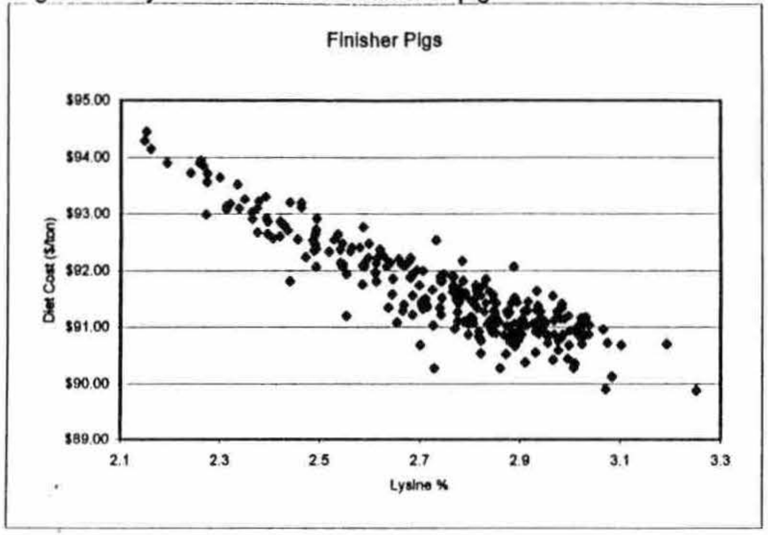


Figure 24: Threonine v. diet cost for finisher pig diets.

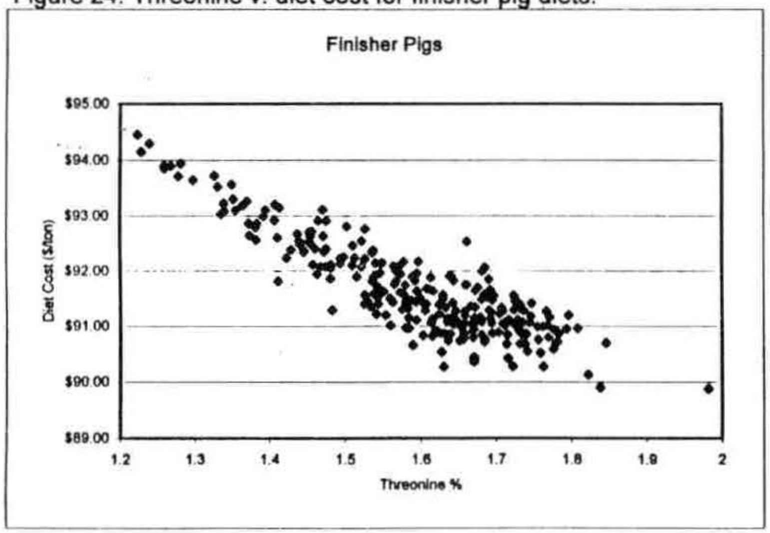


Figure 25: Total sulphur AA's v. diet cost for finisher pig diets.

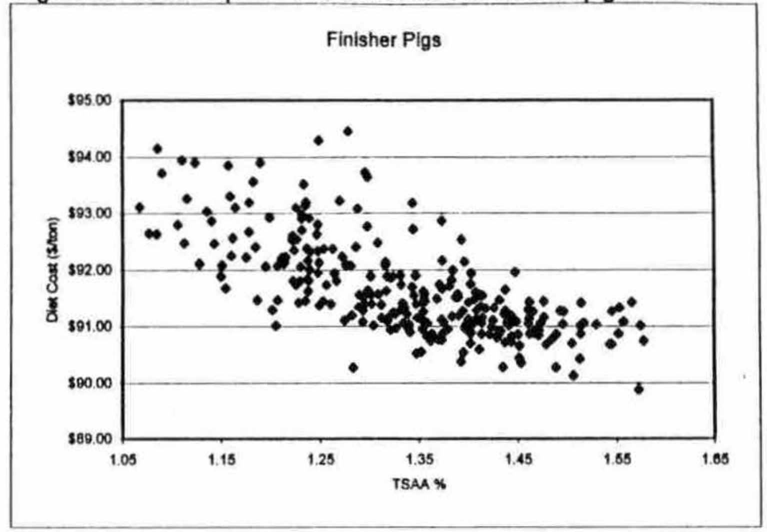


Figure 26: Tryptophan v. diet cost for finisher pig diets.

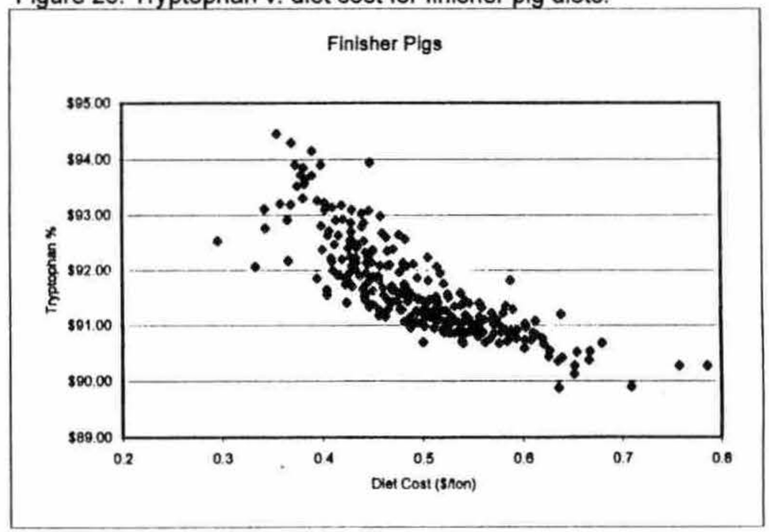


Figure 27: Change in rank v. AA rank for 3-6 week chick diets.

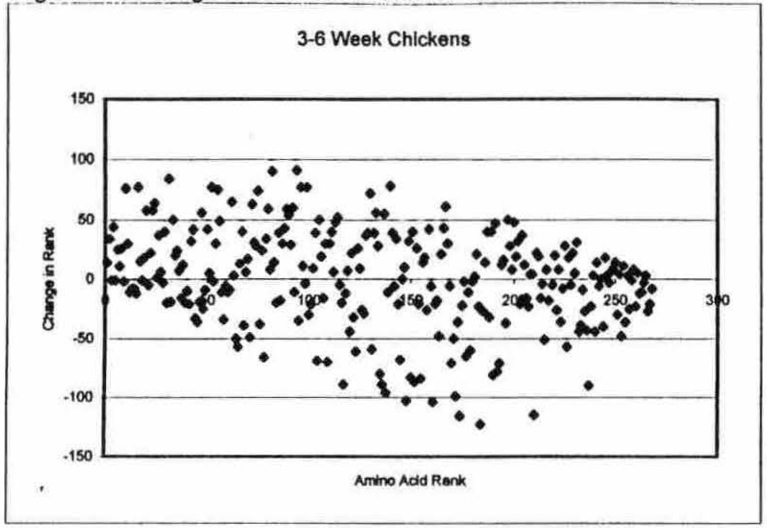


Figure 29: Change in rank v. AA rank for 6-8 week chick diets.

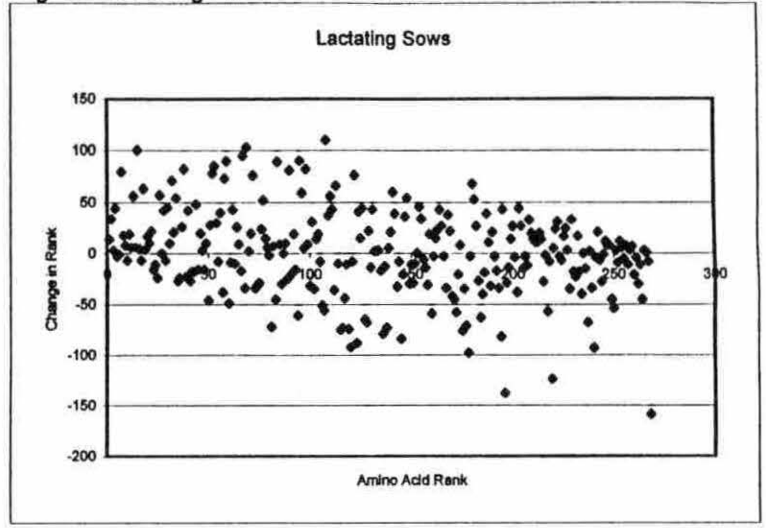


Figure 28: Change in rank v. AA rank for finisher pig diets.

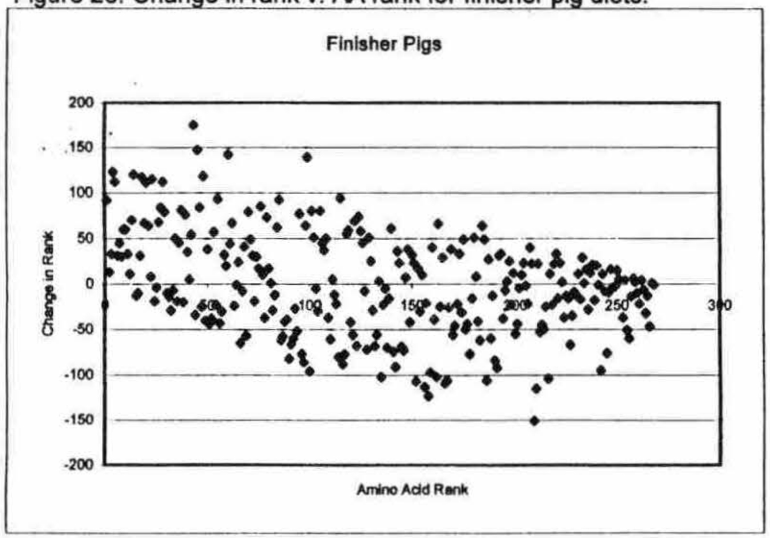


Figure 30: Change in rank v. AA rank for grower pig diets.

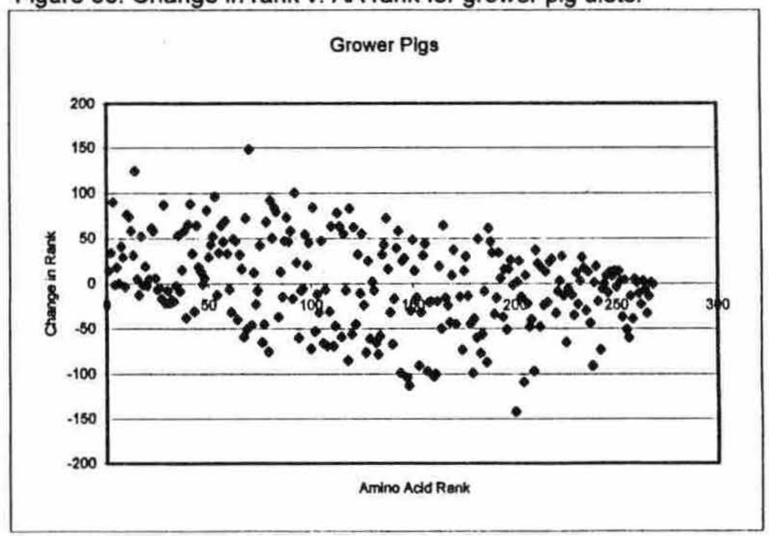


Figure 31: Change in rank v. AA rank for lactating sow diets.

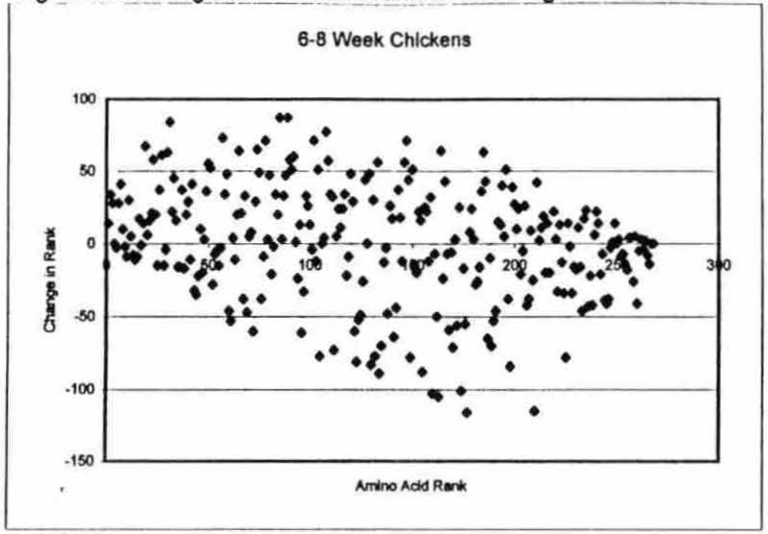


Figure 33: Logit model based upon EPV.

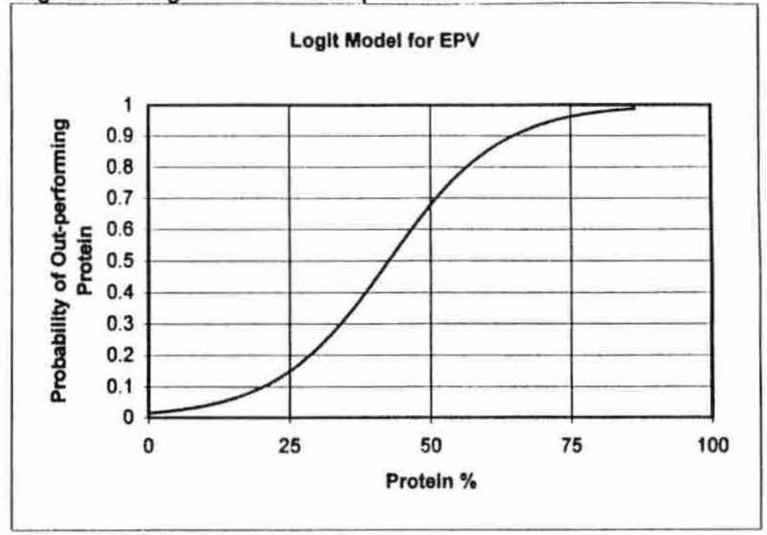


Figure 32: Change in rank v. AA rank for gestating sow diets.

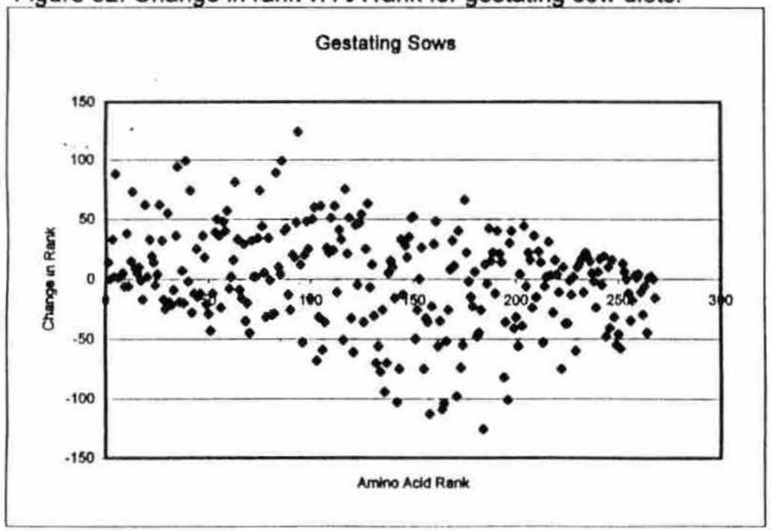


Figure 34: Logit model based upon 3-6 week chicken diets.

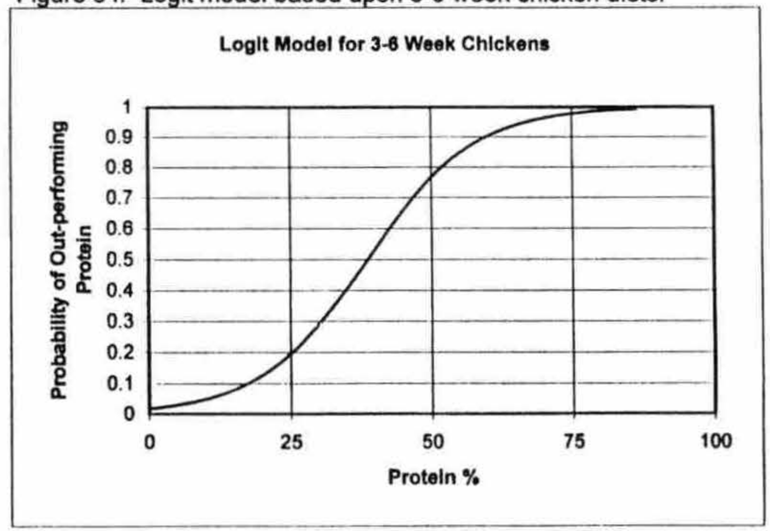


Figure 35: Logit model based upon grower pig diets.

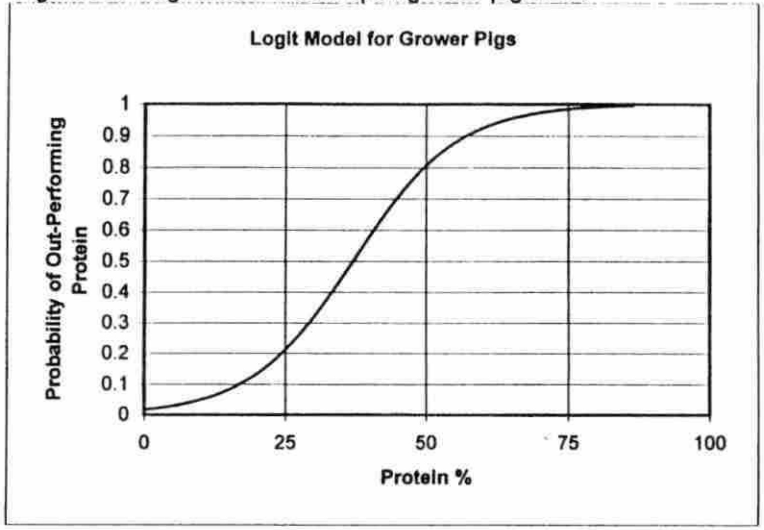


Figure 36: Logit model based upon finisher pig diets.

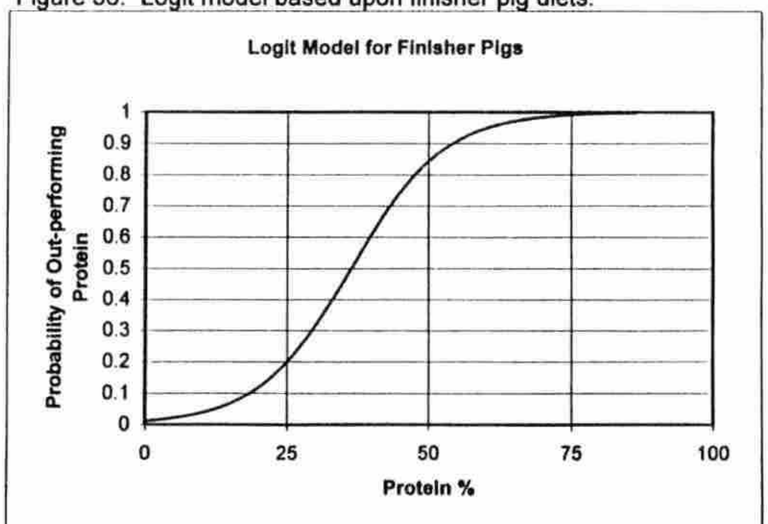


Figure 37: Logit model based upon gestating sow diets.

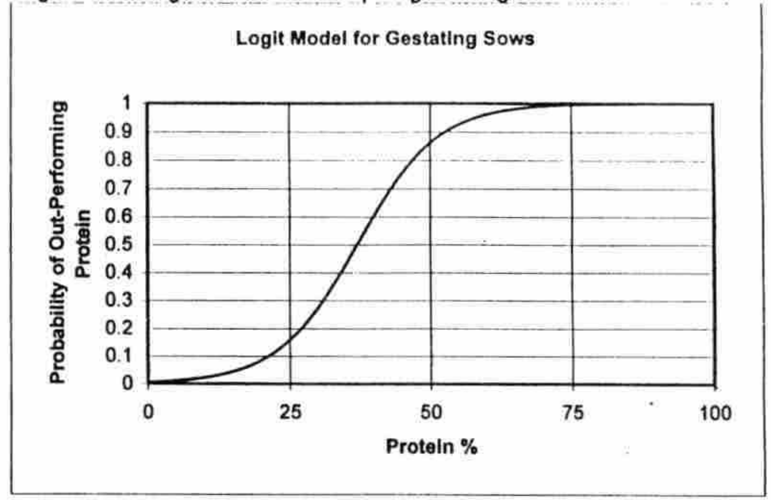
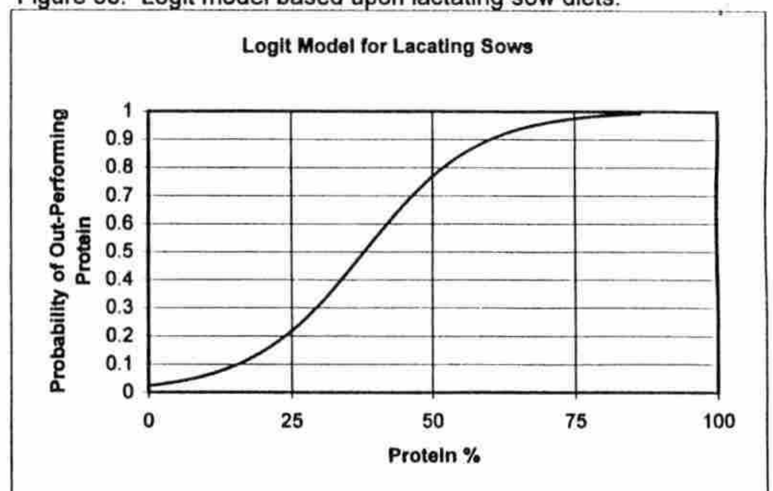


Figure 38: Logit model based upon lactating sow diets.



APPENDIX B: SAMPLE DIETS

Iowa State University
Plant..........MKT
User : CRE

Product No.....SWIN1
Product Name...swine, 35 kg grower, mixed m/f
Today's Date...08-10-2000
Date/Time......08-10-2000 08:36:54 # 2409

Rounded Ingredient Amount	Ing Code	Ing Name	Pct of Mix	Cost/ 100LB	Low Range	High Range	Rest/ 100LB	Min	Max
1521.49	CORNSWIN	corn grain	76.074	3.93	3.53	6.21			
421.37	SBMSWIN	47.5% SBM	21.068	9.00	6.82	9.37			
21.50	410	Limestone	1.075	1.20		3.31			
17.81	407	DiCalcium	0.890	12.68	1.99	348.93			
13.19	488	Salt (Sodi	0.660	2.00		3.30			
2.6431	LYS	lysine	0.132	92.00	80.48	159.28			0.200
2.0000	VITMIN	vitamin mi	0.100	50.00				0.100	0.100

Total Weight 2000.00 103.93 $ Per TON 5.20 $ Per 100LB

Rejected Ingredient Section

Ing Code	Ing Name	Pct of Mix	Cost/ 100LB	Low Range	High Range	Min	Max
97	Fat, Animal, Hy		10.50	3.30			
MBM	meat bone meal		9.85	8.35			
MET	methionine		109.00	3.30			0.200
THR	threonine		185.00	158.47			0.200
TRY	tryptophan		327.00	3.30			0.200

Nutrient Name	Nutrient Minimum	Actual	Nutrient Maximum	Cost
1 Weight	1.0000	1.0000	1.0000	
2 Dry Matter		89.4923		
3 Moisture		0.0267		
6 Metabolizable Energy	3.2650	3.3199		
10 Crude Protein		16.4483		
18 20/23		1.2374		
19 Cation/Anion Balance		-0.5448		
20 Calcium	0.6000	0.6500	0.6500	0.0619

21 Chlorine		0.4489		
22 Magnesium		0.1817		
23 Phosphorus	0.5000	0.5253		
24 Potassium		0.7038		
25 Sodium	0.2300	0.2800	0.2800	0.0332
26 Sulphr		0.2019		
27 Cobalt		0.0864		
28 Copper		6.5823		
30 Iron		221.1520		
31 Manganese		15.5012		
32 Selenium		0.1101		
33 Zinc		26.1448		
34 Fluorine		15.5481		

Iowa State University
Plant..........MKT User : CRE

Product No.....SWIN1
Product Name...swine, 35 kg grower, mixed m/f
Today's Date...08-10-2000
Date/Time......08-10-2000 08:36:54 # 2409

Nutrient Name	Nutrient Minimum	Actual	Nutrient Maximum	Cost
35 Non Structural Carbo		2.5983		
36 Salt		0.6595		
111 Lysine	0.8300	0.8300		-1.1371
112 Arginine	0.3300	0.9397		
113 Histidine	0.2600	0.3976		
114 Isoleucine	0.4500	0.5903		
115 Leuchine	0.8300	1.3792		
116 Methionine	0.2200	0.2448		
118 Meth + Cystine	0.4700	0.5048		
119 Phenylalanine	0.4900	0.7152		
121 Phenylalan + Tyrosin	0.7800	1.2295		
122 Threonine	0.5200	0.5200		-1.5753
123 Tryptophan	0.1500	0.1616		
124 Valine	0.5600	0.6790		
127 Linoleic Acid	0.1000	1.5870		
132 Phosphours - Avail	0.2300	0.2300		-0.5714

Iowa State University
Plant..........MKT User : CRE

Product No.....SWIN2
Product Name...swine, 100 kg grower, mixed m/f
Today's Date...08-10-2000
Date/Time......08-10-2000 08:36:54 # 2410

Rounded Amount	Ing Code	Ing Name	Pct of Mix	Cost/ 100LB	Low Range	High Range	Rest/ 100LB	Ingredient Min	Ingredient Max

```
 1801.35 CORNSWIN corn grain  90.068     3.93    2.70   4.37
  156.35 SBMSWIN  47.5% SBM    7.817     9.00    8.59  11.14
   19.40       410 Limestone   0.970     1.20           3.44
   10.93       407 DiCalcium   0.546    12.68    2.04  76.55
  6.5900       488 Salt (Sodi  0.329     2.00           3.44
  3.2018 LYS      lysine       0.160    92.00   25.95 104.80
0.200
  2.0000 VITMIN   vitamin mi   0.100    50.00                          0.100
0.100
  0.1802 TRY      tryptophan  0.0090   327.00    3.30 402.98
0.200
Total Weight  2000.00            91.15 $ Per TON          4.56 $ Per 100LB


Rejected Ingredient Section
          Ing            Ing          Pct    Cost/    Low     High
Ingredient
          Code           Name        of Mix 100LB   Range   Range    Min
Max
==========================================================================
======
                97 Fat, Animal, Hy            10.50    3.44
         MBM      meat bone meal               9.85    7.11
         MET      methionine                 109.00    3.44
0.200
         THR      threonine                  185.00   32.94
0.200

    Nutrient               Nutrient              Nutrient
    Name                   Minimum     Actual    Maximum      Cost
=============================================================
  1 Weight                  1.0000     1.0000    1.0000
  2 Dry Matter                        89.2884
  3 Moisture                           0.0164
  6 Metabolizable Energy    3.2650     3.3524
 10 Crude Protein                     11.3499
 18 20/23                              1.2236
 19 Cation/Anion Balance              -0.3283
 20 Calcium                 0.4500     0.5000    0.5000     0.0659
 21 Chlorine                           0.2491
 22 Magnesium                          0.1546
 23 Phosphorus              0.4000     0.4086
 24 Potassium                          0.4660
 25 Sodium                  0.1000     0.1500    0.1500     0.0367
 26 Sulphr                             0.1579
 27 Cobalt                             0.0530
 28 Copper                             4.3185
 30 Iron                             150.1631
 31 Manganese                         10.7093
 32 Selenium                           0.0842
 33 Zinc                              21.0418
 34 Fluorine                           9.5419
Iowa State University
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Plant..........MKT User : CRE

Product No.....SWIN2

Product Name...swine, 100 kg grower, mixed m/f
Today's Date...08-10-2000
Date/Time......08-10-2000 08:36:54 # 2410

Nutrient Name	Nutrient Minimum	Actual	Nutrient Maximum	Cost
35 Non Structural Carbo		1.8296		
36 Salt		0.3295		
111 Lysine	0.5200	0.5200		-1.1353
112 Arginine	0.1600	0.5523		
113 Histidine	0.1600	0.2713		
114 Isoleucine	0.2900	0.3697		
115 Leuchine	0.5100	1.0750		
116 Methionine	0.1400	0.1855		
118 Meth + Cystine	0.3100	0.3830		
119 Phenylalanine	0.3100	0.4824		
121 Phenylalan + Tyrosin	0.4900	0.8109		
122 Threonine	0.3400	0.3400		-0.2995
123 Tryptophan	0.1000	0.1000		-3.2848
124 Valine	0.3500	0.4618		
127 Linoleic Acid	0.1000	1.7762		
132 Phosphours - Avail	0.1500	0.1500		-0.5686

Iowa State University
Plant..........MKT User : CRE

Product No.....SWIN3
Product Name...swine, gestation, 175kg, 40kg gain
Today's Date...08-10-2000
Date/Time......08-10-2000 08:36:54 # 2411

Rounded Ingredient Amount	Ing Code	Ing Name	Pct of Mix	Cost/ 100LB	Low Range	High Range	Rest/ 100LB	Min	Max
1728.97	CORNSWIN	corn grain	86.449	3.93	3.53	6.21			
204.32	SBMSWIN	47.5% SBM	10.216	9.00	6.82	9.37			
32.04	407	DiCalcium	1.602	12.68	1.99	348.93			
23.38	410	Limestone	1.169	1.20		3.31			
9.1100	488	Salt (Sodi	0.455	2.00		3.30			
2.0000	VITMIN	vitamin mi	0.100	50.00				0.100	0.100
0.1798	LYS	lysine	0.0090	92.00	80.48	159.28			0.200

Total Weight 2000.00 92.03 $ Per TON 4.60 $ Per 100LB

Rejected Ingredient Section

Ingredient Code	Ing Name	Pct of Mix	Cost/ 100LB	Low Range	High Range	Min	Max
97	Fat, Animal, Hy		10.50	3.30			
MBM	meat bone meal		9.85	8.35			
MET	methionine		109.00	3.30			0.200
THR	threonine		185.00	158.47			0.200
TRY	tryptophan		327.00	3.30			0.200

Nutrient Name	Nutrient Minimum	Actual	Nutrient Maximum	Cost
1 Weight	1.0000	1.0000	1.0000	
2 Dry Matter		89.4150		
3 Moisture		0.0481		
6 Metabolizable Energy	3.2650	3.3023		
10 Crude Protein		12.0364		
18 20/23		1.3057		
19 Cation/Anion Balance		-1.0104		
20 Calcium	0.7500	0.8000	0.8000	0.0619
21 Chlorine		0.3250		
22 Magnesium		0.1676		
23 Phosphorus	0.6000	0.6127		
24 Potassium		0.5064		
25 Sodium	0.1500	0.2000	0.2000	0.0332
26 Sulphr		0.1755		
27 Cobalt		0.1554		
28 Copper		4.7920		
30 Iron		307.7325		
31 Manganese		14.3910		
32 Selenium		0.0881		
33 Zinc		22.7334		
34 Fluorine		27.9709		

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Plant..........MKT User : CRE

Product No.....SWIN3
Product Name...swine, gestation, 175kg, 40kg gain
Today's Date...08-10-2000
Date/Time......08-10-2000 08:36:54 # 2411

Nutrient Name	Nutrient Minimum	Actual	Nutrient Maximum	Cost
35 Non Structural Carbo		3.1784		
36 Salt		0.4555		
111 Lysine	0.4600	0.4600		-1.1371
112 Arginine	0.0001	0.6189		

```
113 Histidine                0.1500    0.2920
114 Isoleucine               0.2700    0.4070
115 Leuchine                 0.4400    1.1201
116 Methionine               0.1300    0.1946
118 Meth + Cystine           0.3200    0.4016
119 Phenylalanine            0.2700    0.5207
121 Phenylalan + Tyrosin     0.4600    0.8804
122 Threonine                0.3700    0.3700              -1.5753
123 Tryptophan               0.0900    0.1033
124 Valine                   0.3100    0.4974
127 Linoleic Acid            0.1000    1.7211
132 Phosphours - Avail       0.3500    0.3500              -0.5714
Iowa State University
Plant..........MKT                                                 User : CRE

Product No.....SWIN4
Product Name...lactating sow, 175kg, 0change, 200kg
Today's Date...08-10-2000
Date/Time......08-10-2000 08:36:54   #  2412

 Rounded  Ing         Ing        Pct   Cost/   Low     High   Rest/
Ingredient
 Amount   Code        Name      of Mix 100LB   Range  Range  100LB    Min
Max
==========================================================================
======
 1518.52 CORNSWIN corn grain  75.926    3.93   2.90   6.21
  412.88 SBMSWIN  47.5% SBM   20.644    9.00   6.82   9.95
   30.71      407 DiCalcium    1.535   12.68   1.96 348.93
   22.31      410 Limestone    1.115    1.20          3.24
   11.66      488 Salt (Sodi   0.583    2.00          3.24
  2.0000 VITMIN   vitamin mi   0.100   50.00                         0.100
0.100
  1.9210 LYS      lysine       0.096   92.00   2.88 159.28
0.200
Total Weight  2000.00          104.00 $ Per TON          5.20 $ Per 100LB


Rejected Ingredient Section
          Ing            Ing         Pct   Cost/   Low    High
Ingredient
          Code           Name       of Mix 100LB   Range  Range   Min
Max
==========================================================================
======
                97 Fat, Animal, Hy           10.50   3.24
         MBM       meat bone meal             9.85   8.64
         MET       methionine               109.00   3.24
0.200
         THR       threonine                185.00   3.24
0.200
         TRY       tryptophan               327.00   3.24
0.200
```

	Nutrient Name	Nutrient Minimum	Actual	Nutrient Maximum	Cost
1	Weight	1.0000	1.0000	1.0000	
2	Dry Matter		89.5317		
3	Moisture		0.0461		
6	Metabolizable Energy	3.2650	3.2989		
10	Crude Protein		16.1997		
18	20/23		1.2446		
19	Cation/Anion Balance		-0.9661		
20	Calcium	0.7500	0.7999	0.8000	0.0599
21	Chlorine		0.4023		
22	Magnesium		0.1848		
23	Phosphorus	0.6000	0.6427		
24	Potassium		0.6947		
25	Sodium	0.2000	0.2501	0.2500	0.0315
26	Sulphr		0.2070		
27	Cobalt		0.1489		
28	Copper		6.5555		
30	Iron		311.8730		
31	Manganese		17.2149		
32	Selenium		0.1089		
33	Zinc		26.5103		
34	Fluorine		26.8098		

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Plant..........MKT User : CRE

Product No.....SWIN4
Product Name...lactating sow, 175kg, 0change, 200kg
Today's Date...08-10-2000
Date/Time......08-10-2000 08:36:54 # 2412

	Nutrient Name	Nutrient Minimum	Actual	Nutrient Maximum	Cost
35	Non Structural Carbo		3.1879		
36	Salt		0.5830		
111	Lysine	0.7900	0.7900		-1.1380
112	Arginine	0.4400	0.9253		
113	Histidine	0.3200	0.3924		
114	Isoleucine	0.4400	0.5818		
115	Leuchine	0.9000	1.3640		
116	Methionine	0.2100	0.2420		
118	Meth + Cystine	0.3900	0.4990		
119	Phenylalanine	0.4300	0.7056		
121	Phenylalan + Tyrosin	0.8900	1.2127		
122	Threonine	0.4900	0.5128		
123	Tryptophan	0.1400	0.1590		
124	Valine	0.6700	0.6700		-1.3013
127	Linoleic Acid	0.1000	1.5816		
132	Phosphours - Avail	0.3500	0.3500		-0.5727

Iowa State University
Plant..........MKT User : CRE

Product No.....CHIC1
Product Name...Chickens 0-3 weeks nrc
Today's Date...08-10-2000
Date/Time......08-10-2000 08:35:12 # 2406

Rounded Amount	Ing Code	Ing Name	Pct of Mix	Cost/ 100LB	Low Range	High Range	Rest/ 100LB	Ingredient Min	Max
1158.82	CORN	corn grain	57.941	3.93		4.59			
650.38	SBM	48.5% SBM	32.519	9.00	8.61				
64.17	FEEDFAT	Animal fat	3.209	10.50	8.34	379.71			
60.00	MBM	meat bone	3.000	9.85		10.30	-0.455	3.000	3.000
35.48	407	DiCalcium	1.774	12.68		54.72			
12.53	410	Limestone	0.627	1.20		23.48			
8.1200	488	Salt (Sodi	0.406	2.00		12691			
5.9999	VITMIN	vitamin mi	0.300	50.00			50.000	0.300	0.300
4.0000	MET	methionine	0.200	109.00		660.72	-551.72		0.200
0.5000	BMD	BMD 75	0.025	334.00				0.025	0.025

Total Weight 2000.00 130.57 $ Per TON 6.53 $ Per 100LB

Rejected Ingredient Section

Ing Code	Ing Name	Pct of Mix	Cost/ 100LB	Low Range	High Range	Ingredient Min	Max
LYS	lysine		92.00	4.13			0.200
THR	threonine		185.00	1.04			0.200
TRY	tryptophan		327.00	5.96			0.200

Nutrient Name	Nutrient Minimum	Actual	Nutrient Maximum	Cost
1 Weight	1.0000	1.0000	1.0000	
2 Dry Matter		89.3726		
3 Moisture		0.0782		
6 Metabolizable Energy	3.0500	3.0500	3.1000	-42.569
10 Crude Protein		22.3618		

11 Ether Extract		2.8269		
13 Crude Fiber		2.6269		
18 20/23		1.1777		
19 Cation/Anion Balance		-1.1362		
20 Calcium	1.0000	1.0000	1.0500	-0.2015
21 Chlorine	0.2000	0.3066		
22 Magnesium		0.2237		
23 Phosphorus		0.8491		
24 Potassium		0.8632		
25 Sodium	0.2000	0.2000	0.2500	-0.1948
26 Sulphr		0.2243		
27 Cobalt		0.1721		
28 Copper		6.8481		
30 Iron		365.7753		
31 Manganese		23.6213		

Iowa State University
Plant..........MKT User : CRE

Product No.....CHIC1
Product Name...Chickens 0-3 weeks nrc
Today's Date...08-10-2000
Date/Time......08-10-2000 08:35:12 # 2406

Nutrient Name	Nutrient Minimum	Actual	Nutrient Maximum	Cost
32 Selenium		0.0574		
33 Zinc		32.8255		
34 Fluorine		30.9740		
35 Non Structural Carbo		2.7533		
36 Salt		0.4060		
111 Lysine	1.1000	1.1915		
112 Arginine	1.2500	1.4502		
113 Histidine	0.3500	0.5783		
114 Isoleucine	0.8000	0.9036		
115 Leuchine	1.2000	1.8940		
116 Methionine	0.5000	0.5409		
118 Meth + Cystine	0.9000	0.9000		-133.040
119 Phenylalanine	0.7200	1.0354		
121 Phenylalan + Tyrosin	1.3400	1.4601		
122 Threonine	0.8000	0.8283		
123 Tryptophan	0.2000	0.2835		
124 Valine	0.9000	1.0245		
127 Linoleic Acid	1.0000	1.5150		
132 Phosphours - Avail	0.4500	0.4500		-0.7496

Iowa State University
Plant..........MKT User : CRE

Product No.....CHIC2
Product Name...Chickens 3-6 weeks nrc
Today's Date...08-10-2000
Date/Time......08-10-2000 08:35:12 # 2407

Rounded Ingredient Amount	Ing Code	Ing Name	Pct of Mix	Cost/ 100LB	Low Range	High Range	Rest/ 100LB	Min	Max
1311.64	CORN	corn grain	65.582	3.93		5.73			
543.43	SBM	48.5% SBM	27.171	9.00	3.64				
60.00	MBM	meat bone	3.000	9.85	4.02		9.850	3.000	3.000
32.42	FEEDFAT	Animal fat	1.621	10.50	6.41	305.29			
25.40	407	DiCalcium	1.270	12.68	0.03	816.19			
13.74	410	Limestone	0.687	1.20		20.34			
5.9999	VITMIN	vitamin mi	0.300	50.00			50.000	0.300	0.300
5.5600	488	Salt (Sodi	0.278	2.00		345.21			
1.3095	MET	methionine	0.065	109.00	4.39	620.76			0.200
0.5000	BMD	BMD 75	0.025	334.00				0.025	0.025

Total Weight 2000.00 119.36 $ Per TON 5.97 $ Per 100LB

Rejected Ingredient Section

Ing Code	Ing Name	Pct of Mix	Cost/ 100LB	Low Range	High Range	Ingredient Min	Max
LYS	lysine		92.00	5.55			0.200
THR	threonine		185.00	3.16			0.200
TRY	tryptophan		327.00	6.98			0.200

	Nutrient Name	Nutrient Minimum	Actual	Nutrient Maximum	Cost
1	Weight	1.0000	1.0000	1.0000	
2	Dry Matter		89.0691		
3	Moisture		0.0631		
6	Metabolizable Energy	3.0500	3.0500	3.1000	-33.036
10	Crude Protein		20.3390		
11	Ether Extract		3.0638		
13	Crude Fiber		2.5865		
18	20/23		1.2114		
19	Cation/Anion Balance		-0.8080		
20	Calcium	0.9000	0.9001	0.9500	-0.0952
21	Chlorine	0.1500	0.2294		
22	Magnesium		0.2152		
23	Phosphorus		0.7430		

Nutrient Name	Nutrient Minimum	Actual	Nutrient Maximum	Cost
24 Potassium		0.7799		
25 Sodium	0.1500	0.1499	0.2000	-0.1028
26 Sulphr		0.2013		
27 Cobalt		0.1232		
28 Copper		6.2264		
30 Iron	80.0000	291.8419		
31 Manganese		20.3902		

Iowa State University
Plant..........MKT User : CRE

Product No.....CHIC2
Product Name...Chickens 3-6 weeks nrc
Today's Date...08-10-2000
Date/Time......08-10-2000 08:35:12 # 2407

Nutrient Name	Nutrient Minimum	Actual	Nutrient Maximum	Cost
32 Selenium		0.0543		
33 Zinc		30.7709		
34 Fluorine		22.1742		
35 Non Structural Carbo		2.1969		
36 Salt		0.2780		
112 Arginine	1.1000	1.2932		
113 Histidine	0.3200	0.5274		
114 Isoleucine	0.7300	0.8124		
115 Leuchine	1.0900	1.7704		
116 Methionine	0.3800	0.3856		
117 Cystine		0.3344		
118 Meth + Cystine	0.7200	0.7200		-21.205
119 Phenylalanine	0.6500	0.9393		
121 Phenylalan + Tyrosin	1.2200	1.2200		-1.1943
122 Threonine	0.7400	0.7505		
123 Tryptophan	0.1800	0.2485		
124 Valine	0.8200	0.9363		
127 Linoleic Acid	1.0000	1.6125		
132 Phosphours - Avail	0.3500	0.3500		-0.6777

Iowa State University
Plant..........MKT User : CRE

Product No.....CHIC3
Product Name...Chickens 6-8 weeks nrc
Today's Date...08-10-2000
Date/Time......08-10-2000 08:35:12 # 2408

Rounded Ingredient Amount	Ing Code	Ing Name	Pct of Mix	Cost/ 100LB	Low Range	High Range	Rest/ 100LB	Min Max
1425.43	CORN	corn grain	71.271	3.93		5.54		
463.25	SBM	48.5% SBM	23.163	9.00	3.10			

```
60.00 MBM       meat bone     3.000     9.85    3.43          9.850  3.000
3.000
     20.51      407 DiCalcium     1.026    12.68    0.16 899.15
   11.49       410 Limestone    0.574     1.20          21.16
    8.4691 FEEDFAT  Animal fat   0.423    10.50    6.84 304.93
    5.9999 VITMIN   vitamin mi   0.300    50.00  50.000  0.300        0.300
  4.0300       488 Salt (Sodi   0.201     2.00         380.40
  0.5000 BMD       BMD 75       0.025   334.00            0.025        0.025
  0.3196 MET       methionine   0.016   109.00   4.39 1239.2           0.200
Total Weight  2000.00          112.35 $ Per TON          5.62 $ Per 100LB


Rejected Ingredient Section
          Ing            Ing           Pct    Cost/   Low     High
Ingredient
          Code            Name       of Mix 100LB   Range   Range    Min
Max
============================================================================
======
         LYS       lysine                      92.00    5.69
0.200
         THR       threonine                  185.00    3.36
0.200
         TRY       tryptophan                 327.00    7.07
0.200

    Nutrient                Nutrient              Nutrient
    Name                    Minimum     Actual   Maximum      Cost
=================================================================
  1 Weight                   1.0000     1.0000    1.0000
  2 Dry Matter                         88.8425
  3 Moisture                            0.0558
  6 Metabolizable Energy     3.0500     3.0500    3.1000   -32.131
 10 Crude Protein                      18.8493
 11 Ether Extract                       3.2399
 13 Crude Fiber                         2.5553
 18 20/23                               1.1623
 19 Cation/Anion Balance               -0.6524
 20 Calcium                  0.8000     0.8000    0.8500   -0.0851
 21 Chlorine                 0.1200     0.1832
 22 Magnesium                           0.2063
 23 Phosphorus                          0.6883
 24 Potassium                0.3000     0.7173
 25 Sodium                   0.1200     0.1200    0.1700   -0.0940
 26 Sulphr                              0.1855
 27 Cobalt                              0.0995
 28 Copper                              5.7720
 30 Iron                              249.4979
 31 Manganese                          18.3531
Iowa State University
Plant..........MKT                                                 User : CRE

Product No.....CHIC3
```

Product Name...Chickens 6-8 weeks nrc
Today's Date...08-10-2000
Date/Time......08-10-2000 08:35:12 # 2408

Nutrient Name	Nutrient Minimum	Actual	Nutrient Maximum	Cost
32 Selenium		0.0520		
33 Zinc		29.3530		
34 Fluorine		17.9052		
35 Non Structural Carbo		1.7707		
36 Salt		0.2015		
111 Lysine	0.8500	0.9492		
112 Arginine	1.0000	1.1753		
113 Histidine	0.2700	0.4892		
114 Isoleucine	0.6200	0.7439		
115 Leuchine	0.9300	1.6774		
116 Methionine	0.3200	0.3200		-1.0585
118 Meth + Cystine	0.6000	0.6358		
119 Phenylalanine	0.5600	0.8671		
121 Phenylalan + Tyrosin	1.0400	1.0400		-1.3136
122 Threonine	0.6800	0.6920		
123 Tryptophan	0.1600	0.2223		
124 Valine	0.7000	0.8701		
127 Linoleic Acid	1.0000	1.6846		
132 Phosphours - Avail	0.3000	0.3000		-0.6708

APPENDIX C: DISTRIBUTION RESULTS

Table 39: Best Fit results for a protein premium system.

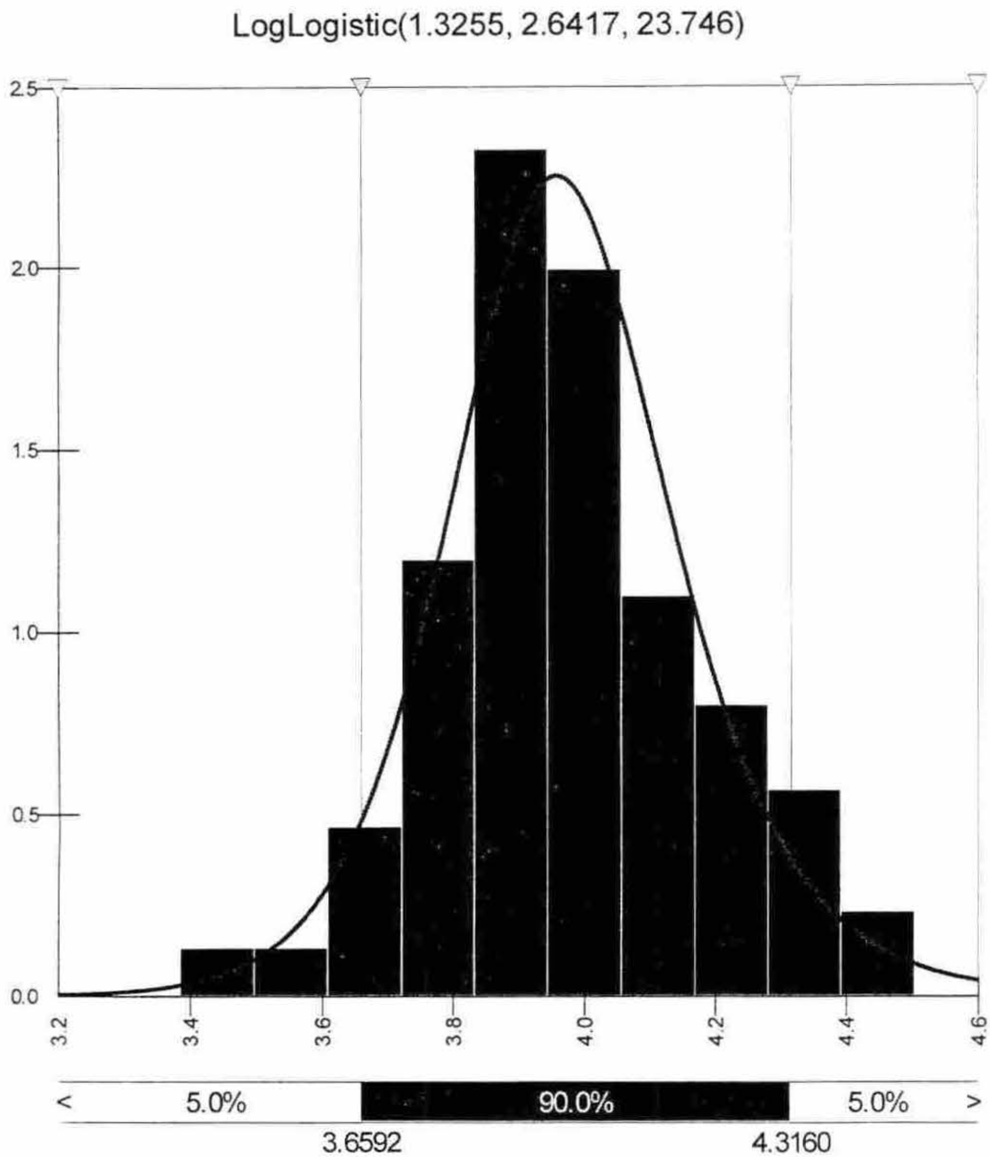


Table 40: Best Fit results for the EPV system.

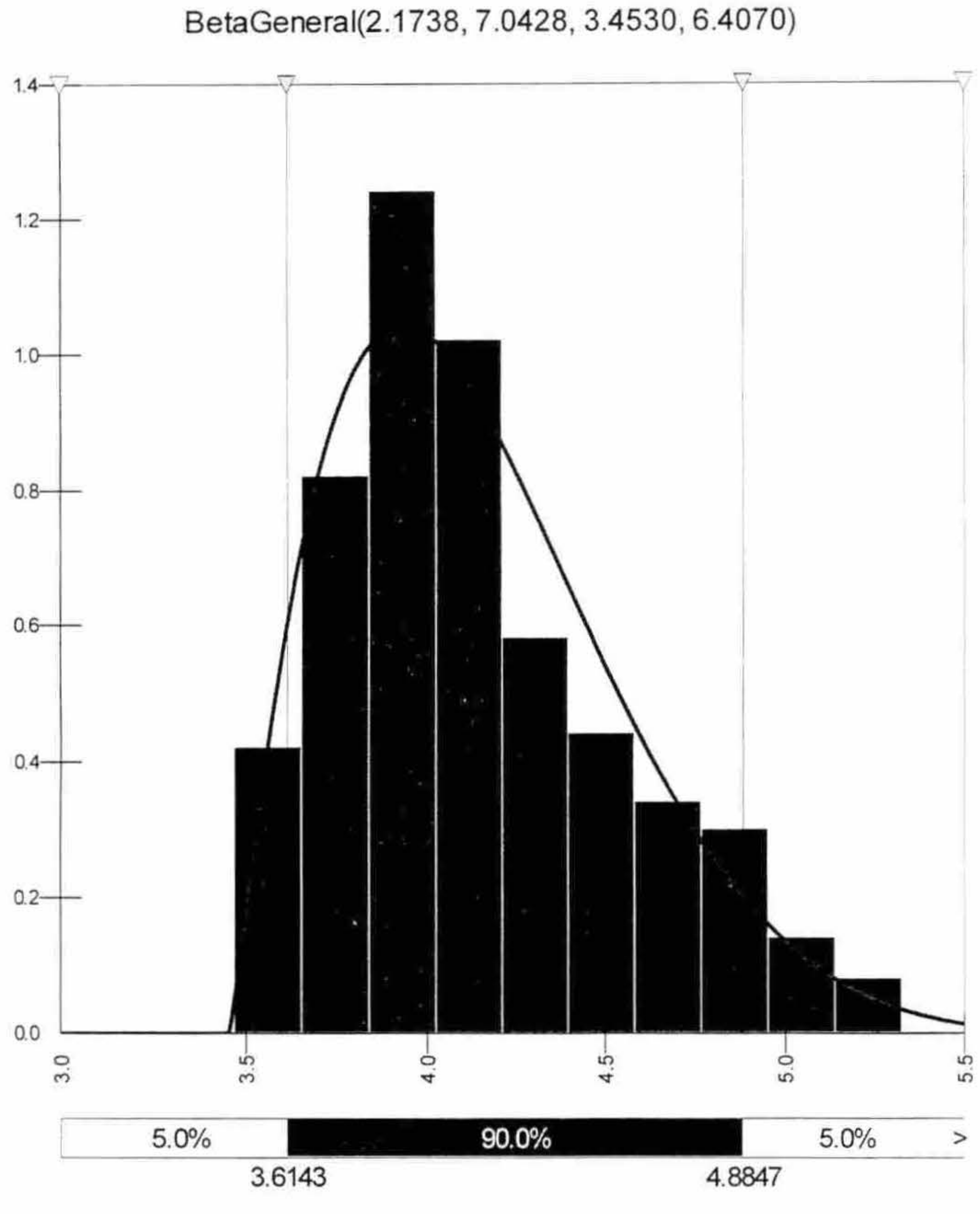


Table 41: Best Fit results for a pricing system based on 0-3 week chicken diets.

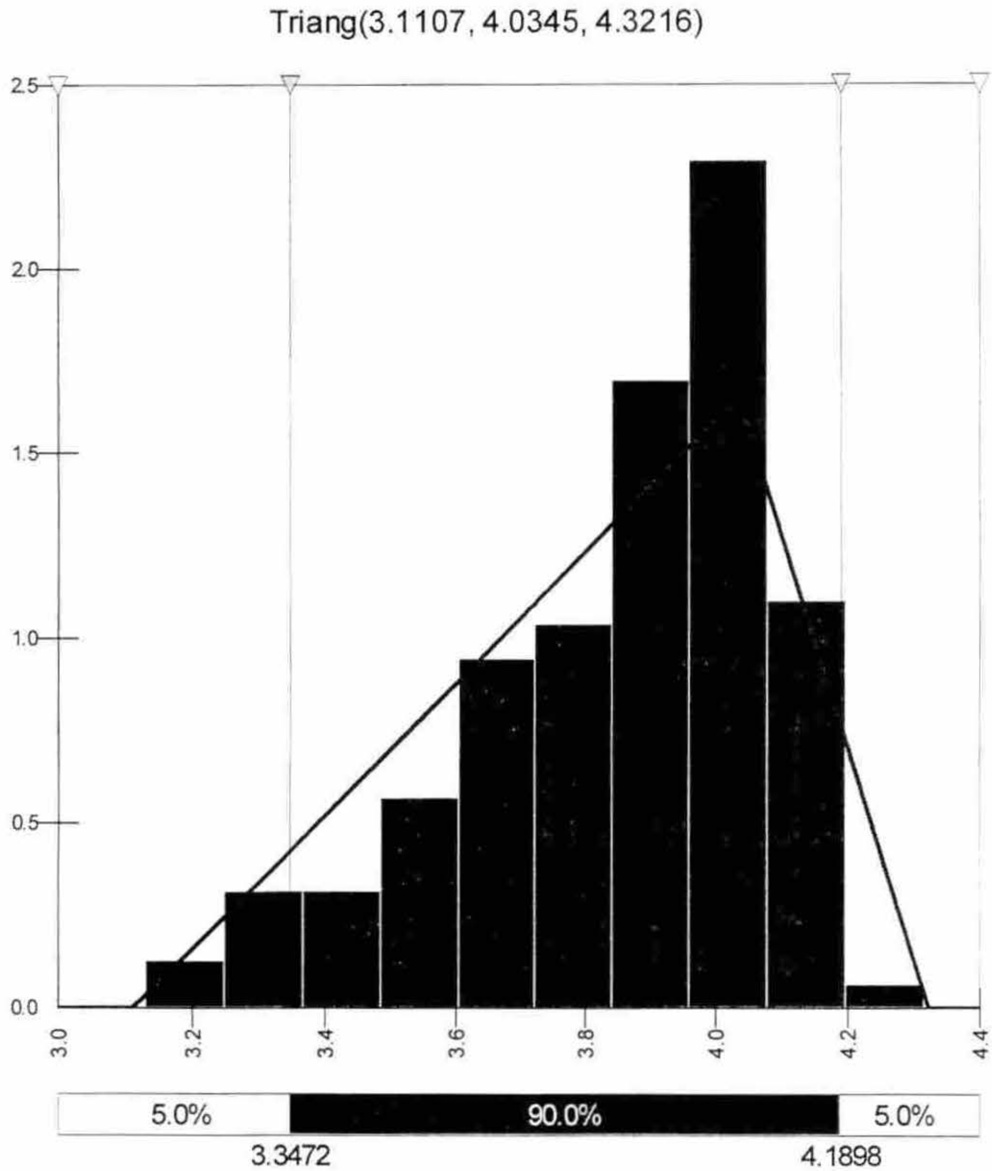


Table 42: Best Fit results for a pricing system based on 3-6 week chicken diets.

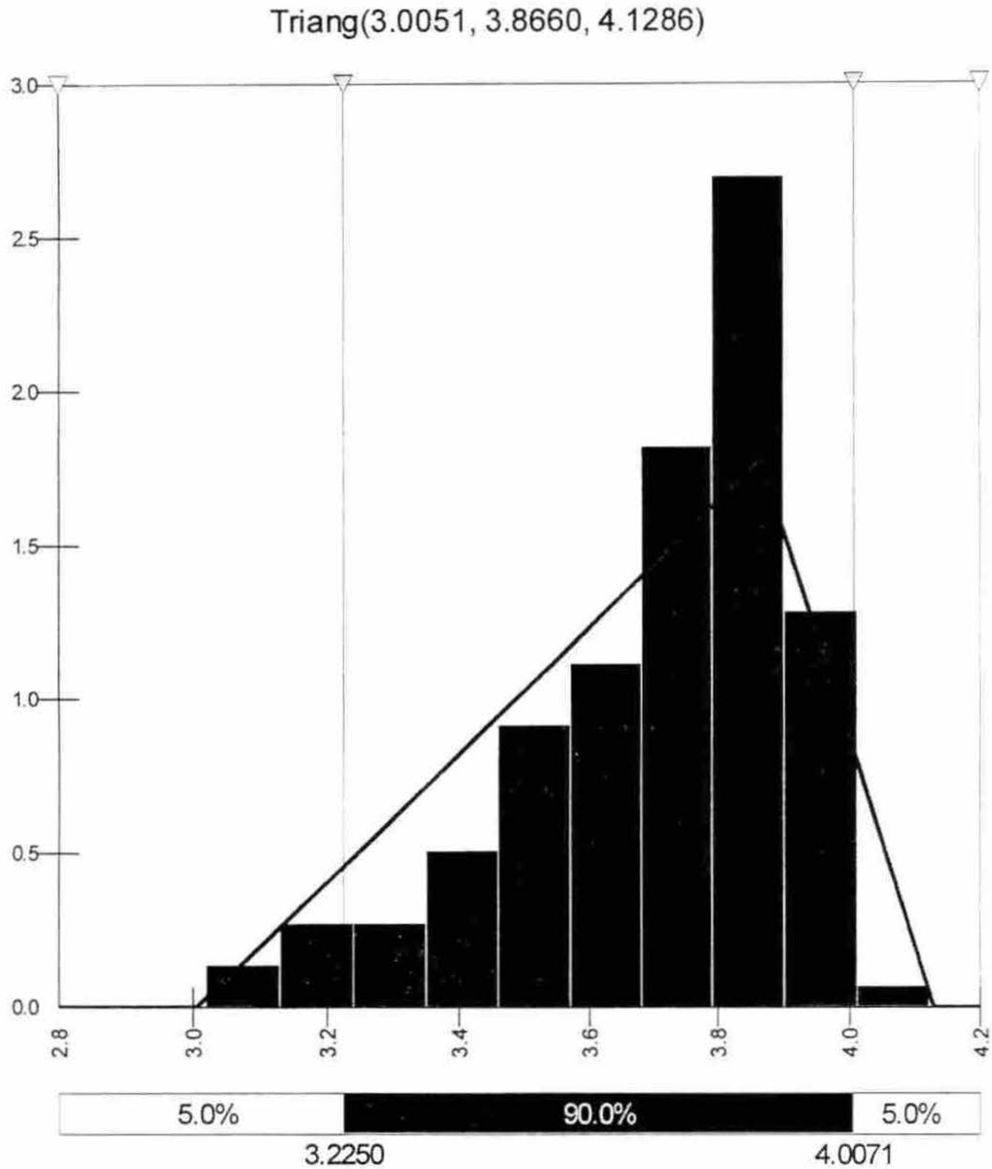


Table 43: Best Fit results for a pricing system based on 6-8 week chicken diets.

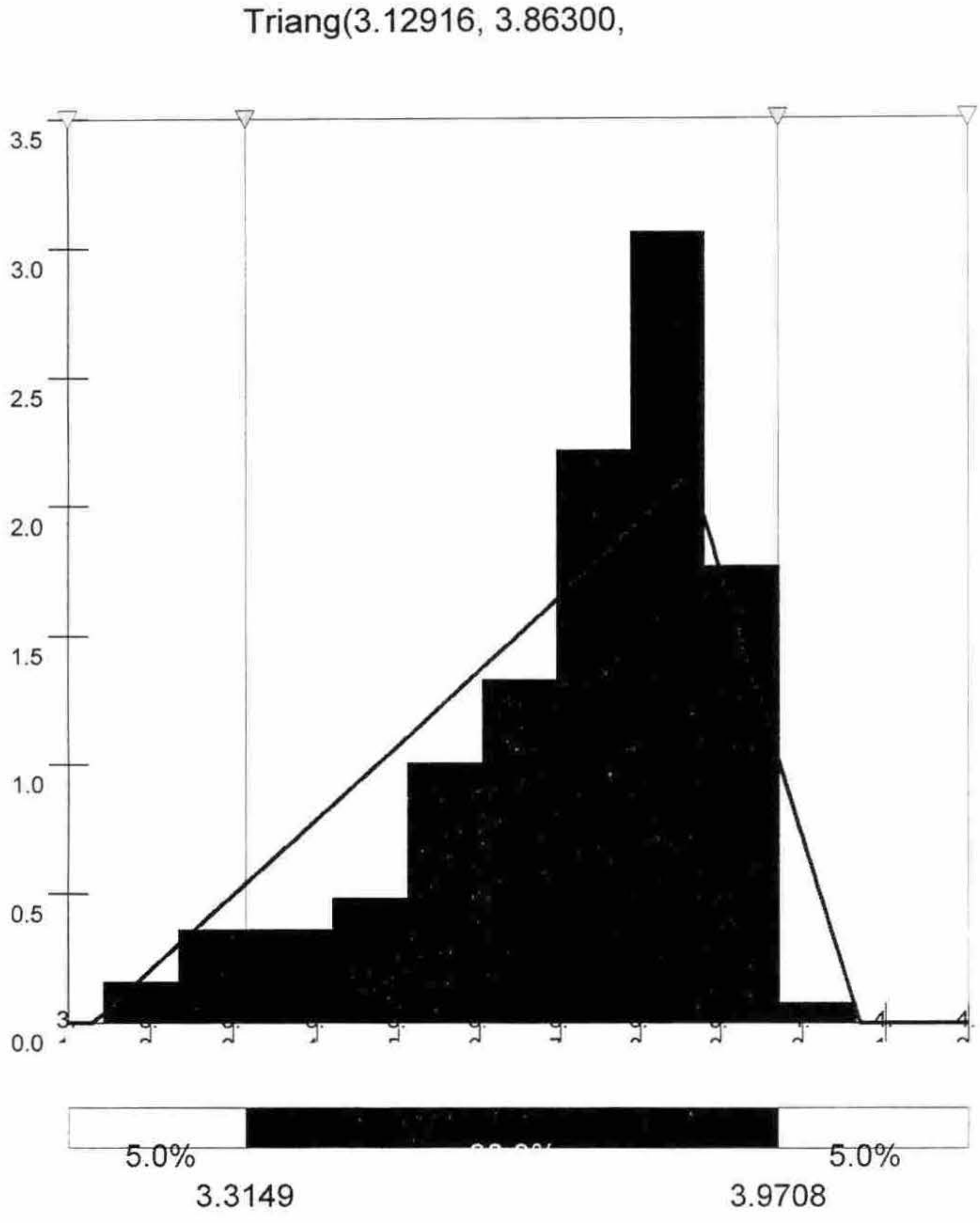


Table 44: Best Fit results for a pricing system based on grower pig diets.

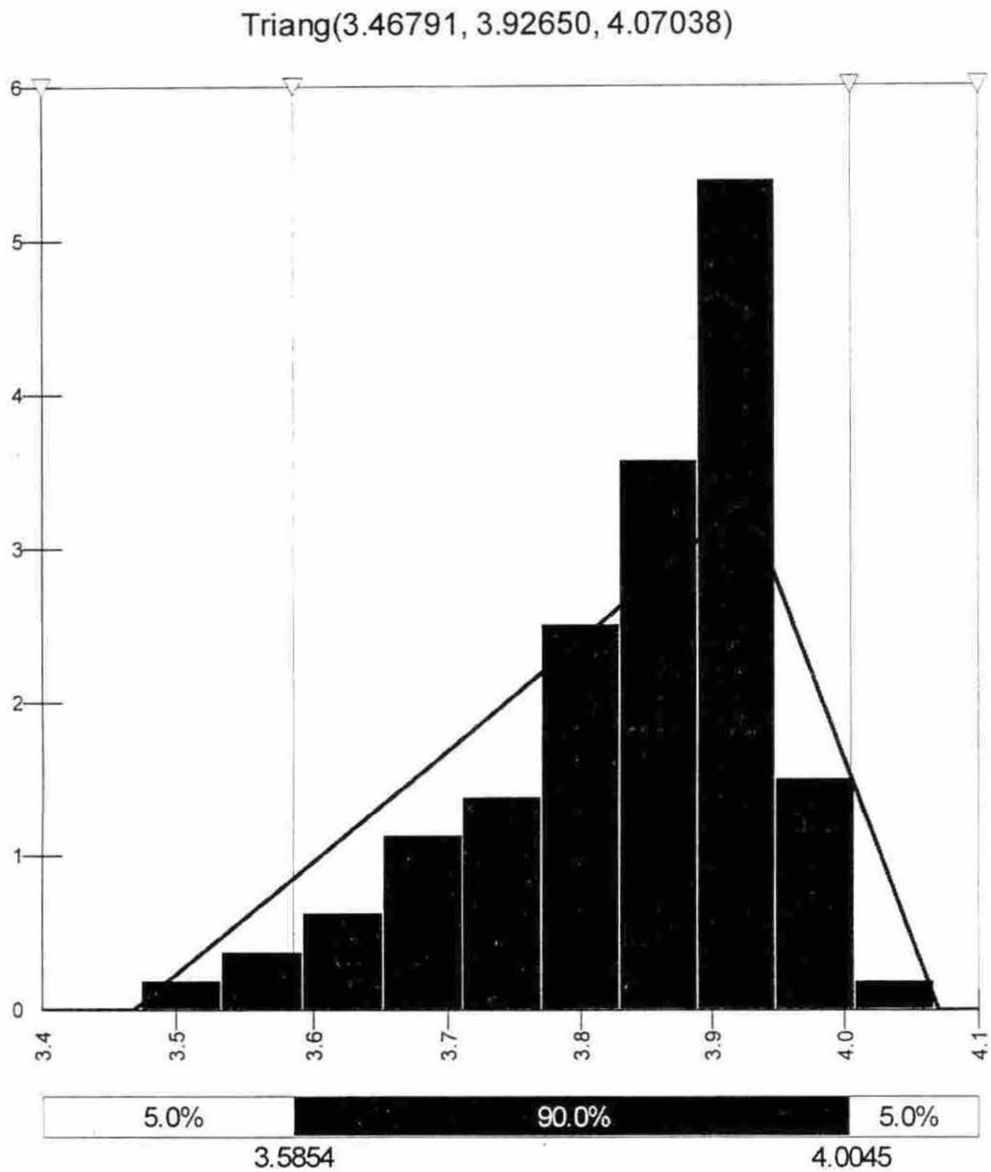


Table 45: Best Fit results for a pricing system based on finisher pig diets.

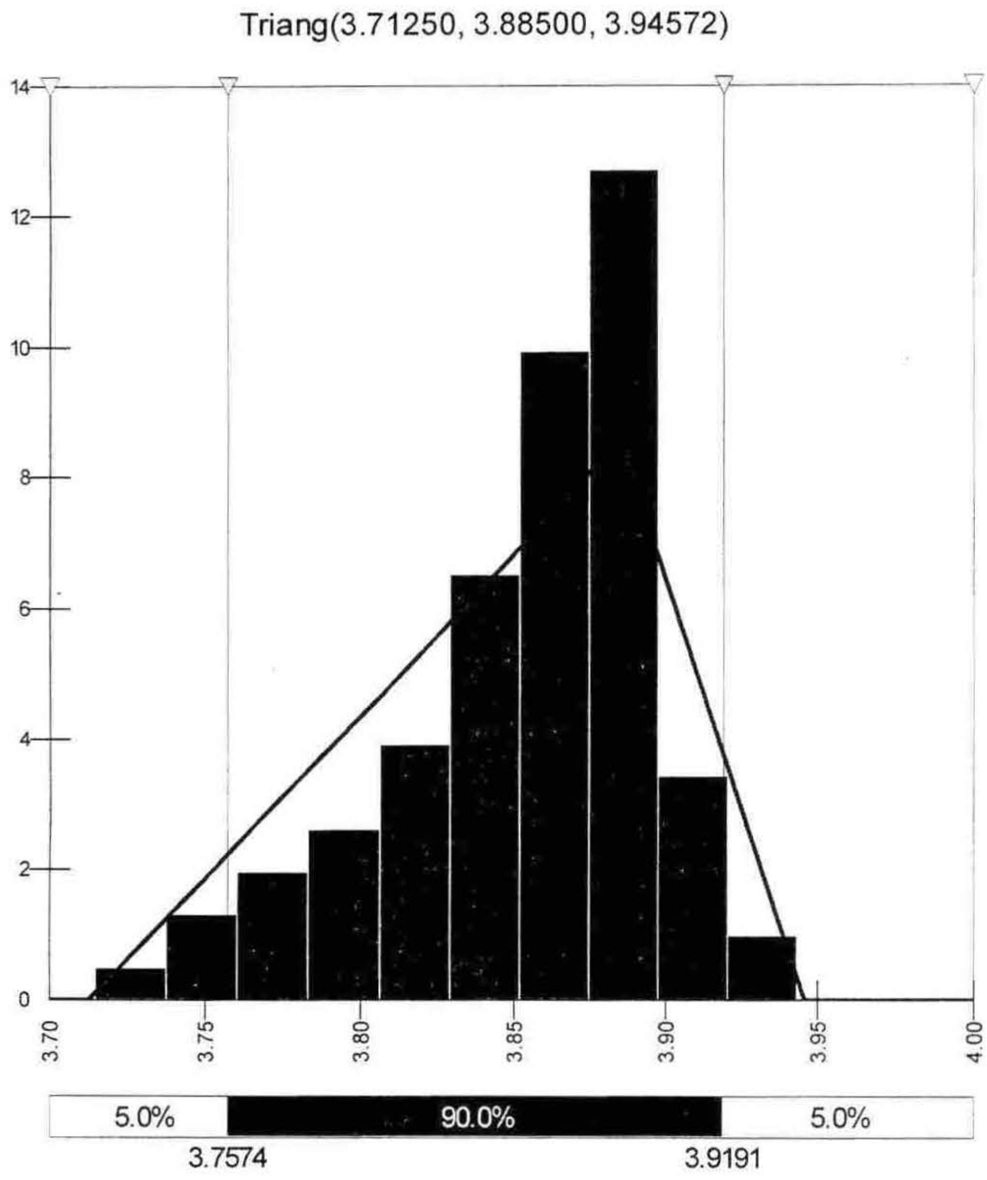


Table 46: Best Fit results for a pricing system based on gestating sow diets.

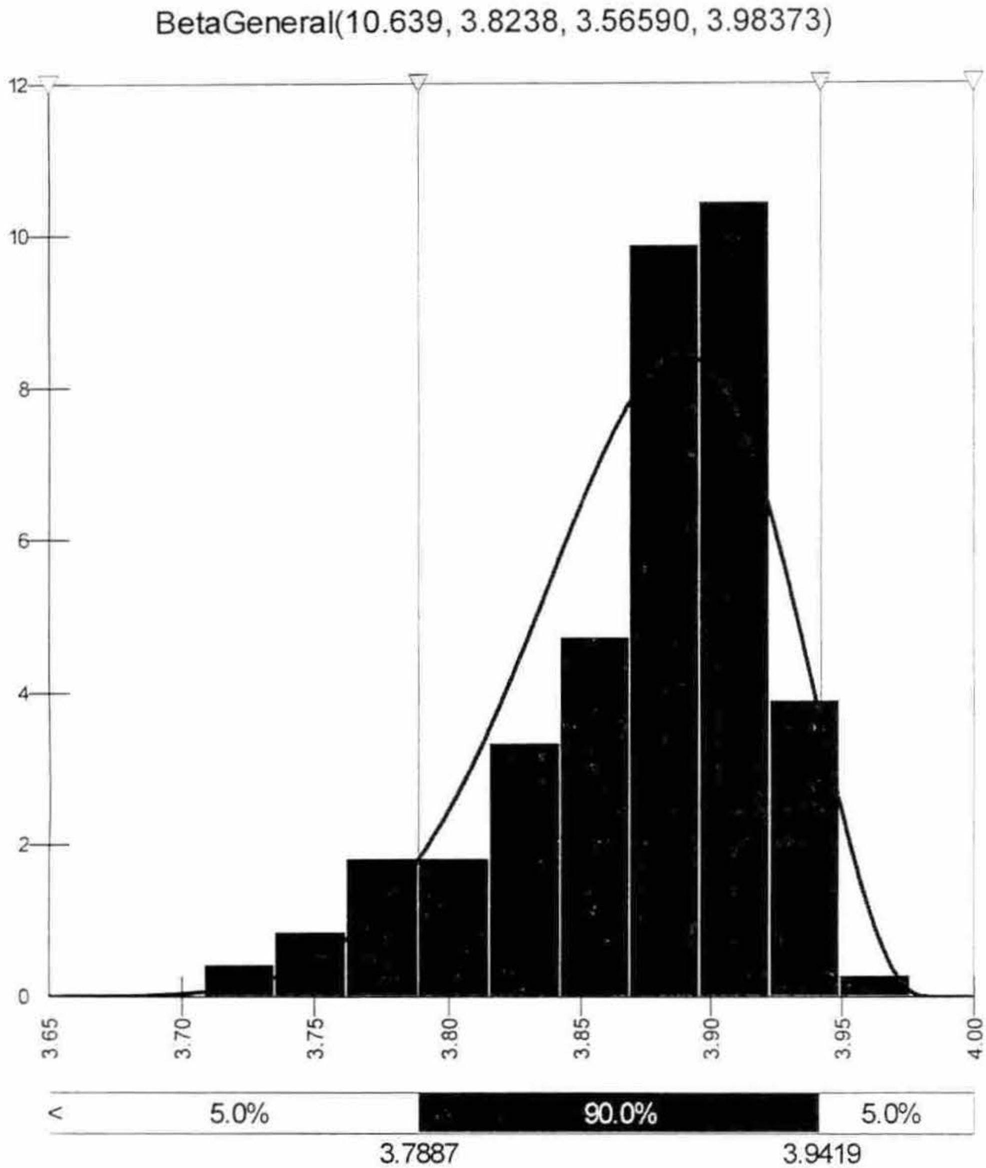
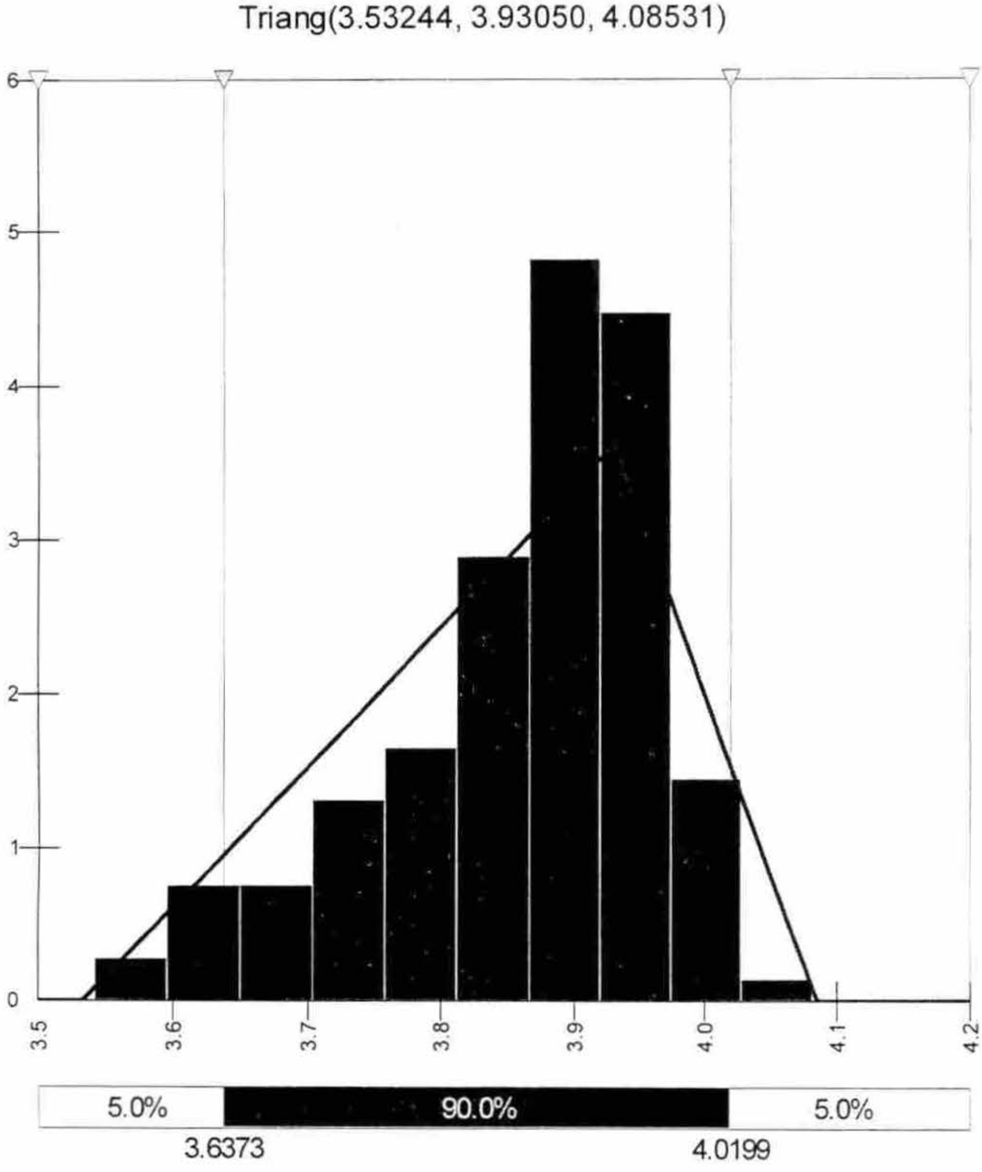


Table 47: Best Fit results for a pricing system based on lactating sow diets.



APPENDIX D: NON-PARAMETRIC RESULTS

Table 21: Pearson's product moment correlation coefficients.

	Protein Premium	EPV	0-3 Week Chic Price	3-6 Week Chic Price	6-8 Week Chic Price	Grower Pig Price	Finisher Pig Price	Gestating Sow Price	Lactating Sow Price
Protein Premium	1	0.90026	0.93848	0.94337	0.95659	0.94549	0.92748	0.95508	0.94652
EPV	0.90026	1	0.83977	0.84224	0.8494	0.80415	0.79165	0.80891	0.79823
0-3 Week Chic Price	0.93848	0.83977	1	0.98446	0.98467	0.97419	0.96302	0.97573	0.97006
3-6 Week Chic Price	0.94337	0.84224	0.98446	1	0.99515	0.97294	0.96072	0.9786	0.97173
6-8 Week Chic Price	0.95659	0.8494	0.98467	0.99515	1	0.97385	0.95986	0.98038	0.97409
Grower Pig Price	0.94549	0.80415	0.97419	0.97294	0.97385	1	0.99284	0.99158	0.98614
Finisher Pig Price	0.92748	0.79165	0.96302	0.96072	0.95986	0.99284	1	0.97622	0.9717
Gestating Sow Price	0.95508	0.80891	0.97573	0.9786	0.98038	0.99158	0.97622	1	0.98308
Lactating Sow Price	0.94652	0.79823	0.97006	0.97173	0.97409	0.98614	0.9717	0.98308	1

Table 22: Spearman's Rho results.

	Protein Premium	EPV	0-3 Week Chic Price	3-6 Week Chic Price	6-8 Week Chic Price	Grower Pig Price	Finisher Pig Price	Gestating Sow Price	Lactating Sow Price
Protein Premium	1	0.91898	0.93527	0.95073	0.959	0.9469	0.92539	0.95953	0.95149
EPV	0.91898	1	0.87299	0.87757	0.88279	0.83277	0.81573	0.83568	0.83033
0-3 Week Chic Price	0.93527	0.87299	1	0.98413	0.98033	0.96357	0.94912	0.96439	0.95992
3-6 Week Chic Price	0.95073	0.87757	0.98413	1	0.99648	0.96491	0.94782	0.97101	0.96669
6-8 Week Chic Price	0.959	0.88279	0.98033	0.99648	1	0.96171	0.94212	0.97061	0.96621
Grower Pig Price	0.9469	0.83277	0.96357	0.96491	0.96171	1	0.98976	0.98931	0.98649
Finisher Pig Price	0.92539	0.81573	0.94912	0.94782	0.94212	0.98976	1	0.96794	0.96586
Gestating Sow Price	0.95953	0.83568	0.96439	0.97101	0.97061	0.98931	0.96794	1	0.98507
Lactating Sow Price	0.95149	0.83033	0.95992	0.96669	0.96621	0.98649	0.96586	0.98507	1

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