TITLE: Precision Feeding in Dairy Ration Cost Minimization Under Producer's Risk Management

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Conference name, place, and date:

Selected Paper prepared for presentation at the
Southern Agricultural Economics Association Annual Meetings
Mobile, Alabama, February 4-7, 2007

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Introduction

Dairy farming in the United States (US) is faced, among other things, with economic and environmental challenges. The costs of most production inputs continue to increase while milk prices have remained stable or declined for many years, (Rotz et al., 1999). Phosphorus (P) and nitrogen (N) are major pollutants of concern which are normally brought into the farm as feed supplements and fertilizers. If excess manure is excreted, N can leach into ground water and P can build up in the soil and contaminate the surface water, harming the environment.

One of the primary tasks of a dairy producer is to make decisions based on the goals and missions of the farm with the ultimate objective of profit maximization. There are some occurring events that impact these goals which may introduce a great deal of uncertainty into the farm business. These uncertainties will affect farmers differently depending on their behavior toward risks. While there are various risk management strategies available to dairy producers, managing feed ingredient nutrient and price variability in the selection of minimum cost feed rations can be used as one of the tools in managing income risk.

Feeding excessive amounts of a nutrient may decrease the efficiency of nutrient utilization resulting in increased costs as well as nutrient excretions that may degrade the environment. While similar studies on ration cost minimization have been done, this study has further included the effect of nutrient variability on the choice of optimal feed ration and made comparison between whole herd and precision feeding. The specific objectives are to: (1) compare and analyze whole herd against precision feeding on ration cost minimization under producer's risk behavior, (2) analyze the impact of the feed nutrient and ingredient price risk on the choice of optimal feed ration, and (3) compare and contrast nitrogen and phosphorus excretions in whole herd and precision feeding practices.

Background

Individuals normally base risky decisions on the expected utility received from the outcomes rather than on the expected value of outcomes (Bernoulli, 1954). According to expected utility hypothesis, utility maximization is a rational decision when faced with risky choices (von Neumann and Morgenstern, 1947). In this scenario, alternatives are evaluated on the expected value and probability of each alternative occurring. The risk aversion decision makers, the most common situation, actually maximize utility by reducing the variability surrounding the expected value of an outcome. They are then willing to pay extra or forgo some amount of expected income to manage the risk associated with available choices.

The traditional linear programming (LP) models normally minimize cost feed ration on the assumptions that all feed ingredient prices and nutrient levels are known with certainty. Nicholson et al. (1994) used an LP model to compare nutritional management strategies for dual-purpose herds. While LP has been used extensively, especially in farm management and production economic studies (Anderson, Dillon, and Hardaker, 1997; Beneke and Winterboer, 1990), it has a limitation of the absence of risk or uncertainty from the modeling. Feeding the animals for the entire period will normally require multiple purchases of the feed ingredients, depending on the size of a farm and its feed storage capacity. Therefore, a farm manager will be generally faced with variability in the nutritional composition of feedstuffs from one purchase to the next. Similarly, in the absence of any market risk management, feed ingredient prices will also be vulnerable to fluctuations. In this scenario, the ration might not be optimal to a risk averse producer who is faced with nutrient and price fluctuations. An ideal model to use for optimal feed ration in this case is a non-linear programming (NLP) model that considers both feed ingredient nutrient and price variability.

Various studies in agricultural economics have incorporated expected value variance (E-V) analysis in mathematical programming model for feed cost minimization subject to producer's risk behavior (Boisvert and McCarl, 1990; Coffey, 2001; Dillon, 1999; Dillon, 1992). According to Von Neumann and Morgenstern (1947), E-V analysis is considered to be consistent with expected utility theory if any of the following scenarios ensue: (1) the cumulative density function of the random variables differs only by location and scale (Meyer, 1987), (2) the situation in which income distribution is normal (Freund, 1956), and (3) the utility can be estimated by a quadratic function (Markowitz, 1959).

While cattle excretions contain many nutrients, nitrogen and phosphorus excretions are of great concern in this study. About 20 to 25% of P in dairy diets is in excess of the National Research Council (NRC, 2001) suggested requirement. Livestock, in general, excrete about 60 – 80% of consumed P (Knowlton, 2004), an indication that a larger portion of P is excreted on the farm. Out of the excess N in feed, fertilizer, and N fixation in legumes combined which is about 62 to 79%, imported feed produces about 62 to 87% N (Klausner, 1993).

Weather and environmental conditions may induce behavioral and metabolic changes in cattle which may influence performance directly (West, 1994). National Research Council (1981) indicated that mild to severe heat stress will increase net energy requirements for maintenance by 7 to 25 percent, respectively. Young (1976) observed that for each 10^{o}C reduction in ambient temperature below 20 ^{o}C, there is an average reduction of 1.8% in dry matter digestibility. National Research Council (2001) indicated that the effect of low temperature on digestibility may cause feed energy values to be lower than expected.

Method and Materials:

The Cornell Net Carbohydrate and Protein System (CNCPS) software version 5.0 and non-linear programming model incorporating E-V framework and Merrill's approach were used to model a hypothetical dairy farm of 100 head of Holstein lactating cattle (Table 1) in the selection of minimum-cost ration under producer's risk behavior.

Table 1. Herd description

Group	Number of head	Age (months)	Days preg.	Days in milk	Lact. number	Milk (lb day^{-1})	Fat %	Protein %	Ave. weight (lb)	Body condition score
Fresh cows	22	50	70	120	2	76.7	4.5	3.0	1301	2.5
Ist-calf heifer	21	36	150	195	1	71.7	3.5	3.2	1257	3.0
High cows	47	60	123	183	3	83.1	3.5	3.0	1499	2.9
Low cows	10	60	157	220	2	50.7	4.2	3.3	1609	3.6
Average/ total	100					70.5	3.9	3.13		

The CNCPS model has been widely applied in the evaluation of herd feeding programs for dairy cattle (Dinn et al., 1998; Fox et al., 1995). In their study of integration of cattle and crop production on a dairy farm using CNCPS model, Tylutki and Fox (2000) found that profit improved with environmental benefits of reducing erosion and phosphorus loading.

In this study the following operations were carried out:

1) The CNCPS software was used to address nutrient contents and requirements of each feed ingredient (corn silage, alfalfa hay, alfalfa silage, wheat middlings, corn gluten feed, canola meal, whole cottonseed, soybean meal, limestone/minerals, and distillers dry grain) for the whole herd from the base feeding program. The simulation also predicted manure, P and N excretions.
2) In this second scenario, the nutrient requirements of each feed ingredient - dry matter intake (DMI), metabolizable energy (ME), metabolizable protein (MP), physically effective neutral detergent fiber (peNDF), calcium (Ca), and phosphorus (P) - simulated from the base line feed ingredient ration (step 1 above) were used as coefficients in non-linear programming model to estimate the minimum-cost ration and other economic indicators for whole herd feeding.
3) In this third feeding management practice, seasonal effect (summer, fall, winter, spring) accommodating weather and environmental changes were put into play. The animals were fed by type according to their characteristics (Table 1). The CNCPS simulation used the same feed ingredients as 1 above to incorporate these seasonal changes in generating nutrient contents and requirements (DMI, ME, MP, peNDF, Ca, and P) of each feed ingredient according to animal type. These

feed values for each season were then used as coefficients in non-linear programming model to arrive at minimum-cost ration and other economic indicators for precision feeding group.

The biophysical simulation data from CNCPS as well as economic data were used in non-linear programming model in minimizing diet cost subject to animal requirements under producer's risk behavior due to nutrient and price variations. It was assumed that: (i) the herd is in a steady-state condition, (ii) the rations being fed are representative of the whole period in question, (iii) there were no losses of feeds during storage and feeding. The feedstuff prices, based on monthly prices of individual feed ingredients, were obtained from historic price series in Kentucky and neighboring states collected by United State Department of Agriculture from 1999 to 2005. Vitamin/limestone was less than 1% of the feed ration expenses and therefore its cost was ignored in this paper. The feed ration compositions as well as the choice of optimum ration in each risk level was determined and analyzed for each group of animals. Management practices, feed ration, feed price, and feed values were used as decision variables. The constraints were based on animal requirements and relevant accounting equations.

For maximum microbial yield, corn silage, alfalfa hay and alfalfa silage were entered in each diet formulation in order to produce peNDF higher than 20%. The least-cost rations obtained in 2 and 3 above were re-evaluated using CNCPS software to generate manure, N and P excretions. The ration cost and nutrient excretions in the three feeding management programs were analyzed and compared.

Model specification

Given a producer facing uncertain feed ingredient nutrients and prices, the traditional minimum cost feed ration model was expanded to accommodate E-V analysis and Merrill's approach in the selection of optimal feed ration for a dairy farm. The following mathematical model minimized the risk-adjusted mean total feed ration cost per head per day in pounds.

$$\min \overline{DC} + \Phi \sum_t \left(\frac{1}{T-1}\right)\left(DC_t - \overline{DC}\right)^2 \quad (1)$$

$$\sum_t \frac{1}{T} DC_t - \overline{DC} = 0$$

$$\sum_j p_{j,t} F_j - DC_t = 0, \ \forall t$$

$$\sum_j n_{i,j} F_j - \Psi\left(\sum F_j^2 \sigma_{i,j}^2\right)^{1/2} \geq LL_i, \ \forall i$$

$$F_j \geq 0, \ \forall j$$

Where the subscript: j = the jth feed ingredient; i = the ith nutrient; t = the tth time period (in months).

T = total time periods in months; F = feed ingredient. $\overline{DC}$ is the mean total diet ration cost over T time periods. The time period t is in months with a total of 72 (T) months. DC_t is the total ration cost at tth period. $P_{j,t}$ denotes the price of jth feed ingredient at tth period and F_j is a non-negative amount of the jth feed. LL_i is the lower limit requirements for the ith nutrient in the total diet ration. Φ is the value of the risk-aversion parameter in which its use must be known in advance. However, this limitation was relaxed by using the following technique suggested by McCarl and Bessler (1989) when the utility function is unknown:

$$\Phi = 2Z_\alpha / S_y, \quad (2)$$

where Φ is as defined above, Z_α is the standardized normal Z value of α level of significance and S_y is the relevant standard deviation from the risk-neutral scenario. The risk aversion levels were represented as risk-neutral, low, medium, and high risk.

Results and Discussion

Two management feeding practices under producer's risk behavior were evaluated in this study. The whole herd feeding program where the cows were uniformly fed the ration throughout the year irrespective of their characteristics. The second program was the precision feeding where the cattle were fed by type (e.g., milk production, age, and weight) and according to seasonal changes (fall, winter, spring, summer) in relation to feed requirements. The optimal ration for whole herd was chosen for various levels of aversion to nutrient and price risk while that of precision feeding group was evaluated only for levels of price risk aversion.

For the whole herd group, varying levels of aversion to nutrient variability (Ψ) represented significance levels of 0.50 (risk neutral), 0.60 (low aversion), 0.70 (medium aversion), and 0.80 (high aversion) in order to realize at least the required amount of nutrients 50%, 60%, 70%, and 80% of the time (Table 2). Assuming no aversion to nutrient or price risk, the minimum cost ration entered eight out of the twelve available ingredients (See Table 2). As aversion to nutrient risk was increased subsequently from neutral to higher levels, holding price risk at neutral level, the model response was to increase alfalfa hay and distillers dried grain while decreasing alfalfa silage and soybean meal (Table 2). The amounts of ingredients for each ration corresponding to each risk averse level were variable. Wheat middlings (WHMid) and corn gluten feed (CGF) entered the ration only at neutral risk aversion level.

Table 2. Ration composition (lbs/day/cow dry matter) with nutrient variability risk (Whole herd feeding)

Type of Animal	Ingredients[1]	Risk aversion levels (%)			
		50	60	70	80
Whole herd feeding	CSI	18.00	18.00	18.00	16.87
	AHY	8.00	9.18	12.24	15.93
	ASI	14.80	13.62	10.56	8.00
	WHMid	0.37			
	CGF	1.53			
	WCSD	6.23	6.94	3.39	7.97
	SBM	5.57	5.19	3.24	2.55
	DDG		2.04	3.17	3.18
Total		54.50	54.50	54.50	54.50
CV[a]		10.38	10.13	9.35	8.79
Cost price ($)		1.87	1.90	1.94	2.05

[1]CSI: corn silage; AHY: alfalfa hay; ASI: alfalfa silage; WHMid: wheat middling; CGF: corn gluten feed; WCSD: whole cottonseed; SBM: soybean meal; DDG: distillers dried grain.
[a]CV = coefficient of variation expressed as percentage of standard deviation over the mean

The substitution of ingredients is a way of increasing the probability of meeting the nutrient requirements resulting in the total ration with less volatile amount of nutrients in terms of coefficient of variation. The nutrient risk aversion was negatively related to coefficient of variation (Table 2). However, this increase in probability of realizing the nutrient requirements comes at a cost per head per day. For example, as nutrient risk aversion increases from neutral to high risk level, the cost of managing the nutrient variability is $0.18 per head per day. This tradeoff between the probability of realizing the required nutrients and the increased ration cost at a higher risk levels is presented as a frontier of nutrient risk efficient points (Figure 1). Choosing among rations located on this frontier would require a risk averse producer to compare the risk management benefits to the cost of achieving it.

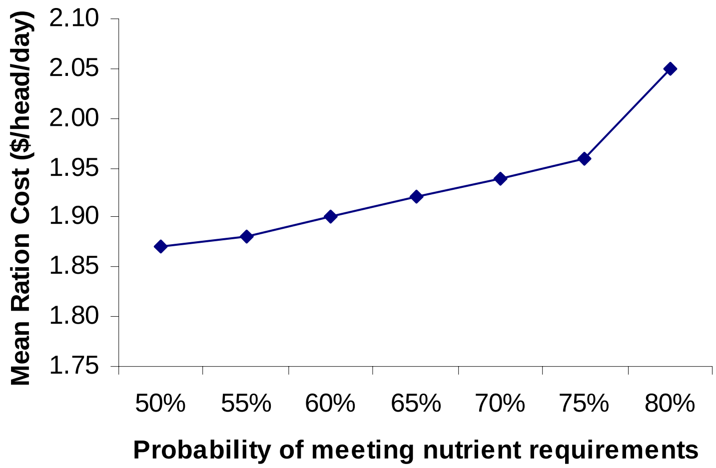

Figure 1. Mean probability frontier of nutrient risk efficient choices

The aversion to price risk was introduced to both whole herd and precision feeding practices under nutrient risk neutrality. The models look to substitute among available feed ingredients to arrive at an optimal feed ration. Significant levels of 0.50 (risk neutral), 0.60 (low), 0.70 (medium), and 0.80 (high) represent the levels of price risk aversion to realize the same or lower feed costs 50%, 60%, 70%, and 80% of the time respectively (Table 3). For whole herd feeding practice (Table 3), corn silage (CSI), the most inexpensive ingredient having a low standard deviation (Table 4), was entered the same amount in all reported price risk aversion levels. As price risk aversion levels increase, alfalfa hay (AHY), WHMid, and CGF increased while alfalfa silage (ASI), whole cottonseed (WCSD), and soybean meal (SBM) decreased (Table 3). This substitution of feed ingredients is an indication of increasing the probability of meeting the minimum cost feed with less volatility of prices in terms of coefficient of variation. As price risk increases, the coefficient of variation decreases while the mean cost increases, an indication that the price risk management comes at a cost (Table 3).

Table 3. Ration composition (lbs/day/cow dry matter) with price variability risk (Whole herd feeding)

Type of Animal	Ingredients[1]	Risk aversion levels (%)			
		50	60	70	80
Whole herd	CSI	18.00	18.00	18.00	18.00
	AHY	8.00	9.12	14.80	14.80
	ASI	14.80	13.68	8.00	8.00
	WHMid	0.37	0.94	3.86	3.86
	CGF	1.53	1.54	1.55	1.55
	WCSD	6.23	6.04	5.06	5.06
	SBM	5.57	5.19	3.24	3.24
Total		54.50	54.50	54.50	54.50
CV[1]		10.38	9.99	8.26	8.26
Cost price ($)		1.87	1.88	1.93	1.93

[1]CSI: corn silage; AHY: alfalfa hay; ASI: alfalfa silage; WHMid: wheat middling; CGF: corn gluten feed; WCSD: whole cottonseed; SBM: soybean meal.
[a]CV = coefficient of variation expressed as percentage of standard deviation over the mean

Table 4. Descriptive analysis of feed ingredient prices

Ingredient	Mean ($/ton)	Std. deviation ($/ton)	Maximum ($/ton)	Minimum ($/ton)	CV[a] (%)
Corn silage	20.92	2.81	28.98	16.72	13.44
Alfalfa hay	106.33	8.08	125.00	90.00	7.58
Alfalfa silage	35.09	2.66	41.25	29.70	7.58
Wheat middling	64.46	11.11	91.46	43.53	17.23
Corn gluten feed	67.35	10.79	102.65	49.30	16.02
Whole cottonseed	124.02	25.40	181.33	80.40	20.47
Soybean meal	197.79	36.08	316.91	160.41	18.24
Canola meal	162.81	20.72	216.34	128.75	12.73
Distillers dry grain	86.20	15.29	129.05	69.19	17.74

[a]CV = coefficient of variation expressed as percentage of standard deviation over the mean

With reference to precision feeding group, the compositions of all optimal rations evaluated for each type of animal in different seasons are displayed in Tables 5 and 6. The choice and amount of ingredients in different seasons are mixed when risk aversion parameters were varied. From the eleven available ingredients, some are only suitable under certain conditions and some definitely present a need for price risk management. Corn silage, alfalfa hay and alfalfa silage were entered in all groups of animals across the board for the reasons mentioned earlier. Corn silage and alfalfa silage had the lowest mean prices of all ingredients (Table 4). The CGF was entered in all rations under both risk aversion levels (Table 5 and 6). The WCSD and canola meal that did not enter in any ration in all seasons are among the most expensive ingredients.

Table 5**.** Feedstuff composition (lbs/day dry matter) with risk aversion parameter = 0.00 (risk-neutral)

Type of animal	Ingredients[1]	Fall	Winter	Spring	Summer
Fresh cow	CSI	18.00	18.00	18.00	18.00
	AHY	8.00	8.00	8.00	8.00
	ASI	11.08	11.08	11.08	11.08
	WHMid	0.97	2.96		1.22
	CGF	7.95	10.50	10.50	10.50
	MV	0.69			
	DDG	7.00	3.53	5.67	4.79
	LMSTN	0.20		0.20	
Total		53.89	54.07	53.45	53.59
High cows	CSI	17.99	18.00	18.00	18.00
	AHY	8.00	9.28	10.69	8.00
	ASI	16.11	15.44	14.03	16.72
	WHMid			1.52	1.74
	CGF	10.50	9.81	10.50	10.50
	MV		1.01		1.01
	DDG	7.00	7.00	5.07	5.46
	LMSTN	0.20	0.20		
Total		59.80	60.74	59.81	61.43
1st calf heifers	CSI	15.91	15.90	15.90	15.90
	AHY	11.97	10.68	9.27	11.98
	ASI	8.00	9.30	10.71	8.00
	WHMid	1.99		1.44	
	CGF	10.50	8.26	7.57	7.56
	SBM	1.76	1.76	1.76	1.76
	DDG	3.25	6.72	6.51	7.00
Total		53.38	52.62	53.16	52.20
Low cows	CSI	18.00	18.00	18.00	18.00
	AHY	8.00	8.00	8.00	8.00
	ASI	19.96	19.36	19.36	19.32
	CGF	1.89	2.27	2.27	2.28
	MV	1.01	0.57		
	LMSTN		0.20		
Total		48.86	48.40	47.63	47.6

[1]CSI: corn silage; AHY: alfalfa hay; ASI: alfalfa silage; WHMid: wheat middling; CGF: corn gluten feed; MV: minerals/vitamins; SBM: soybean meal; DDG: distillers dried grain; LMSTN: limestone

The significance levels of 0.50 (neutral) and 0.999 (high risk) reported in precision feeding group in this study (Tables 5 and 6) represent levels of price risk aversion for a decision maker to have a probability of realizing the same or lower feed costs 50% and 99.9% of the time respectively. It is worthwhile to note that managing for price risk variability generally increases the mean cost while decreasing the coefficient of variation of the ration cost (Table 7). This means accepting higher expenses for the sake of less variable feed expenses, a penalty for a producer to manage income risk with the selection of minimum cost ration. Therefore, achieving a given variance of feed cost and making a decision of selecting an optimum ration comes at a cost per head per day. Therefore, the substitution of feed ingredients with less price variability is a way of managing price risk associated with the feed ration to minimize cost.

Table 6**.** Feedstuff composition (lbs/day dry matter) with high risk aversion parameter (99.9%)

Type of animal	Ingredients[1]	Fall	Winter	Spring	Summer
Fresh cow	CSI	17.94	18.00	18.00	18.00
	AHY	8.00	8.00	8.00	8.00
	ASI	11.14	11.08	11.08	11.08
	WHMid	6.82	3.30		3.58
	CGF	7.71	10.01	10.50	10.50
	MV	0.81			
	DDG	2.94	3.67	5.67	3.08
	LMSTN	0.20		0.20	
Total		55.56	54.06	53.45	54.24
High cows	CSI	18.00	18.00	18.00	18.00
	AHY	8.00	8.00	9.13	8.00
	ASI	16.72	16.72	15.59	16.70
	WHMid		5.17	8.47	5.48
	CGF	10.50	10.50	10.50	10.50
	MV		1.01		
	DDG	6.72	2.08	0.36	2.76
	LMSTN	0.20	0.20		
Total		60.14	61.68	62.05	61.44
1st calf heifers	CSI	15.96	15.90	15.90	15.90
	AHY	11.75	11.97	10.84	11.98
	ASI	8.00	8.01	9.14	8.00
	WHMid	2.24	0.59	0.59	
	CGF	10.50	8.05	7.55	7.56
	SBM	1.76	1.76	1.76	1.76
	DDG	3.18	6.20	6.82	7.00
Total		53.39	52.48	52.60	52.20
Low cows	CSI	18.00	18.00	18.00	18.00
	AHY	8.00	8.00	8.00	8.00
	ASI	19.96	19.36	19.36	19.36
	CGF	2.11	2.27	2.27	2.26
	MV	1.01	0.57		
	LMSTN		0.20		
Total		49.01	48.40	47.63	47.62

[1]CSI: corn silage; AHY: alfalfa hay; ASI: alfalfa silage; WHMid: wheat middling; CGF: corn gluten feed; MV: minerals/vitamins; SBM: soybean meal; DDG: distillers dried grain; LMSTN: limestone

Among the three feeding management practices, base line feeding scenario (i.e. original feeding program) had the highest meant cost at US$ 2.40 per head per day.

Precision feeding indicated to have the lowest mean cost per head per day (Tables 3 and 7). Therefore, an opportunity exists for a producer to save more by practicing precision feeding in terms of ration cost.

In terms of ration costs, as price risk increases the mean costs increased slightly while the CV decreased in both whole herd and precision feeding (table 3 and 7). Indication of higher mean costs in producer's high risk aversion attitude is a measure of penalty to manage feed rations that are more variable in terms of feed ration cost. As attitude towards risk increases, a producer pays a penalty while CV is reduced as a way of managing risk.

Table 7. Economic indicators ($/cow/day)

SEASONS	Risk-aversion (%)	Mean	Minimum	Maximum	Std. deviation	CV[1]
Whole herd feeding	50	1.87	1.60	2.42	0.19	10.38
	99.9	1.93	1.67	2.33	0.16	8.26
Precision feeding	50	1.41	1.21	1.71	0.43	7.62
	99.9	1.42	1.22	1.69	0.43	7.50

[1]CV = coefficient of variation

In terms of manure excretions, original whole herd feeding had the highest total manure output including fecal and urine (figure 2). While optimized seasonal (precision) feeding indicated to load higher total and fecal manure than optimized whole herd feeding, it had the lowest urine excretion. Therefore, the model showed to have the potential in reducing manure excretions, thus reduction in environmental pollution.

The nitrogen and phosphorus balances produced under original whole herd feeding practice were the highest of all (figure 3). The optimized whole herd feeding was higher in nitrogen but lower in phosphorus loading than optimized seasonal (precision) feeding. This shows that the model has the potential in minimizing feed cost ration while improving environmental conditions of a dairy farm.

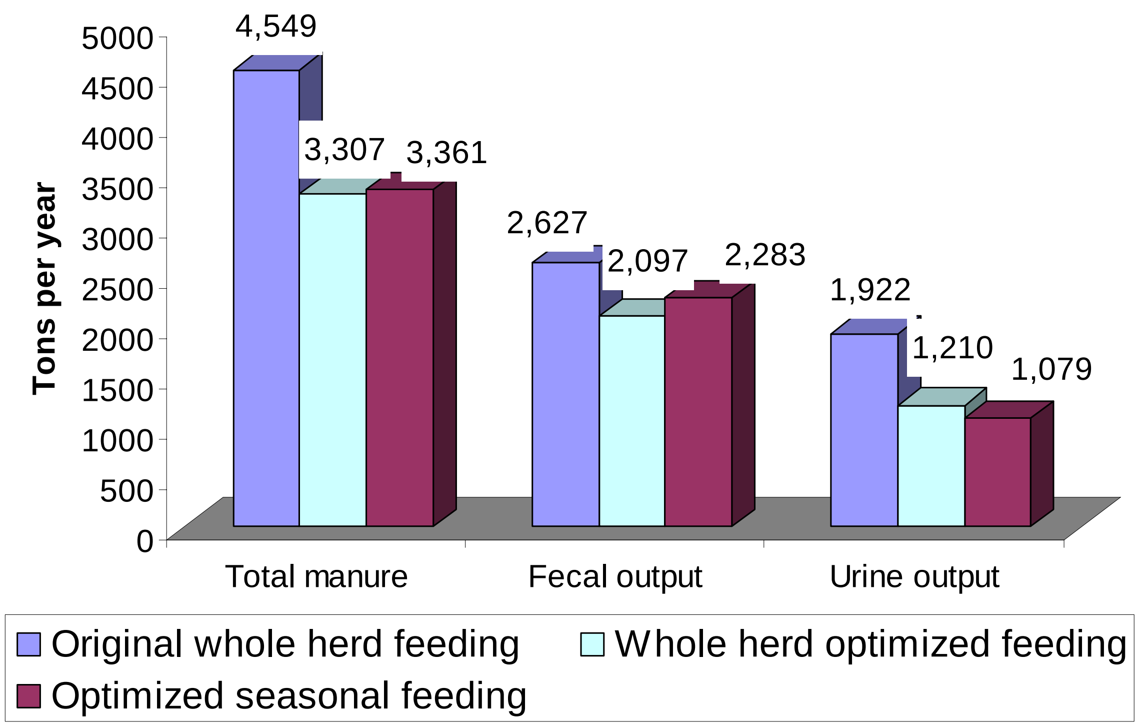

Figure 2. Predicted manure excretions

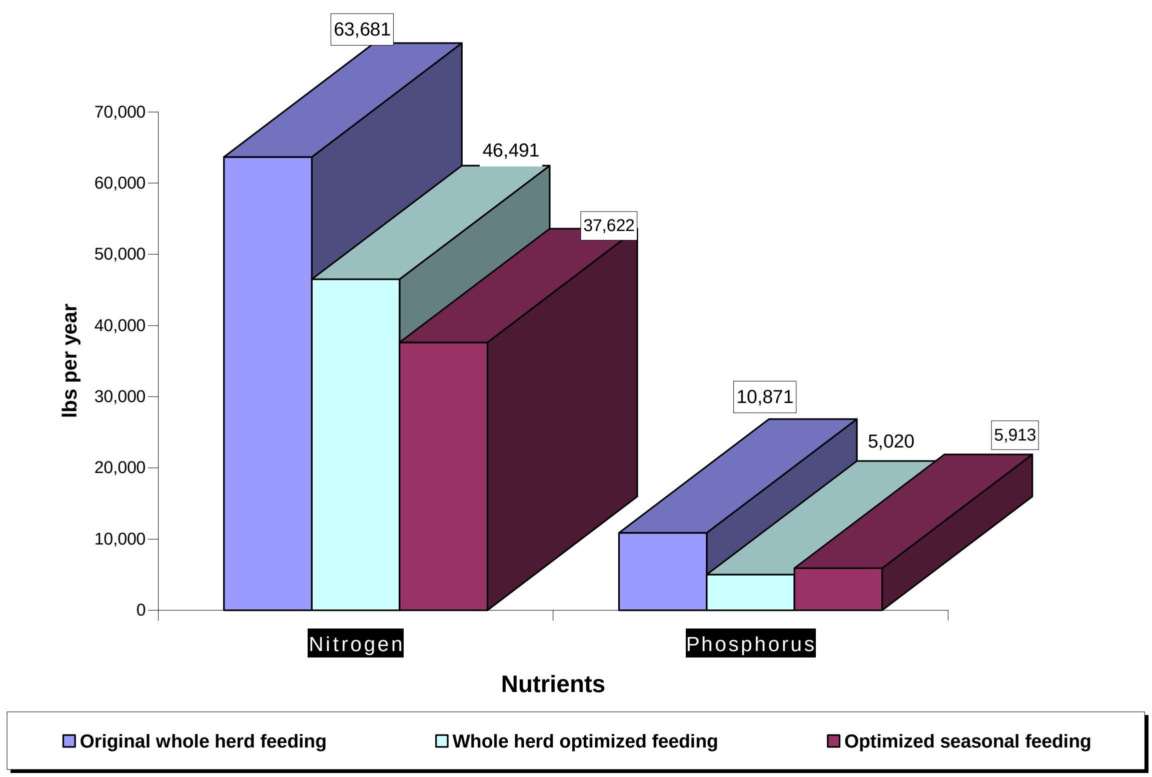

Figure 3. Predicted nutrient excretions

Original whole herd feeding has the least efficiency of nutrient utilization of all (figure 4). Optimized seasonal (precision) feeding was more efficient in nitrogen use but less efficient in phosphorus utilization than optimized whole herd feeding.

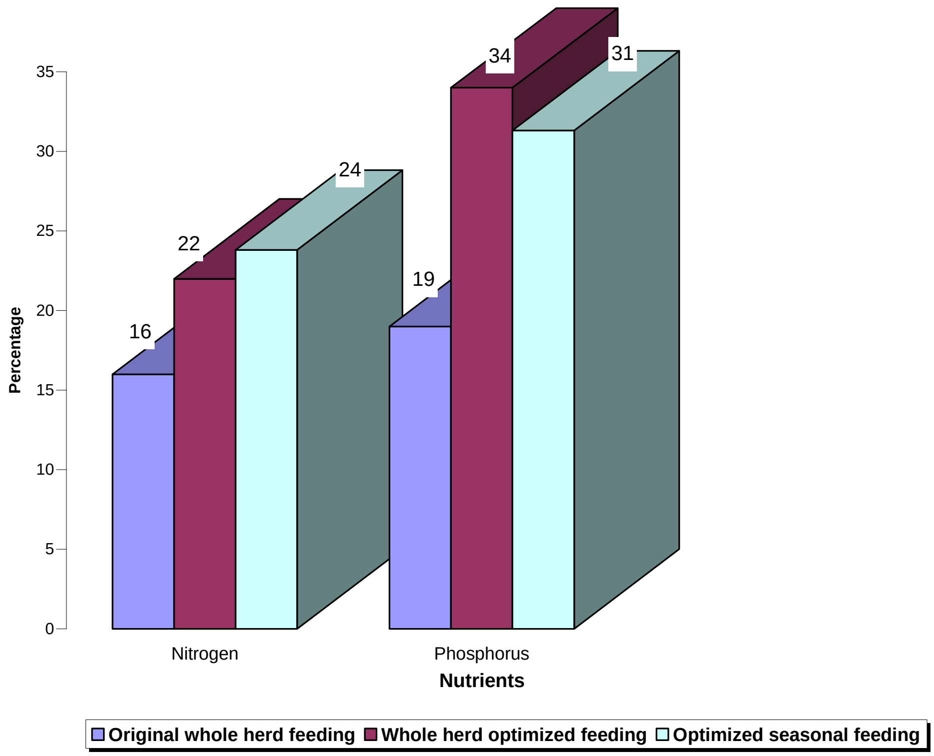

Figure 4. Efficiency of nutrient use

Summary and Conclusion

This study has the objective of comparing and contrasting whole herd against precision feeding on ration cost minimization under producer's risk behavior while managing environmental pollution. The impact of the feed ingredient nutrient and price variability on the choice of optimal feed ration was analyzed. Similarly, phosphorus and nitrogen loadings were compared in all management practices. The CNCPS was used to address nutrient values in each feed ingredient and requirements for each animal per day. The study used non-linear programming model that incorporated E-V framework and

Merrill's approach to arrive at minimum-cost ration under producer's risk behavior due to ingredient nutrient and price variability. The optimal ration for whole herd feeding was chosen for various levels of aversion to nutrient and price risk while that of precision feeding group was evaluated only for levels of price risk variability.

The overall results indicated that the model can be used to identify minimum feed cost rations while reducing environmental pollution due to nitrogen and phosphorus under decision maker's risk behavior. There was a substitution among available feed ingredients to arrive at an optimal feed ration as risk levels were varied. This is an indication of increasing the probability of meeting the nutrient requirements with less volatile amount of nutrients in terms of coefficient of variation. As price risk increases, the coefficient of variation decreases while the mean cost increases, an indication that the price risk management comes at a cost. Therefore, the substitution of feed ingredients with less price variability is a way of managing price risk associated with the feed ration to minimize cost. The model showed to have the potential in reducing excretions, thus reduction in environmental pollution.

An opportunity exists for a producer to save more by practicing precision feeding in terms of ration cost. The alternative strategies indicate considerable potential to reduce mass nutrient balance on diary farms without adversely affecting milk production. The model illustrates how decision makers with different attitude toward risk would allocate different feed rations. While price and nutrient risk were managed independently, it would be worthwhile to further investigate both simultaneously. It would be ideal to examine the effect of managing price risk on nutrient variability and vice versa.

References

Anderson, J. R., J. L. Dillon, and J. B. Hardaker. *Agricultural Decision analysis*. Ames, Iowa: Iowa State University Press. 1997.

Bernoulli, D. *Secimen Theotriae Novae de Mensura Sortis (Exposition of a New Theory on the Measurement of Risk).* Papers of the Imperial academy of sciences in Petersburg. In: Sommer, L (ed.), *Econometrica,* 22(1954):167-179.

Boisvert, R. N., and B. A. McCarl. "Agricultural risk modeling using mathematical programming." *Southern Cooperative Series Bulletin 356*. Cornell University Agricultural Experiment Station. 1990.

Coffey, B .K. "An analysis of the effects of feed ingredient price risk on the selection of the minimum cost backgrounding feed rations." *Journal of Agricultural and Applied Economics*, 33(2)(2001):353-365.

Dillon, C. R. "Microeconomic effects of reduced yield variability cultivars of soybeans and wheat." *Southern Journal of Agricultural Economics*, 24(1)(1992): 121-133.

Dillon, C. R. "Production practice alternatives for income and suitable field day risk management." *Journal of Agricultural and Applied Economics*, 231(2)(1999): 247-261.

Dinn, N. E., J. A. Shelford, and L. G. Fisher. "Use of the Cornell Net Carbohydrate and Protein System and rumen protected and rumen-protected lysine and methionine to reduce nitrogen excretion from lactating dairy cows." *J. Dairy Sci.* 81(1998):229-237.

Fox, D. G., M. C. Barry, R. E. Pitt, D. K. Roseler, and W. C Stone. "Application of the Cornell Net Carbohydrate and protein model for cattle consuming forage." *J. Anim. Sci*. 73(1995):267-277.

Freund, R. "The introduction of risk into a programming model." *Econometrica,* 21(1956):253-263.

Klausner, S.D. "Mass nutrient balances on dairy farms." In: *1993 proceedings of the Cornell Nutrition Conference for Feed Manufacturers.* Cornell University, Ithaca, New York, USA, pp. 126-129, 1993.

Knowlton, K. F., J. S. Radcliffe, C. L. Novak, and D. A. Emmerson. "Animal management to reduce phosphorus losses to the environment." *Journal of Animal Science,* 82(2004):E173-E195.

Markowitz, H. M. *Portfolio selection: Efficient diversification of investments*. New York: John Wiley and Sons, Inc. 1959.

McCarl, B. A. and D. Bessler. "Estimating an upper bound on the Pratt Aversion Coefficient when the utility function is unknown." *Australian Journal of Agricultural Economics*, 33(1989):56-63.

Meyer, J. "Two-Moment Decision Models and Expected Utility Maximization." *American Economic Review.* 77(1987): 421-430.

National Research Council. *Effect of environment on nutrient requirements of domestic animals*. Washington, D.C.: National Academy Press. 1981.

National Research Council. *Nutrient requirement of dairy cattle*. 7th ed. National Academy Press, Washington, D.C. 2001.

Nicholson, C. F., R. W. Black, C. I. Urbina, D. R. Lee, D. G. Fox, and P. J. Van Soest. “Economic comparison of nutritional management strategies for Venezuelan dual-purpose cattle systems.” *J. Anim. Sci*. 72(1994):1680-1696.

Rotz, C. A., L. D. Satter, D. R. Mertens, and R. E. Muck. “Feeding strategy, nitrogen recycling, and profitability of dairy farms.” *Journal of Dairy Science* 82(1999): 2841-2855.

Tylutki, T. P., and D. G. Fox. “An integrated cattle and crop production model to develop whole-farm nutrient management plans”. In: McNamara, J. P., J. France, and D. Beever (eds.) *Modeling nutrient utilization in farm animals,* CABI Publishing, New York, NY. 2000.

Von Neumann, J. and O. Morgenstern. *Theory of Games and Economic Behavior*. Princeton, N.J.: Princeton University Press, 1947.

West, J. W. “Interactions of energy and bovine somatotropin with heat stress.” *J. Dairy Sci*. 77(1976):2091-2102.

Young, B. W. 1976. “Effects of cold environments on nutrient requirements of ruminants.” (1976):491-496 in *Proc. 1st International Symposium on Feed Composition, Animal Nutrient Requirements, and Computerization of Diets*, P. V. Fonnesbeck, L. F. Harris, and L. C. Kearl, eds. Logan: Utah State University.