Risk management on application of minimum-cost feed ration for nitrogen and phosphorus reduction on dairy farm

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Abstract

The traditional mathematical programming model with the objective function of feed ration cost minimization is used to accommodate risk management responses to price variability associated with feeding a particular feed ration over time. The model incorporated biophysical simulation data using Cornell Net Carbohydrate and Protein System (CNCPS) software in addressing nutrient requirements and excretions. In addition, it used historic feedstuff prices in a mean-variance (E-V) framework analysis. The optimized seasonal feeding indicated to have a lower mean ration cost and lowest nutrient loading followed by optimized uniform feeding program. The feed cost optimization proved to be a better strategy in minimizing ration cost and reducing excretions both manure and nutrients. The results in this study can be used as guidelines for making nutrient. The information in this study can be used by a producer facing feed price risk to select optimal ration while reducing environmental pollution.

Keywords: *Mathematical programming, environmental pollution, nutrient excretion, minimum cost feed, seasonal feeding, mean-variance analysis*

Introduction

While milk prices have remained stable or declined for many years, the costs of most production inputs have continued to increase (Rotz, Satter, Mertens and Muck, 1999). Some regulatory initiatives and heightened public scrutiny come at a time when much of the dairy sector is losing money due to competition, reduced federal program support, unfavorable weather, and low milk prices. Since feed is a primary input for dairy farms, a producer's net returns are greatly affected by the feed expenses. If dairy cattle are fed in excess amounts of feed nutrients above requirement, large amounts of the nutrients will be excreted in feces and urine, resulting in environmental pollution and increased cost of dairy production (Chandler 1996). As a result of high-profile human health and environmental problems, there has been increasing emphasis placed on the role of dairy farms.

While feeding excessive amounts of a nutrient will decrease the efficiency of nutrient utilization resulting in an increased environmental pollution, decreased profits for dairy producers, and increased costs for the consumers of dairy products, deficient feeding in any nutrient will decrease production of milk and milk components. Dairy cattle should be fed to meet but not to exceed their nutrient requirements at a minimum cost feed. While least-cost ration formulations using linear programming techniques have been developed, studies that compare and contrast nitrogen and phosphorus excretions with respect to different dairy feeding management practices are lacking. The primary objective of this study is to provide, besides optimal feed ration decision tools, insight into how dairy producers facing feed price variability risk can manage manure and nutrient excretions, especially nitrogen and phosphorus. Specifically, this study (1) developed a minimum-cost feed ration with feed price risk involved using feed biological values in mathematical programming model, (2) analyzed the effect of the feed ingredient price risk on the choice of optimal feed ration, (3) aimed to compare and contrast the minimum-cost diet rations from three feeding management scenarios, and (4) analyzed excretions especially nitrogen and phosphorus balances in different feeding management scenarios.

Information resulting from this study will serve as the basis for more advanced decision-making tools for large scale livestock producers to consider, with risk element, formulating minimum-cost diet rations designed to manage nitrogen and phosphorus balances. Formulation and adoption of improved dairy cattle feeding systems driven by the concept of minimum-cost feed ration under risk management to meet nutrient

requirements and to prevent environmental pollution will result in increased efficiency of nutrient use.

Background

Feed being a primary input for dairy producers, variation of feed expenses will greatly affect the producer's net income variability (Prevatt et al. 1978). It has been reported that expenditures on feed in the Appalachian Region of the United States comprised about 23 percent of total farm expenditures (Kentucky Agricultural Statistical Service, 1999-2000). Depending on the size of the stock and storage facilities, among other things, producers may make multiple purchases of the same feed ingredients during the feeding period. As feed price variability influences production costs as well as net returns, the choice of a feed ration will be of importance to be included in the rational decision-making process.

Several papers have used linear programming (LP) techniques to optimize feed ration through least-cost ration formulation. McCarl and Spreen (1997) applied LP to minimize the total cost of the ration as the objective function subject to nutritional constraints. Nicholson et al. (1994) used an LP model to compare nutritional management strategies for dual-purpose herds in Latin America. Several other studies offered examples of models that also examine minimum-cost cattle rations (Coffey 2001; Tedeschi et al. 2000; Thomas et al. 1992; Wang et al. 2000).

The mathematical programming formulation that has been used to identify minimum-feed cost rations included risk management responses to price variability associated with feeding a ration over period. While the model merely minimizes the expected mean cost of the ration over the feeding period, producers would be willing to

forego some net returns in order to reduce the variability of the cost of the feed ration. This is due to some risk aversion associated with the funds available (Freund, 1956; Markowitz, 1959). This model, known as expected value variance (E-V) analysis, is a technique that attempts to minimize costs subject to risk aversion and has been widely applied to agricultural decision-making tools (Anderson, Dillon, and Hardaker 1997; Boisvert and McCarl 1990; Dillon 1999; Dillon 1992).

E-V analysis deals with uncertainty of contributions to the objective function of a mathematical programming model. While it has been widely published in agricultural economic literature, its theoretical appropriateness to represent decision-making tool has been questioned. However, E-V analysis is considered to be consistent with expected utility theory developed by Von Neumann and Morgenstern (1947) if any of the following scenarios are satisfied: (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). Given this consistency with the ability to use means and variances to make decisions, this research makes the use of E-V analysis applicable to model a dairy producer's response to uncertainties due to variability of feed ingredient prices.

The Cornell Net Carbohydrate and Protein System (CNCPS) model can be used to predict metabolized values of each feed in a given diet. Its use is basically nonlinear because the feed biological values vary with animal, feed characteristics, feed composition, passage rate, and their interactions. These metabolized values can then be used as coefficients in a linear matrix. The role of the CNCPS is to optimize diets for all

groups of animals in the herd and to predict herd nutrient requirements and nutrient excretion (Tylutki and Fox, 1997). The CNCPS has been used for dairy cattle (Dinn et al. 1998; Fox et al. 1995) applications and to evaluate herd feeding programs. Tylutki and Fox (2000) used CNCPS model to integrate cattle and crop production on a dairy farm and found that profitability improved with environmental benefits of reducing erosion and phosphorus contamination of water bodies.

Phosphorus consumed in excess of cattle requirements is excreted in the feces, with only a small amount excreted in the urine. Livestock generally excretes 60 to 80% of P consumed (Knowlton et al. 2004), an indication that a higher portion of P brought on to the farm in feed stays on the farm instead of being exported in meat or milk. A study by Klausner (1993) showed that on the typical dairy farm, N imported in feed, fertilizer, and N fixation in legumes is more than that exported in milk or meat by 62 to 79%, of which 62 to 87% of the excess N comes from imported feed. Approximately, 70% of the excess N escapes into the off-farm environment through volatilization and leaching into groundwater (Hutson et al. 1998). Successfully defining nutrient requirements and minimum-cost diet ration of dairy cattle will minimize nutrient losses in feces, urine, and gases. Hence, decreasing the concerns about the effects of waste disposal on the environment.

Weather changes may induce behavioral and metabolic changes in cattle (West 1994). For example, heat stress may cause changes in panting and increase energy expenditures. Mild to severe heat stress has been estimated to increase net energy requirements for maintenance by 7 to 25 percent, respectively (National Research Council, 1981). Other changes that may induce, for example, reduction in dry matter

intake, reduced activity, and reduced metabolic rate might reduce heat production of the animal too. The change in energy requirements might be small in cold environments due to high heat production for lactating cows consuming large amounts of feed. In his experiments with ruminants, Young (1976) observed an average reduction in dry matter digestibility of 1.8 percentage units for each 10^oC reduction in ambient temperature below $20\,^oC$. The high percentage of this reduced digestibility under cold condition may be related to an increased rate of passage of feed through the digestive tract (Kennedy et al. 1976). Under extreme cold environments, feed energy values might be lower than expected due to the effect of low temperature on digestibility (National Research Council, 2001).

Method and Materials

The traditional mathematical programming model with the objective function of feed ration cost minimization was used to accommodate risk management responses to price variability associated with feeding a particular feed ration over time. The decision-making environment of a hypothetical Kentucky dairy farm has incorporated biophysical simulation data using Cornell Net Carbohydrate and Protein System (CNCPS) software in addressing nutrient requirements and excretions. This study used 100 head of lactating Holstein cattle for analysis as described in table 1.

Three management feeding scenarios were analyzed and compared:

1) The first feeding management practice as the base line used the Cornell Net Carbohydrate and Protein System (CNCPS) software (version 5.0) to generate the biological values to characterize nutrient contents of each feed for the specific group for which the diet was formulated. The CNCPS model has been used to

generate the specific values used to predict the metabolized values and other biological values of each ingredient in a given diet. In this step, the CNCPS also predicted nutrient requirements, nutrient balances, manure excretion, P and N excretion for the feeding group described (table 1). The initial dry matter intake (DMI) was estimated for each animal in each group (table 2).

2) In this second scenario, the feed and biological values of interest - DMI, metabolizable energy (ME), metabolizable protein (MP), physically effective neutral detergent fiber (peNDF), calcium (Ca), and phosphorus (P) - simulated from the initial diet (step 1 above) were used as coefficients in mathematical programming model for minimum cost diet. The utilization of an initial diet to achieve these coefficients for each ingredient was important because the nutritional value of the diet depends on the interaction between rates of degradation and rates of passage of feeds, feed composition, animal, and intake (Tedeschi et al. 2000).

3) The CNCPS simulation in this feeding alternative scenario, using the same ration as 1 above (Table 2), will accommodate seasonal effects (summer, fall, winter, spring) in evaluating feed biological values of interest (DMI, ME, MP, peNDF, Ca, and P) because environmental changes might affect DMI and possibly some biological value requirements of the groups. These coefficients for each season will be accommodated in mathematical programming model to arrive at minimum cost ration.

Data computed by the CNCPS are coupled with other physical and economic data in developing, given a producer's risk preferences, the mathematical programming model

with the objective function of minimizing diet cost subject to animal requirements. The

following assumptions were made when using CNCPS: (i) the herd is in a steady-state

condition (neither expanding nor reducing herd numbers), (ii) the rations being fed are

representative of the whole period in question, (iii) there were no losses of feeds during

storage and feeding. Decision variables included feeding management practice, feed

ration, feed price, and feed biological values.

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		

Table 2. Rations fed as base feeding scenario (lbs/animal/day dry matter)

Ingredient	Fresh cows	1st calf heifers	High cows	Low cows
Corn silage	13.0	14.0	15.4	8.7
Alfalfa hay	8.0	8.0	8.0	6.0
Alfalfa silage	16.0	17.7	18.7	9.4
Wheat middling	5.6	5.7	6.6	4.0
Gluten feed	6.6	7.8	7.1	8.8
Cotton seed	0.7	2.2	3.3	1.0
Soybean meal	8.1	7.7	8.3	4.4
Canola meal	5.5	2.2	2.6	2.0
Minerals	0.2	0.2	0.4	0.4
Distillers dry grain	2.0	2.0	3.0	2.0
Total	65.7	67.5	73.4	46.7

The constraints were set based on animal requirements as forage, DMI, ME, MP,

peNDF, Ca, P, and relevant accounting equations. Ranges (minimum and maximum of

the requirement) for each constraint were used. For example, the nutritional contributions

of each feed ingredient multiplied by the amount of the feed ingredient to be included in

the ration must fall below upper-limit nutritional constraints and above certain lower-

limit nutritional constraints. Minimum nutrient constraints were set to ensure the

minimized feed meets the animal requirements. The maximum constraints were set at the

lowest maximum to avoid unacceptable levels of overfeeding based either on feed

availability or low priced feed ingredients. In addition to these constraints, upper and

lower limits for the amount of DMI and forage were used. Corn silage, alfalfa hay and

alfalfa silage were deliberately entered in the diet formulation to meet the forage

requirements having peNDF higher than 20% for maximum microbial yield. Forage has a

physical structure that helps in buffering capacity to balance ruminal pH, promote

chewing and saliva production (National Research Council 2001). The minimized feeds

in steps 2 and 3 above were reevaluated by the CNCPS model to check if the ration meets

the requirements and to generate nutrient 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 prices, the traditional minimum cost

feed ration model was expanded to accommodate E-V analysis 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 day in pounds.

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

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

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

$$\sum_j n_{i,j} F_j \leq UL_i, \ \forall i$$

$$\sum_j n_{i,j} F_j \geq LL_i, \ \forall i$$

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

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

In this model, $\overline{DC}$ is the mean total diet ration cost over T time periods. The time period t accommodated is in months with a total of 72 (T) months. DC_t is the total diet ration at t^{th} period. The price of jth feed ingredient at t^{th} period is represented by $P_{j,t}$. The non-negative amount of the jth feed ingredient to be included in the diet ration is represented by F_j. LL_i and UL_i are the lower and upper limit requirements respectively for the ith nutrient in the total diet ration. Φ is the value of the risk-aversion parameter.

The limitation in using this approach is that the risk aversion parameter must be known in advance. However, this limitation was overcome by using the following technique offered by McCarl and Bessler (1989) to estimate a level of risk aversion when the utility function is unknown.

$$\Phi = 2Z_\alpha/S_y, \tag{2}$$

where Φ as defined above, Z_α = the standardized normal Z value of α level of significance and S_y = the relevant standard deviation from the risk-neutral scenario. In this study, S_y was calculated using all year round feeding program by a producer with a risk-neutral attitude. This should represent attitudes toward ingredient price variability across all types of cattle.

The risk aversion levels were represented as risk- neutral and high risk-aversion using 50% and 99.9% Z values respectively. For the calculation of risk-aversion parameters, Z was varied in the formula to represent a farmer's preference to comprehend the same or lower ingredient costs 50 percent or 99.9 percent of the time (table 3). It is expected that the ingredients with more price variability will be less favorable to farmers in their decision of optimizing balanced feed ration at a minimum cost and at higher

levels of risk aversion. The calculation of feed ration cost was based on monthly prices of individual feed ingredients obtained from an historic price series in Kentucky and neighboring state markets collected by United State Department of Agriculture (USDA) from 1999 to 2005. The cost for mineral and vitamin was ignored in this paper because of their small contribution to the expense of feed ration (less than 1%).

Table 3. Risk-aversion parameters (standard deviation = 11.45)

A	Z_α	Parameter value
50%	0.000	0.00
99.9%	3.075	0.537

Results and Discussion

Rations for all levels of risk aversion were tested using CNCPS version 5 for nutritional balance. The compositions of all optimal rations calculated for each type of animal and Z in different seasons are displayed in tables 4 and 5. These tables summarize changes in ingredient allocation to each animal type as producer's risk attitude changes.

The results of changes in the amount of ingredients in different seasons are mixed when risk aversion parameter is changed. It seems that, from the eleven available ingredients, some are only suitable under certain conditions and some definitely present risk-management opportunities.

Corn silage, alfalfa hay and alfalfa silage were present in all groups of animals across the board for the reasons mentioned before. After all, these forages were among the ingredients having the lowest STD and lowest CV. Corn silage and alfalfa silage had the lowest mean prices of all ingredients. Whole cottonseed was only used by first-calf heifers fed uniform ration program in each risk level.

Table 4. Feedstuff composition (lbs/day dry matter) with risk aversion parameter = 0.00 (risk-neutral)

Type of animal	Ingredients[1]	Uniform feed year round	SEASONS			
			Fall	Winter	Spring	Summer
Fresh cow	CSI	17.99	17.99	17.99	17.99	17.99
	AHY	8.00	8.00	8.00	8.00	8.00
	ASI	8.00	8.00	8.00	8.00	8.00
	WHMid	5.70	5.55	5.23	7.00	7.00
	CGF	6.50	6.5	6.5	4.87	4.88
	MV	1.01	1.01		1.01	0.85
	SBM				0.04	
	DDG	3.00	3.00	3.00	2.95	3.00
Total			50.20	50.05	48.72	49.86	49.72
High cows	CSI	18.00	17.93	18.00	18.00	18.00
	AHY	8.04	8.00	8.00	8.04	8.00
	ASI	14.50	13.15	13.16	13.11	13.15
	WHMid	7.00	6.00	6.46	7.00	6.50
	CGF	6.50	6.50	6.50	6.50	6.46
	SBM	0.008	0.26			
	DDG	3.00	3.00	3.00	2.60	3.00
	LMSTN				0.20	0.20
Total		57.05	54.84	55.12	55.45	55.31
1st calf heifers	CSI	16.89	16.89	16.73	16.73	16.73
	AHY	8.00	8.00	8.00	8.00	8.00
	ASI	8.00	8.00	8.16	8.00	8.00
	WHMid	0.56	5.97	2.87	3.14	2.97
	CGF	6.50	4.71	6.50	6.42	6.50
	WCSD	3.48				
	MV		0.19	1.01	0.94	
	SBM	2.62	2.07	2.65	2.61	2.65
	DDG	3.00	3.00	3.00	3.00	3.00
Total		49.06	48.83	48.92	48.84	47.85
Low cows	CSI	18.00	18.00	18.00	18.00	18.00
	AHY	8.00	8.00	8.00	8.00	8.00
	ASI	8.00	8.78	8.41	8.28	8.70
	WHMid	6.96	1.96	7.00		2.70
	CGF	5.74	6.50	2.75	6.5	6.5
	LMSTN			0.20	0.20	
	DDG				1.997	
Total		46.70	43.24	44.36	42.98	43.90

While it had high mean price and high CV, whole cottonseed was probably entered to balance the nutrient requirements. Only high cow and first-calf heifer groups fed under uniform program used canola meal (table 5) which had the second highest mean price after soybean meal. Since these measures take into account mean and standard deviation, it indicates that these low mean costs come at the prices paid for the feed rations. Therefore, frequent inclusion of these lower priced ingredients with less price variability is a way of managing price risk associated with the feed ration across all

levels of risk aversions as expected. In general, the quantity of ration used for uniform

feeding all year round was higher than the average of the seasonal feeding. Most cows

indicated to take higher DMI per day in winter than other seasons.

Table 5. Feedstuff composition (lbs/day dry matter) with risk aversion parameter = 0.537 (high risk-aversion)

Type of animal	Ingredients[1]	SEASONS				
		Uniform feed year round	Fall	Winter	Spring	Summer
Fresh cow	CSI	17.99	17.99	17.99	17.47	17.99
	AHY	8.00	8.00	8.00	8.00	8.00
	ASI	8.00	8.00	8.00	8.00	8.00
	WHMid	7.00	7.00	5.23	7.00	7.00
	CGF	6.50	6.50	6.50	5.06	6.50
	SBM				0.15	
	MV			1.01		
	DDG	2.06	1.72	3.00	3.00	1.72
	LMSTN		0.16		0.16	
Total		49.55	49.37	49.73	48.69	49.21
High cows	CSI	18.00	17.47	18.00	17.73	18.00
	AHY	8.00	8.17	8.00	8.00	8.00
	ASI	13.16	13.16	13.16	13.43	12.29
	WHMid	7.00	7.00	7.00	7.00	7.00
	CGF	6.50	6.19	6.50	6.50	6.50
	CM	0.01				
	DDG	3.00	3.00	2.61	2.40	3.00
	LMSTN					0.11
Total		55.67	54.99	55.27	55.06	54.70
1st calf heifers	CSI	13.54	16.89	15.70	16.30	15.70
	AHY	11.35	8.00	8.00	8.26	9.08
	ASI	8.00	8.00	9.19	8.00	8.00
	WHMid	1.14	3.34	4.04	4.18	3.15
	CGF	6.50	6.50	6.50	6.50	6.50
	MV		0.81	1.01		
	WCSD	2.86				
	SBM	1.30	2.41	2.41	2.55	2.41
	CM	1.37				
	DDG	3.00	3.00	2.54	3.00	3.00
	LMSTN	0.12			0.14	
Total		49.18	48.95	49.39	48.93	47.84
Low cows	CSI	18.00	18.00	18.00	18.00	18.00
	AHY	8.00	8.00	8.00	8.00	8.00
	ASI	8.00	8.47	8.41	8.02	8.12
	WHMid	6.96	4.58	7.00	2.81	4.96
	CGF	5.74	4.19	2.75	5.93	2.75
	MV				0.03	
	LMSTN	0.15	0.005		0.024	0.12
Total		46.85	43.24	44.16	42.81	41.95

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

In addition to forages, wheat middling (WHMid) and corn gluten feed (CGF) are

present in the ration of each animal type across all feeding seasons (tables 4 and 5). They

are among the ingredients having low mean price, standard deviation (STD) as well as

low coefficient of variation (table 6). Dry distillers grain (DDG) was also used in most of the rations except low cow group which used only once in spring. Upon closer inspection of CGF and WHMid, their low mean prices, STDs and CVs seem to be very close to each other (table 6). DDG also had low mean price and CV. These might be some of the reasons for the appearance of these ingredients in most rations of the animals.

Table 6. Descriptive analysis of feed ingredient prices

Ingredient	Mean ($/ton)	Std. deviation ($/ton)	Maximum ($/ton)	Minimum ($/ton)	CV (%)[1]
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

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

In terms of ration costs, as price risk increases the mean costs increased slightly while the CV decreased in both uniform and seasonal feeding (table 7). The low variance of ingredient prices might be one of the reasons of the very low mean differences. Indication of higher mean costs in producer's high risk aversion attitude is a measure of penalty to 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.

Among the three feeding management practices, base line feeding scenario (i.e. original feeding program) had the highest average ration cost at US$ 2.40 per head per day, almost twice as in optimized ration cost. Seasonal feeding indicated to have lower mean cost compared to uniform feeding (table 7). This means that a producer might save

more if using seasonal feeding program in terms of ration costs than uniform feeding.

However, to evaluate their effects on net farm returns, the ration feed costs used to

compare the alternatives in this paper must be adjusted for differences in labor cost,

machinery, transportation, and facilities needed to improve production and grouping

strategy.

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

SEASONS	Risk-aversion (%)	Mean	Minimum	Maximum	Std. deviation	CV[1]
Uniform ration year round	50	1.40	1.20	1.69	11.45	8.18
	99.9	1.42	1.22	1.71	11.20	7.88
Seasonal feeding (all 4 seasons)	50	1.34	1.14	1.62	10.85	8.04
	99.9	1.35	1.14	1.63	10.81	8.01

[1]CV = coefficient of variation

In terms of manure excretions, original uniform feeding had the highest total

manure output including fecal and urine followed by original seasonal feeding (figure 1).

Optimized seasonal feeding had the lowest manure excretions followed by optimized

uniform feeding. Therefore, optimized seasonal feeding has the potential in reducing
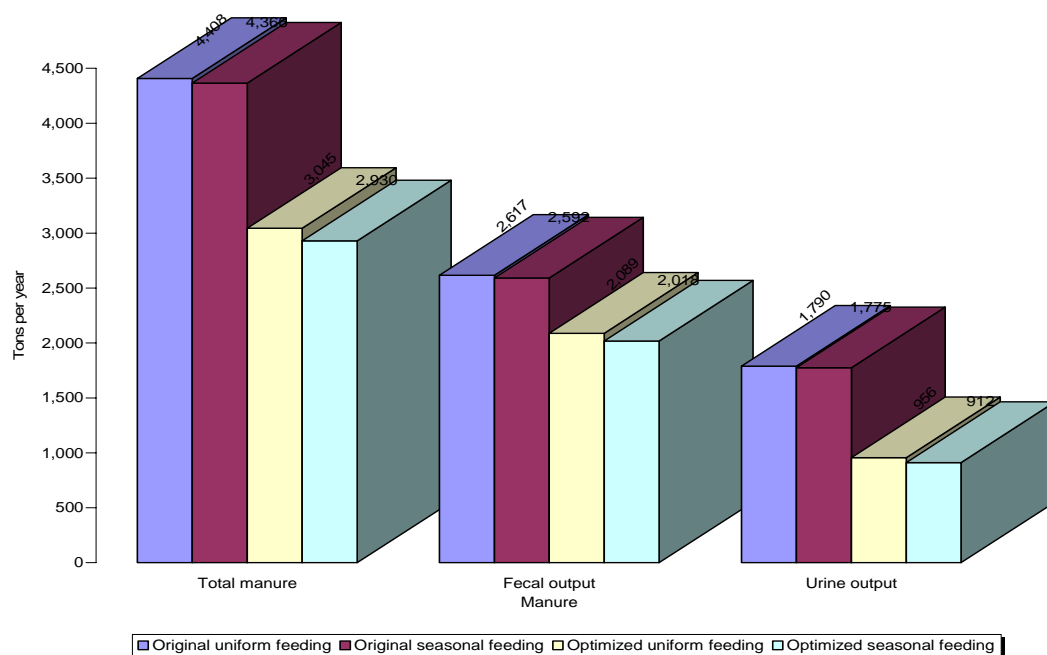
environmental pollution.

Figure 1. Predicted manure excretions

The nitrogen and phosphorus balances produced under original uniform feeding program were the highest followed by original seasonal feeding program (figure 2). Optimized seasonal feeding had the lowest nitrogen and phosphorus excretions. This is an indication that this model of cost minimization has the potential to improve environmental condition of a dairy farm.
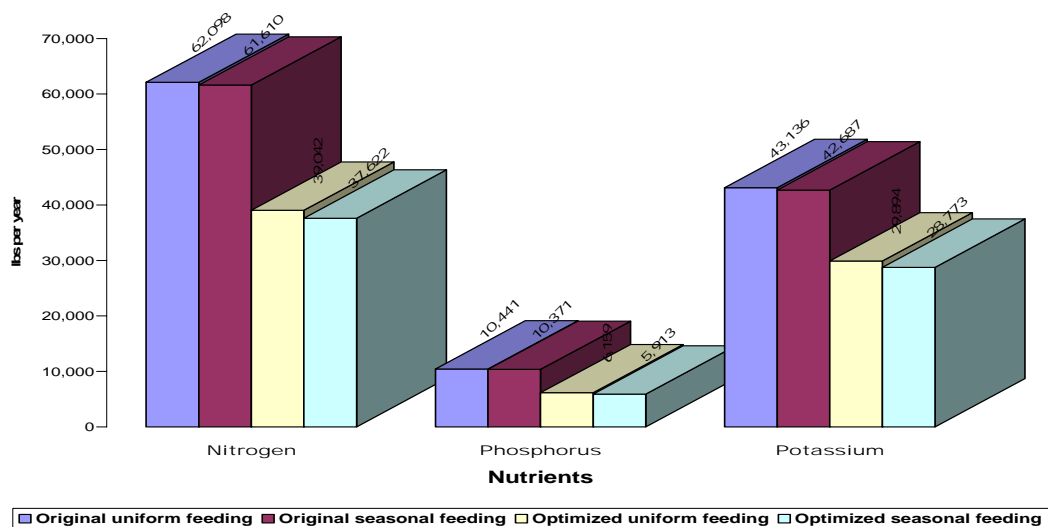

Figure 2. Predicted nutrient excretions

Optimized seasonal feeding was the most efficient in nutrient use compared to other feeding programs (figure 3). In general, original uniform and seasonal feeding programs indicated to have the lowest efficiency in nutrient use (figure 3).
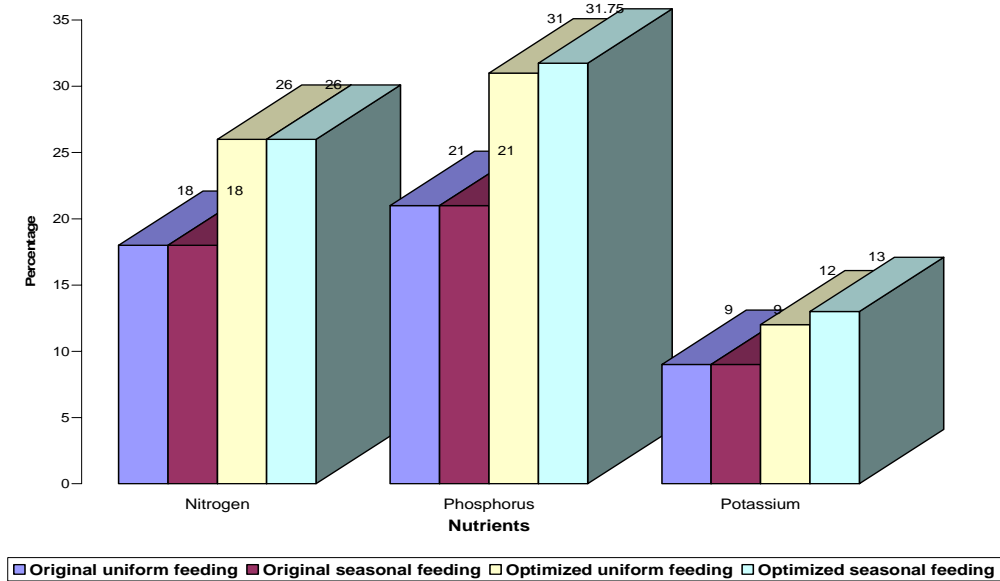

Figure 3. Efficiency of nutrient use

Summary and Conclusion

Given a producer's risk preferences, the study has the objective of minimizing feed ration cost while managing nutrient excretions and providing optimal feed ration decision tools in the face of ingredient price variability. The mathematical programming incorporated risk associated to ingredient price variability while CNCPS software was used to address nutrient requirements and nutrient excretions. The results demonstrate how this model can be used to identify alternative feeding strategies that minimize feed ration costs while reducing environmental pollution due to nitrogen and phosphorus. The optimized seasonal feeding has a lower mean ration cost and lowest nutrient loading followed by optimized uniform feeding program. In general, optimization proved to be a better

strategy in minimizing ration cost and reducing excretions both manure and nutrients. For further analysis on net farm returns, the ration feed costs realized in this paper must be adjusted for differences in labor cost, machinery, transportation, and facilities.

The results in this study can be used as guidelines for making nutrient management decisions while considering reduction of environmental pollution. The alternative strategies indicate considerable potential to reduce mass nutrient balance on diary farms without adversely affecting milk production. The model has the potential to be used to allocate feed ingredients for most efficient nutrient use and illustrates how dairy farmers or managers with different attitude toward risk would choose different feed rations to include in their feeding programs. It can lead to a better understanding of optimal resource allocation and its effect on the environment. It is also an option for livestock producers wishing to manage input price risk and net farm return risk, at least in part.

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