FS 00-03 January 2000

PRODUCTION AND PROFITABILITY RESPONSES TO ALTERNATIVE PROTEIN SOURCES IN BROILER RATIONS

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Abstract:

Profitability of using peanut meal as an alternative protein source in broiler production was investigated through the development of a two-stage mathematical program that optimizes broiler production. The concept of value of marginal product incorporated in this model allows demand adjustments before decisions on the production and processing take place.

Key words: soybean meal, cotton seed meal, maximum profits, mathematical program

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INTRODUCTION

Outside the United States, peanut meal has been widely used as an inexpensive source of protein in animal rations (Anderson, 1982). The feed industry in the United States, however, uses soybean meal as the protein basis for broiler rations, considering peanut meal to be an inferior protein ingredient. Peanut meal protein lacks important nutrients required for broilers, deficient in at least three amino acids: threonine, methionine and lysine (National Research Council, 1994). Such deficiencies may be overcome, however, by supplementing purified synthetic forms of such amino acids that are now available commercially at prices that allow their use in livestock feeds. Methionine and lysine have been added to poultry diets for many years; threonine has only recently become available in synthetic form. Because peanut meal is generally lower in price than soybean meal, peanut meal with amino acid supplements may be competitive with soybean meal in poultry feeds.

Apart from the possibilities of acceptable substitution of protein sources, it behooves the peanut and feed industries to determine the profitability of using peanut meal in broiler rations. Profitability will be driven initially by the farm price that a production firm receives for each pound of broiler sold at the farm level. Production decisions on input use will then depend on the productivity of inputs and thus relative costs. Although farm price is required for economically optimal production decisions, using supply and demand as a basis for discovering the farm price of broilers is difficult to apply in an integrated market for broiler production. In fact, there is no marketplace, or mechanism, for discovering broiler price at the farm level in a system vertically integrated to that stage of production. However, it may be useful to estimate an equivalent farm price derived from supply-demand conditions at wholesale level in order to determine a competitively efficient market solution.

Least cost feed formulation has been the major tool for broiler production economics and profit maximization models. In the 1950's, mathematical programming generated a renewed interest in feed formulation. Since then, the major concern has been to minimize cost of feed, and no consideration has been allocated to other determinants of maximizing profit. Least cost rations minimize the cost of diets, given a certain set of ingredients and their nutritional content. An important assumption of least cost formulated diets is that every unit of a least cost formulated ration has the same productivity regardless of ingredient sources (Allison and Baird, 1974). However, this assumption may not be true. Productivity of each unit of input at its optimal level, given cost deductions, must be included in a model that determines the maximum return to production given inputs used. Pesti and Smith (1984) showed that production response of broilers to dietary energy and protein levels show diminishing marginal returns. This conclusion supports those of Yoshida (1962), Pesti (1982) and Pesti and Fletcher (1983). Models that do not consider diminishing marginal returns to inputs, such as protein and energy, are not a good description of the production process and cannot be used to determine maximum profit.

In addition to productivity concerns, other important determinants of profit are not considered when least cost feeds are used as the major tool for broiler production. Total feed consumption and the weights and values of broiler parts are also major determinants of profit. Their influence in optimal allocation of profit and production must change the goal for animal nutrition from least-cost to a more broadly, profit-maximizing feeding ration. Further, a major tenet as a determinant of maximum profit considered in this study is that level of protein fed influences all of the variables that affect profit.

In the 1990's, studies have been developed to determine maximum profit levels instead of least cost feeds. Gonzalez-Alcorta, Dorfman and Pesti (1994) developed a profit maximization model that used nonlinear programming and separable linear programming to determine the precise energy and protein levels in the feed that maximize profit. Their model is distinguished by the assumption that body weight was not fixed at a predetermined level. Feed cost was not determined by least cost feed formulation. Rather, feed cost was determined as a variable of the profit maximization model in a way similar to that described in Pesti *et al.* (1986). They concluded that the mathematical programming functions applied in their model showed that setting energy and protein levels that vary with output and input prices can raise profit compared to fixed diet levels of energy and protein based on previous nutritional guidelines.

This study evaluates and determines profitable, efficient feed compositions and production strategies for broiler production using various feed protein sources and levels, given the prices of carcass and cut-up parts, productivity data, cost of processing and cost of feed ingredients. Variables such as growth period, live and processed weight of a broiler and its cut-up parts, feed consumption, feed composition and feed efficiency (unit of feed per unit of output) are considered within the decision and management framework. The analysis determines what combinations of feed formulation and grow-out processes are most profitable and how much time should be allocated to the grow-out process under varying prices of outputs and inputs.

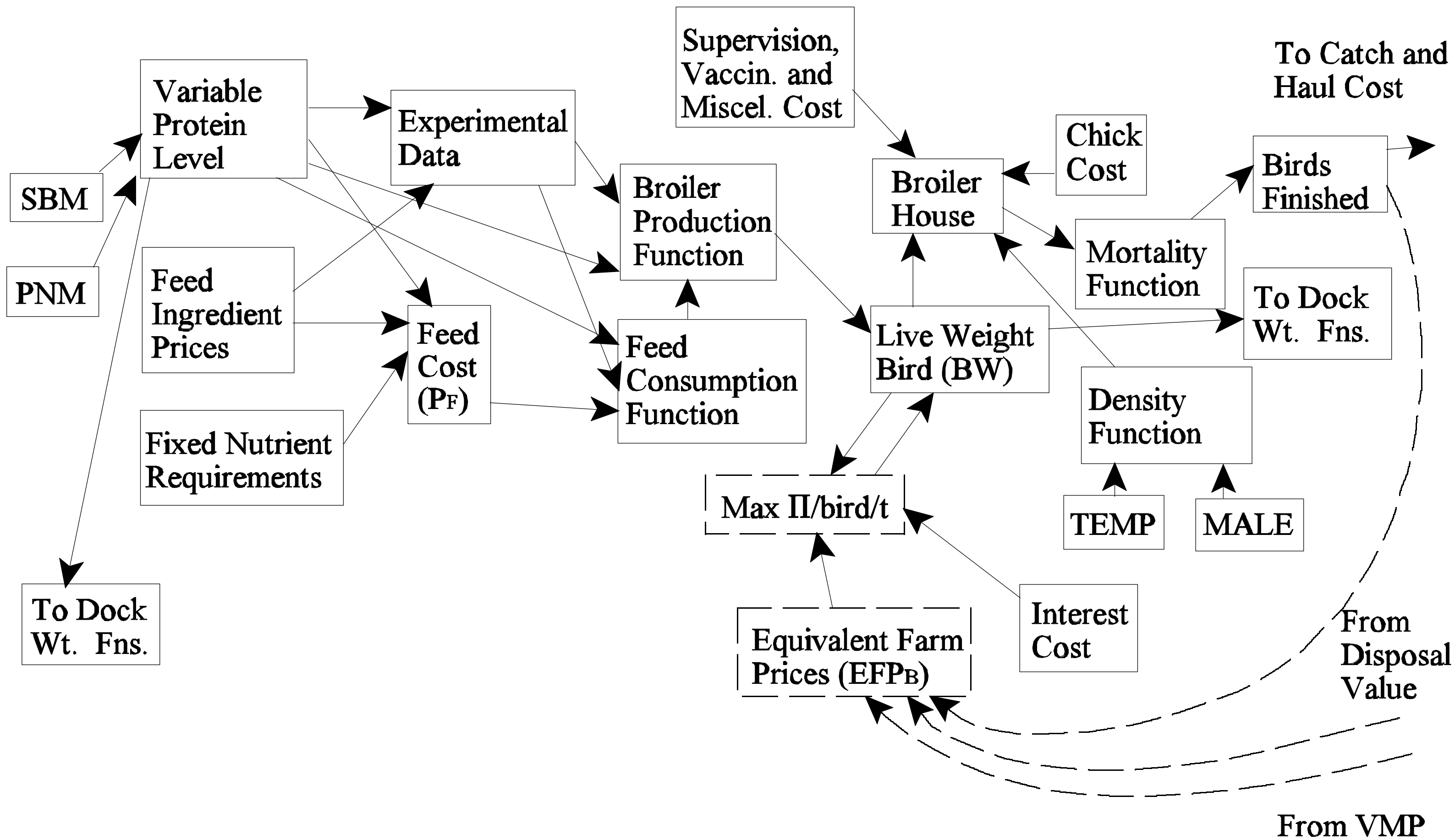
MODELING FRAMEWORK

A procedure for determining a derived demand price at the farm level (or Equivalent Farm Price, EFP_B) for broilers is first required. Dock prices reflect consumer expectations, but these prices must be translated to the production level. Since farm prices for broilers are not available, due to vertically integrated system problems already mentioned, it is desirable to calculate a derived price that will be equal to dock price discounted by the cost involved in the transportation, processing, marketing and other costs that affect producer profit margin.

Even though cost is one determinant of price, the consumer has the option of choosing a less expensive good. While such a situation forces prices to be discovered in the consumer market, supply adjustment can only be made at the farm level. Therefore, it is necessary to account for derived demand at farm level before a supply decision is made. This model will help to determine the most profitable allocation of inputs for the production of broilers given derived demand prices. EFP_B of a broiler is thus a key variable in profitable decision-making on the use of inputs such as soybean meal (SBM), peanut meal (PNM), or other substitute ingredients.

Government agencies and private corporations typically calculate their own equivalent farm prices. We do not try to determine an equivalent farm price that will be used in every production process situation. Instead, we calculate an equivalent farm price to be used in the situation represented by a particular production process that is predetermined in the model. Previous studies have examined the technical aspect of producing broilers fed PNM, but they have not analyzed the productivity nor price conditions under which PNM could replace SBM efficiently. If this substitution process is economically efficient, broiler production in areas that have high peanut production would greatly benefit from using a lower cost PNM.

A two-stage model that consists of feed cost minimization and profit maximization is then constructed to determine the maximum profit per bird per unit of time that can be achieved in a broiler production process given constraints imposed by economic and technical restrictions. Figure 1 describes the process that transforms inputs at the farm level to produce live weight birds and its flow to the processing stage, where carcass weight is the basis. Information feed-back, via value of marginal product (*VMP)* concepts, then is used to determine the level of equivalent farm price, EFP_B, feed efficiency, time, bird live weight and maximum profit, Π. Changes in demand, especially seasonally, can cause adjustments in price, and costs of processing, among other costs, must be discovered for carcass and cut-up parts. On the other hand, supply adjustment takes place at the farm level. This model shows the implications of supply adjustments of birds' live weight to predetermined market prices of whole carcass and cut-up parts.


Supervision,
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Production
Function
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Function
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Feed
Ingredient
Prices
To Dock
Wt. Fns.
Feed
Cost
(PF)
Feed
Consumption
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Live Weight
Bird (BW)
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Disposal
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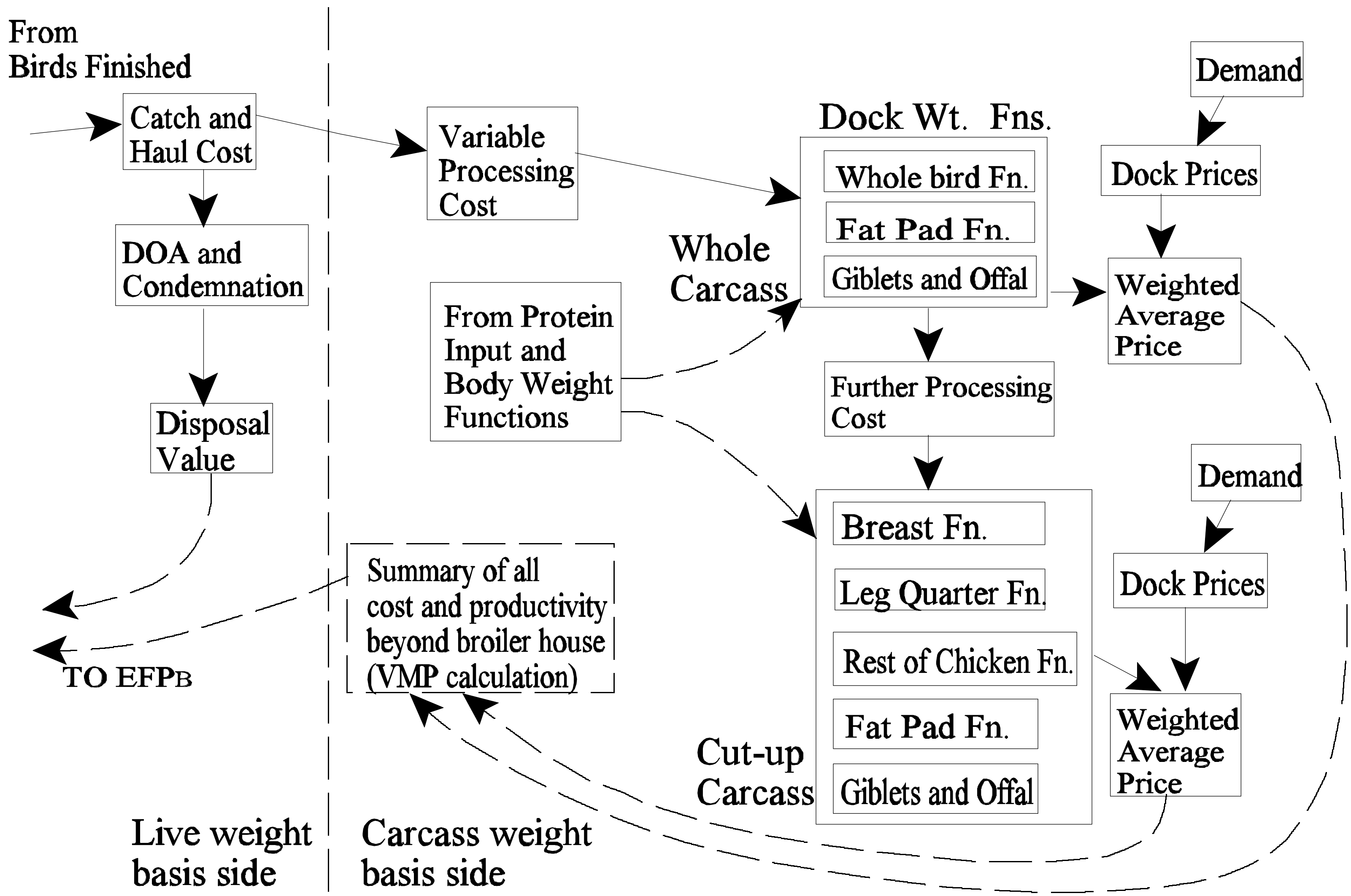
From
Birds Finished
Catch and Haul Cost
DOA and Condemnation
Disposal Value
TO EFPB
Variable Processing Cost
From Protein Input and Body Weight Functions
Summary of all cost and productivity beyond broiler house (VMP calculation)
Dock Wt. Fns.
Whole bird Fn.
Fat Pad Fn.
Giblets and Offal
Whole Carcass
Further Processing Cost
Breast Fn.
Leg Quarter Fn.
Rest of Chicken Fn.
Fat Pad Fn.
Giblets and Offal
Cut-up Carcass
Demand
Dock Prices
Weighted Average Price
Demand
Dock Prices
Weighted Average Price
Live weight basis side
Carcass weight basis side

Figure 1 up to the vertical dotted line shows the supply side, or the side in which variables are calculated on a live weight basis. The right side of the dotted line shows the processes in which variables are calculated in the carcass weight basis. Solid lines indicate flow of feed and chickens through the system. Dotted lines indicate derived demand calculations that, combined with physical flows, determine maximum profit. In the chart, the term function means that coefficients were estimated from experimental designs or secondary data. Labor cost and capital cost at farm level and capital cost at plant level generally must also be considered as variables, but these are not included in the current model. Such costs are thus the inputs to production that must be paid from the fund of profits, or net revenues, that are to be maximized.

The flow chart in figure 1 depicts the production process, beginning when SBM or PNM is chosen as protein source at predetermined protein levels for feed formulation. Feed ingredients are determined and fixed nutrient requirements are set for given biological requirements as determined by the National Research Council (NRC 1994). Feed ingredients, ingredient prices and nutrient requirements are the basis of determination of a least cost ration. Feed cost, equivalent farm price and feed consumed are part of the broiler production function that determines the profitable live weight of a bird. Bird live weight must be produced in the broiler house, where density, a function of average temperature, bird live weight and male percentage, will determine the number of birds to be placed in the house. Chick costs and other costs are then applied to this stage of the process. The mortality function, which is estimated as a function of time, will determine the number of birds finished after the grow-out process is completed. Catching and hauling costs are deducted when birds are transported to the processing plant or to the carcass weight basis side where the second stage is started. At that point, dead on arrivals and field condemned birds must be subtracted from the number of birds finished, and their disposal value must be added to the calculation of equivalent farm price.

On the carcass basis side, variable processing cost (obtained from a confidential industry source) and dock prices of whole carcass and cut-up parts (Georgia Department of Agriculture,

1997) in conjunction with processing yield functions determine whole carcass weight and weight of cut-up parts. The yield functions are determined by fed protein levels and bird live weight. Dock prices, yield functions and processing costs will then determine a weighted average price, or derived demand price of whole carcass or cut-up parts. The weighted average price then enters the *VMP* calculation, and the *VMP* and disposal values are used to determine the equivalent farm price, which is part of the profit function.

$$\sum \beta_i * X_i \;\geq\; PR \tag{3}$$

In the first stage, for given levels of protein and feed sources (SBM or PNM), a feed which minimizes cost is produced. The cost of this feed, P_F, is then included in the second stage

of the program where profit is maximized. The first stage is summarized:

$$Min \;\; P_F \;=\; \sum P_i * X_i \tag{1}$$

Subject to:

$$\sum \alpha_i * X_i \;\geq\; ME \tag{2}$$

That is, the least cost feed function minimizes the cost of feed for determined ingredients, X_i, and their prices, P_F (Eq. 1). The constraints meet nutrient requirements for technically efficient growth and are represented by: level of metabolizable energy in the ration must be at least equal to the predetermined level, *ME*, where α_i is the technical coefficient for energy for each ingredient (2); and level of protein in the ration, *PR*, must be at least equal to the level desired by the firm, where β_i is the technical coefficient for protein of each ingredient (3). Other constraints considered in this model to assure feasibility, unit feed, and other feed requirements are: protein ratio of each nutrient to level of protein in the diet must be at least equal to the level desired, where a technical coefficient for the nutrient value of each ingredient is assumed; the sum of all calcium content in the ingredients must be greater than or equal to desired calcium content; ratio of calcium to available phosphorus must be equal to 2:1, where technical coefficients for calcium and available phosphorus are assumed, respectively; the sum of all ingredients must be equal to a unit of feed; all ingredients must have non-negative values in the solution.

In the second stage, profit per bird per unit of time, Π, is found mathematically:

$$Max\ \Pi = \{(EFP_B * BW) - [(P_F + DEL) * F_C] * I\} / t \qquad \textbf{(4)}$$

Subject to:

$$BW = a_1 + b_1 * F_C + b_2 * F_C^2 + b_3 * DUM_1 + b_4 * DUM_2 \qquad \textbf{(5)}$$

$$F_C = a_2 + b_5 * t + b_6 * t^2 + b_7 * DUM_1 + b_8 * DUM_2 \qquad \textbf{(6)}$$

$$w_i = e^{(a_i + b_i * DUM_1 + b_i * DUM_2)} * BW^{b_i} \qquad \textbf{(7)}$$

Where EFP_B is equivalent farm price, body weight BW, feed cost P_F, feed delivery cost DEL, feed consumed F_C, interest cost I, number of days t necessary to grow broilers. Body weight of a chicken BW, is determined by feed consumed F_C, square of feed consumed F_C^2, and intercept shifters for protein levels, DUM_1 for 16% and DUM_2 for 24% (5). Coefficients a_1, b_1, b_2, b_3 and b_4 are determined by regression analysis, and their values depend on whether SBM or PNM is chosen as the protein source. Intercept coefficient a_1 is modified by dummy variables (DUM_1 and DUM_2) representing the level of protein in the diet. The equation is normalized on a protein level of 20%. Feed consumed F_C, is determined by time t, and intercept shifters for protein levels, DUM_1 for 16% and DUM_2 for 24% (6). Coefficients a_2, b_5, b_6, b_7 and b_8 are determined by regression analysis and their values again depend on whether SBM or PNM is chosen as protein source. Intercept coefficient a_2 is modified by dummy variables (DUM_1 and DUM_2) representing the level of protein in the diet. Equation 7 is estimated as processed weight, w_i, of each part *i* derived from a live bird (*i* = *WB* for whole carcass, *BR* for breast weight, *LQ* for leg quarter, *FP* for fat pad, *RC* for rest of chicken, *GIB* for giblets and *OFF* for offal). Sum of all processed parts, *WB* and *FP* for the whole carcass or *BR*, *LQ*, *RC* and *FP* for the cut-up carcass, and giblets, *GIB*, and offal, *OFF*, must be equal to the live weight of the bird, *BW*, which is processed. Each equation was estimated as a function of live bird weight, *BW*, and protein levels, DUM_1 and DUM_2. Coefficients for equation 7, when used to estimate whole carcass, were estimated by ordinary least squares (OLS) and their values depend on whether SBM or PNM is chosen as protein source, with coefficients a_i modified by the level of protein in the diet. Coefficients for cut-up parts were estimated by seemingly unrelated regressions (SUR), and their values likewise depend on whether SBM or PNM is chosen and are modified by the level of protein in the diet.

Other constraints were also assumed in this model in order to simulate the behavior followed by the industry in this sector. Interest cost is determined by annual interest rate and number of days spent by broilers in the house. EFP_B must equal live value of broilers delivered to plant divided by the number of birds finished per house. Live value of broilers delivered to plant – for whole carcass or for cut-up carcass -- must equal number of birds finished in the house times the sum of the value of live birds delivered to the plant and the value of dead on arrivals and field condemnations. Weighted average price of a bird processed into whole carcass (estimated *VMP* of a live bird) is the sum of the value of the carcass, value of fat pad, value of giblets, and value obtained for offal divided by bird's live weight. The value of carcass is obtained by multiplying the carcass weight by the difference of dock price for the carcass processing cost and catching and hauling cost. The remaining parts account for the value obtained for fat pad, giblets and offal. Processing cost is subtracted from three of the values, with the exception that offal does not have processing cost. Weighted average price of a bird processed into cut-up parts (*VMP*) is the sum of the values of breast, leg quarter, fat pad, rest of chicken, giblets, and value obtained for offal divided by bird's live weight. The number of birds finished in the house equals number of birds started discounted by the mortality of birds as a function of time. Livability is the percent of live birds after subtracting the rate of mortality, calculated as a function of time. Number of birds started is a function of density and size of the house. Density of birds in the house is an estimated function of live bird weight, temperature and the percentage of males in the house.

Since this is an interactive model that uses estimated regression coefficients and is executed in two stages, some variables are determined endogenously in one portion and are later used as predetermined values. Given appropriate parameters from analysis of experimental and secondary data, the model has a two-stage solution procedure for each level of protein and feed ingredient source. Global optimization is achieved by iteration of protein level and ingredient sources. In other words, in the first stage, feed must be formulated using linear programming to obtain a minimum cost at a predetermined level of protein and for a particular feed ingredient source. In the second stage, the formulated feed and cost are used to find the optimum live and processed bird weights and minimum production time that maximize profit using nonlinear programming. The global solution is ascertained after model scenarios are analyzed for all alternative protein levels and ingredient sources available.

Profit and EFP_B are determined at the farm level, because the model takes into account marketing margins as the total of processing and other costs to deliver the product to the buyer. Derived demand price is determined after discounting dock price for the marketing margins between farm and plant. Model construction may be better understood by referring to the estimated *VMP* for a live bird. For example, a point estimate of the *VMP* is equal to the output (*WB*) produced per input (*BW*) used times price per unit of output. Price per unit of output is partially determined by the demand side; that is, by the consumers and the price they are willing to pay for the final product, carcass weight. *WB* is initially a function of bird inputs, i.e., protein level and bird live weight. The transformation of input to output determines the estimated marginal physical product. Finally, *VMP* and EFP_B are determined from carcass values.

RESULTS AND DISCUSSION

Experimental Estimates of Production Coefficients

BW increases at a decreasing rate with respect to F_C for each protein source, although somewhat more rapidly with the SBM diet (Table 1). Also, as protein level shifts to 24%, *BW* value is increased by the coefficient of the dummy variable for 24% level of protein. Conversely, when protein level shifts to 16%, *BW* is decreased. All variables were significant and signs were as expected. F_C over the range of time tested, increases at an increasing rate, again somewhat more rapidly on SBM than on PNM diets. As protein level shifts to 24%, F_C decreases by the coefficient of the dummy variable for 24% protein level. However, when protein level shifts to 16%, F_C is not significantly different from the value at 20% protein level. All signs were obtained as expected for the productivity relationship. *WB* was estimated as a function of *BW* and protein levels (Table 1). The effect of protein level on *WB* was positive (not significant but perhaps important) for higher levels of protein in the PNM model, but negative and significant in the SBM when protein level changed from 20% to 24%.

Table 1. Estimated Body Weight, Feed Consumed and Carcass Weight for Broilers on Peanut Meal and Soybean Meal Protein Feeds.

	Body Weight (*BW*)		Feed Consumed (F_C)		Carcass Weight (*WB*)	
Variable	PNM	SBM	PNM	SBM	PNM	SBM
Intercept	0.0971** (2.42)	0.0448* (1.94)	-0.8868*** (-4.37)	-0.6396*** (-3.19)	-0.2147 (-0.87)	-0.0267 (-0.11)
F_C	0.6031*** (13.96)	0.6919*** (28.00)	-----	-----	-----	-----
F_C^2	-0.0209** (-2.54)	-0.0309*** (-6.60)	-----	-----	-----	-----
t	-----	-----	0.0742*** (4.83)	0.0528*** (3.48)	-----	-----
t^2	-----	-----	0.0012*** (4.58)	0.0015*** (6.14)	-----	-----
BW	-----	-----	-----	-----	0.9797*** (30.13)	0.9602*** (30.28)

DUM_1	0.1183***	0.0517***	0.0385	0.0670	-0.0144	-0.0242*
	(3.99)	(2.92)	(0.94)	(1.66)	(-1.02)	(-1.76)
DUM_2	-0.2338***	-0.2233***	-0.0921**	-0.1011**	0.0154	-0.0354**
	(-7.87)	(-12.66)	(-2.26)	(-2.50)	(1.13)	(-2.56)
R^2	.99	.99	.99	.99	.94	.73
N	36	36	36	36	72	72

Notes: Numbers in parentheses are *t*-statistics. * = significant at 0.10, ** = 0.05, and *** = 0.01.

Estimates for cut-up parts of broilers were obtained by using SUR in SAS, given that all parts of a broiler add up to a whole broiler (Table 2). All equations depended directly on body weight of the chicken. *BR* increased as the percentage of protein increased, but not significantly for PNM model at 24%. *FP* decreased as the percentage of protein increased, but not significantly at 24%. *RC* decreased as the percentage of protein increased but not significantly at 16%. All signs were as expected and PNM coefficients showed more improvement in weight of parts as protein increases than did those in SBM model.

Auxiliary data were used for the estimation of two other important functions in the model. Data on mortality and density functions were collected from a statistical annual report of broiler live production, Agri Stats (1996), that consists of information collected from approximately 116 participants of the broiler industry in the United States. Mortality function was estimated to determine the percentage of birds that eventually die as time in the production process changes. Density function was estimated to determine what is the space provided for birds in the house for given live broiler weight, average temperature of the broiler house and male percentage in the house. Estimated coefficients for density and mortality models were significant and signs were as expected. Mortality increases linearly and significantly with time, because as a unit of time passes, birds get larger and die of overcrowding or other causes. Density of birds in the house is calculated as the number of square feet per bird allocated in the house. Density decreases less rapidly with respect to body weight because as birds get larger, they need more space. Also, as temperature in the house increases, more space is needed for the birds. Density also increases with male percentage, because male birds are larger than females.

Analysis of Optimization Scenarios

The possibility of using two different protein sources, SBM and PNM, and processing a broiler into a whole carcass or into cut-up parts requires the study of alternative scenarios. Peanut meal as a protein source was used for the next analysis of different scenarios (Table 3). As protein level in the diets increased from 16% to 20% and then to 24%, the number of days necessary to grow broilers decreased in the broiler-processed-as-a-whole-carcass (BPW) scenarios and in the broiler-processed-as-cut-up-parts (BPP) scenarios. Bird weight decreased in both processing strategy scenarios and feed cost increased. The increase in feed cost is justified by the increase in percentage of protein in the feed. As protein percentage in the feed increases, more of PNM is needed in the composition of the feed and the feed becomes more expensive. Feed consumed and the feed conversion ratio decreased in both processing strategy scenarios. Equivalent farm price increased in both processing strategy scenarios because a higher level of protein produces a heavier bird, which in turn increases the derived demand prices of the whole carcass or cut-up parts (Table 3).

Profit increased in both processing strategy scenarios, reaching its maximum for PNM scenarios at 2.78 cents/bird/day in the BPP scenario using 24% protein level in the diet. This scenario also represented the highest bird weight (6.13 lbs.), highest feed consumed (11.10 lbs.), highest feed cost (10.37cents/lb.) and highest equivalent farm price (41.08 cents/lb.). The maximum profit scenario did not have the lowest feed conversion ratio (Table 3).

As the firm's strategies changed from producing BPW to producing BPP and the level of protein increased, it was observed that, at the same level of protein in the diet, the number of days necessary to grow broilers increased considerably. Bird weight also increased. Feed cost (per day) remained the same, since there was no change in the feed formulation stage. Feed consumed and feed conversion ratio increased as the strategy changed as well. Equivalent farm price reached its maximum (41.08 cents/lb) in the same scenario as maximum profit.

Soybean meal as a protein source was used for the next analysis of different scenarios (Table 3). As protein level in the diets increased from 16% to 20% and 24%, the number of days necessary to grow broilers decreased in both processing strategy scenarios. Bird weight decreased in the BPW scenarios. For BPP scenarios, bird weight increases to its maximum level (6.11 lbs.) at 20% protein level in the diet and decreases to 5.89 lbs. at 24% protein level in the diet. Feed cost increased in both processing strategy scenarios. Feed consumed (per day) and feed conversion ratio both decreased in both processing scenarios. Profit increased, reaching its maximum at 2.66 cents/bird/day and 20% protein level in the diet, and fell to 2.36 cents/bird/day at 24% protein level in the diet in the BPW scenarios. Similar behavior occurred with the results obtained from BPP scenarios, where profit peaked at 3.17 cents/bird/day at 20% protein level in the diet and then fell to 2.81 cents/bird/day at 24% protein.

Equivalent farm price increased, reaching its maximum of 38.23 cents/lb at 20% protein level in the diet and then decreased to 37.42 cents/lb at 24% protein in the BPW scenarios. In the BPP scenarios, equivalent farm price reached its maximum (42.33 cents/lb) at 20% protein level in the diet and fell to 41.15 cents/lb at 24% protein. The BPP scenario that used SBM as protein source at 20% dietary protein level represented the global maximum profit (3.17 cents/bird/day), highest bird weight (6.11 lbs), highest feed consumed (11.22 lbs.) and highest equivalent farm price (42.33 cents/lb). However, with a feed conversion ratio at 1.84 pounds of feed consumed per each pound of bird weight, this scenario was approximately the middle of the range of observed feed conversion (Table 3).

As the firm’s strategies changed from BPW to BPP and the level of protein increased, it was observed that, at the same level of protein in the diet, the number of days necessary to grow broilers increased considerably. Bird weight also increased. Feed cost is the same per day, since there is no change in the feed formulation. Feed consumed and feed conversion ratio increased as the strategy changed. Equivalent farm price also increased, reaching its maximum (42.33 cents/lb) in the same scenario as profit (Table 3).

Comparing the results obtained from the scenarios where PNM is used with the scenarios where SBM is used, the number of days necessary to grow broilers is shorter for SBM scenarios than for PNM scenarios at the same levels of protein with the exception of the BPW scenario at 24% protein level in the diet. Even though feed cost is still higher for all the SBM scenarios at the same levels of protein, profit is higher for the SBM diets when compared at the same level of protein in the diet with the exception of the BPW scenario at the protein level of 24%. The equivalent farm prices of SBM scenarios are higher in all cases, with exception of the BPW scenario at 24% protein. Feed conversion ratios and feed consumed were lower for the scenarios where SBM was used as a protein source, again with the exception of the BPW scenario at 24% protein level. Bird weight was lower in all scenarios where SBM was used as a protein source, with the exceptions of the BPW scenarios at 20% and 24% protein levels.

An isoprofit analysis compared points where peanut meal and soybean meal have equal profit for a given protein level. The scenario that uses peanut meal at 24% protein level in the diet to produce BPW and the scenario that uses SBM at 20% protein level in the diet to produce BPW represent the highest levels of profit among the scenarios that produce BPW. At re-scaled coefficients for PNM and SBM variables, it was found that equal profit (2.42 cents/bird/day) was reached at re-scaled coefficients for a 23.25% protein level. For the same level of profit, more time (36.84 days) was required for using SBM as protein source than when using PNM (33.96 days) to grow a larger bird (4.52 lbs. for SBM versus 3.98 lbs. for PNM) using more feed (10.41 lbs. for SBM versus 10.18 lbs. for PNM). Feed cost was higher for the soybean meal scenario than for the peanut meal scenario (10.41cents/lb for SBM versus 10.18 cents/lb for PNM), but the feed conversion ratio was higher for the SBM scenario as well (1.63 lb of feed/lb of broiler for SBM versus 1.59 lb of feed/lb of broiler for PNM).

CONCLUSIONS

The value of marginal product concept that was applied in this model indicated that as price of carcass or cut-up parts changed, time, final live weight of a broiler, feed consumed and other variables in the model varied to make the adjustments necessary to determine the maximum profit production process. The results obtained from experiments and from mathematical programming showed that soybean meal is generally more efficient and profitable than peanut meal, especially at lower dietary protein levels. Peanut meal was more profitable than soybean meal only when higher levels of protein were fed to broilers processed into whole carcass. The analysis for isoprofit showed that a level of protein can be found which allows profit to be equal for peanut meal and soybean meal scenarios.

Results of the analysis of experimental data showed that soybean meal productivity decreases earlier than does the productivity of peanut meal as higher levels of protein are fed to the broilers. The experiments were conducted with levels of 16%, 20% and 24% of protein only, and the statistical analysis showed that when protein level changed from 20% to 24%, productivity of soybean meal decreased, while the productivity of peanut meal was still increasing. This result indicates that further analysis may be necessary to determine the level at which peanut meal protein productivity will decline.

Analysis of weekly prices of carcass and of cut-up parts for the last seven years determined the seasonal pattern that prices follow, which could enhance the usefulness of the profit model. That is, feeding rations, production periods, and processing as whole or parts could be altered seasonally to adopt the most profitable production and processing combinations during each time period. Although peanut meal may not be competitive with soybean meal at some prices, it still may behoove the producer and/or processor to alter feeding regimes with soybean meal (e.g., protein level, days on feed) or processing whole vs. parts to take advantage of seasonality in pricing. Also, this broiler profit maximization model determines the maximum economic profit with respect to resources that are used and have variable costs. A long-run model in which all resources are variable may provide further useful implications to the industry for alternative feed programs.

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Table 2. Estimated Effects of Live Weight and Protein Levels on Weights of Cut-up Parts of a Broiler.

	Peanut Meal-Based Diets	Soybean Meal-Based Diets
Variable	Coefficients	Coefficients
Intercept:		
Breast	-3.0381***	-2.8578***
	(-6.33)	(-7.10)
Leg Quarter	-0.8380**	-0.5198
	(-2.49)	(-1.56)
Fat Pad	-4.3753**	-5.3969***
	(-2.55)	(-3.48)
Rest of Chicken	-0.8470***	-0.4654*
	(-3.16)	(-1.78)
Breast	1.1609***	1.1499***
	(18.43)	(21.75)
Dummy variable, 16% protein	-0.0450*	-0.1113***
	(-1.70)	(-5.06)
Dummy variable, 24% protein	0.0328	0.0380*
	(1.28)	(-1.72)
Leg Quarter	0.9078***	0.8681***
	(20.46)	(19.88)
Fat Pad	1.0578***	1.1491***
	(4.70)	(5.63)
Dummy variable, 16% protein	0.2262**	0.5548***
	(2.34)	(6.54)
Dummy variable, 24% protein	-0.1160	-0.1315
	(-1.24)	(-1.54)
Rest of Chicken	0.9589***	0.9106***
	(27.15)	(26.54)
Dummy variable, 16% protein	-----	0.0117
		(0.93)

Dummy variable, 24% protein	-----	-0.0388***
		(-3.05)
R^2	.87, .86, .27 and .91	.89, .85, .54 and .91
No. Observations	72	72

Notes: Numbers in parentheses are *t*-statistics. Single, double and triple asterisks (*) denote statistical significance of the parameter at 0.10, 0.05, and 0.01, respectively.

Table 3. Scenarios Used to Analyze Profitability in the Production of Broilers.

		Peanut Meal						Soybean Meal					
		Whole Carcass			Cut-up Parts			Whole Carcass			Cut-up Parts		
		Protein Level			Protein Level			Protein Level			Protein Level		
Variable	Unit	16%	20%	24%	16%	20%	24%	16%	20%	24%	16%	20%	24%
Time (*t*)	days	46.76	39.18	32.37	54.10	49.76	46.87	42.42	38.56	36.41	47.89	46.07	44.62
Bird weight (*BW*)	lb	5.32	4.64	3.76	6.43	6.33	6.13	5.14	4.82	4.45	6.04	6.11	5.89
Feed cost (P_F)	cents/lb	8.33	9.35	10.37	8.33	9.35	10.37	8.34	9.47	10.62	8.34	9.47	10.62
Delivery cost (*DEL*)	cents/lb	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49
Feed consumed (F_C)	lb/bird	11.45	8.41	5.76	14.57	12.57	11.10	9.83	8.16	7.19	12.16	11.22	10.43
Feed conversion ratio	-----	2.15	1.81	1.53	2.26	1.99	1.81	1.91	1.69	1.62	2.02	1.84	1.77
Profit (Π)	cents/bird/day	1.96	2.27	2.46	2.17	2.57	<u>2.78</u>	2.48	2.66	2.36	2.73	<u>3.17</u>	2.81
Equivalent farm price (EFP_B)	cents/lb	36.35	37.07	37.97	38.39	39.87	41.08	37.50	38.23	37.42	39.63	42.33	41.15

Note: Underline indicates maximum profit level.