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Incorporation of Milk Yield, Dry Matter Intake and Phosphorous Excretion Predictive Functions in the Development of a Multi-Objective Dairy Feed Formulation Software Program

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Abstract

Predictive functions for milk yield, dry matter intake, and phosphorous-manure derived from the National Research Council 2001 and the present study were incorporated in the development of a multiple objective dairy feed formulation software program (MoF-Dairy Edition-2010); that attempted to optimise feed cost, milk yield and profits while minimising Phosphorous-excretion in manure. Important objects in the feed milling industry considered in the program development were feed millers, dairy farmers, and government feed policy regulatory guidelines. The multi-objective formulation approach comprises hierarchical design levels which include data, model, tools, and output layers. Program database objects are manipulated using VB.NET programming language within a Microsoft .NET Framework Environment. Users interact with the program by providing individual details after which a customer system instance is created. Program formulation inputs are entered through VB forms linked to the core simulation model layer (Microsoft SQL Server Database) to automatically calculate and generate nutrient requirements in accordance with NRC, 2001 for the particular cow or cow production groups under specified production performance parameters. The final solution is obtained by allowing the program to solve for the most feasible combination of available ingredients under the imposed formulation, ingredient as well as nutrient constraints. Program outputs include tailor-made reports on feed formulae; and the accompanying physical nutrient compositions and nutrient deviation analysis; potential unit and gross P-manure environmental pollution, and business economic analysis; detailing concentrate supplementation rates per cow per milking as well as the corresponding projected daily milk profit margins.

Keywords: Dairy cattle, feed formulation, multiple objectives formulation

1. Introduction

As feed formulation becomes more of a science and less an art, progressive dairy entrepreneurs are placing greater emphasis on rations which generate greatest economic return per unit feed cost; at minimum excretion of pollutant nutrients through manure aimed at sustainable environmental management and improved livestock productivity. Additionally, operations research has helped people to understand and manage agricultural planning at the farm, formulation of livestock rations and feedstuffs, and environmental implications (Andrés and Carlos, 2006; Joe and Rebecca, 2007). The development of a computerised feed formulation program that meet the needs of today's dairy producers requires that functions be derived which truly reflect production responses of cows at varying quantities and qualities of dry matter, while being able to predict excess nutrient excretion via the manure into the environment (Cerosaletti et al., 2004; Chapuis-Lardy, 2004; Carmen et al., 2005). Consequently, optimum milk yields and profits can be calculated using applied computer technologies given the prices of milk and the feed components. However, factors such as daily nutrient requirements, feed composition and the point at which physiological factors like body size limit intake and production need to be determined (NRC, 2001).

The MoF-Dairy Edition program presented here is a combination of both linear and non-linear functions with the overall goal of maximising milk production and profits, while minimising feed cost as well as excess nutrient excretion into the environment; subject to restrictions specified by the user. Specifically, the methodology integrates feed quality, nutrient content and ingredient cost as three critical formulation goals. Feeds were formulated considering the following nutrients: total digestible nutrients (TDN; energy), crude protein (CP), acid, neutral detergent fibre (NDF), ether extracts (EE), calcium Ca) and phosphorus (P). Previous studies on the development of dairy feed formulation systems (Brown et al., 1977; Brown & Chandler, 1978; Jones et al., 1980; Rehman & Romero, 1984; Varela-Alverez & Church, 1998; Tozer & Stokes, 2001; Thorne & Dijkman, 2005) mainly focused on singular objective (least-cost) approach. However, emerging economic, production and environmental policy regulatory challenges in modern dairy farming are driving the need for the development of feed formulation programs that are based on multiple objectives approach. Such an approach has not found widespread application, perhaps owing in part to the limitations of computer technologies as well as a lack of a systematic multiple-objectives approach among earlier studies on dairy cow diet formulation (Chandler et al., 1978; Lara, 1993; Varela-Alverez & Church, 1998; Tozer & Stokes, 2001; Waldner, 2003). This approach can be integrated in the feed manufacturing decision-making process and manifested in a formulation methodology that attempts to incorporate overall industry entrepreneurial needs, institutional feed policy frameworks as well as regulatory mandates collectively. The objective of this study therefore, was to incorporate milk yield, dry matter intake and P-manure excretion predictive functions in the development of a MoF-Dairy Edition (2010) program.

2. Materials and Methods

2.1 Model Objects and Requirements

The key players in the Kenyan feed industry considered during the development of the multi-objective formulation program were feed millers, dairy farmers, and policy regulatory agencies i.e. Kenya Bureau of Standards (KEBS) and National Environment Management Authority (NEMA), who have conflicting objectives which the program attempted to optimise. Dairy farmers comprise customers who purchase ingredients and feeds for supplementing their lactating cows to increase nutrient intake for improved milk yields with the desire to maximise returns from milk sales. The governments' objective is mainly regulatory, regarding adherence to feed quality standards as well as limiting environmental pollution (e.g. P pollution) from dairy enterprises practicing concentrates feeding operations. Feed formulation interests of dairy producers and policy regulatory guidelines as well as feed millers needs were incorporated into the dairy feed formulation process, design and development as shown in Figure 4.

2.2 Model Design and Description

The data hierarchy is presented in Figure 1, with dairy producers serving as customer. Each customer owns a lactating cow of known production performance as well as a number of available ingredients used to formulate diets for a cow or cow production groups. For every instance a customer interacts with the program, a specification for constraints; e.g. ingredient inclusion levels, daily nutrient intake requirements and excretion limitations, and ingredient cost limits, are set. These are implemented in the multi-objective formulation program to generate a dairy feed formula that meets the formulators overall multiple needs of adherence to feed policy regulatory guidelines and acceptable feed quality while maintaining least cost of feed for their business economic needs. Once a formulation is successful, the diet is moved to the formulae section, as shown in the program reports (Table 6). The ingredients database, dairy cow details and formula data types are owned by a customer and are defined and maintained by the formulation program data layer. However, the formulation program does not define the customised data type representing input data since this data type is used to store information about animal models (Table 4) according to NRC (2001).

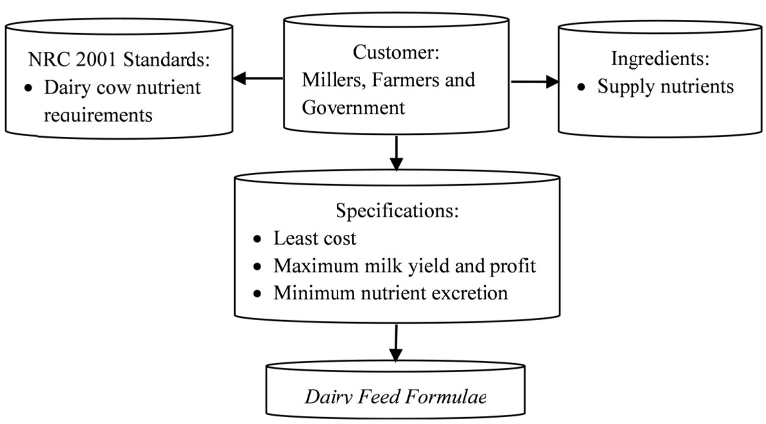

Figure 1. Model data organisation

2.3 Model Schematic Representation

The structure of the model program include: data, model, tools, and output layers as illustrated in Figure 2. The data layer represents actors in the feed milling industry namely; feed millers, dairy farmers, and government regulatory agencies (KEBS and NEMA), and imposed feed formulation constraints. The model layer correspond to the core simulation model (stored in a Microsoft SQL Database) based on NRC (2001) dairy cow daily nutrient requirements dynamically determined by incorporating the MY, DMI and P-manure predictive functions for lactating dairy cows into the feed formulation process. The tools layer is an object-oriented 4^{th} generation language which provide the programming environment for generating program-user interactive interfaces that addresses specific user needs using Microsoft Visual Studio version 6.0 Professional Edition of 2008. The MoF-Dairy Edition (2010) program incorporates very powerful scripting which is a dialect of VB.Net implemented within a Microsoft.Net Framework Environment. The output layer represents the final multi-objective formula based on dairy cow production performance specifications, and prevailing ingredient and nutrient constraints. It generates program reports that serve as decision-making tools under practical dairy feed manufacturing process.

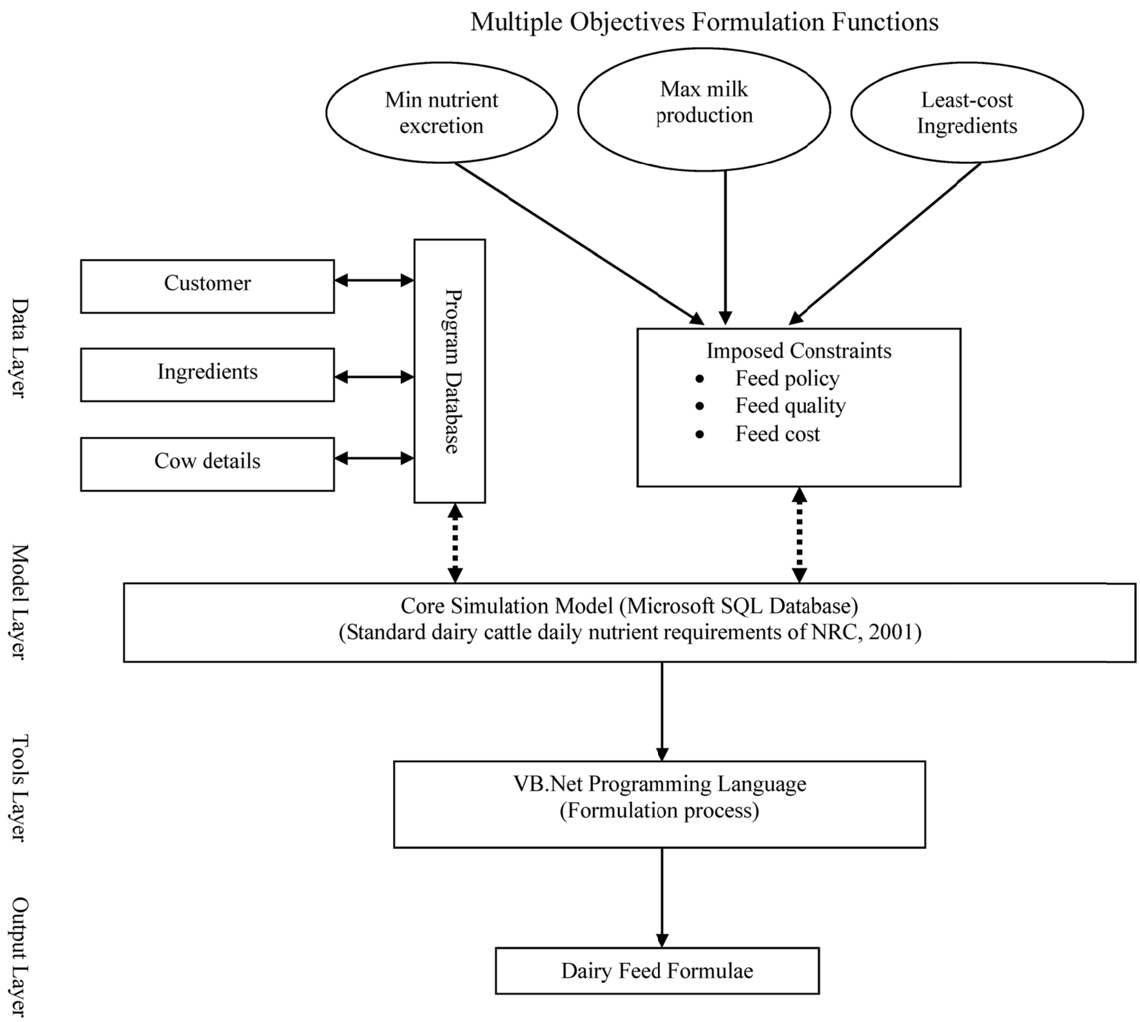

Figure 2. Model schematic representation

2.4 Model Development

Development of cost effective and quality software programs that address business needs for all stakeholders in the feed industry requires a suitable system development process model to direct the project life cycle (CTG, 1998; Kang'ethe, 2002). Hence, the iterative modelling technique described by the Software Engineering Best Practices of 1998 was employed in the development of the MoF-Dairy Edition (2010) Program. Additionally, incorporation of milk production levels, environmental nutrient pollution concerns as well as feed cost were achieved by integrating ingredient quality ratios into minimum P-excretion and least cost functions (Waugh, 1951; Morse et al., 1992; Varela-Alverez and Church, 1998). This approach, aimed at providing a broad decision-making base to formulators of dairy feeds, employed the use of linear as well as non-linear programming (Dave, 2004) to derive the best combination of ingredients in order to realise the lowest possible cost of dairy feeds, maximise milk yield and profits, while maintaining minimum P-excretion in manure. To ensure simplicity of the programming approach, the model was based on MY and DMI, where:

$$MY = (0.4 + (0.15 * BF)) / FCM_{4\%} \qquad \text{(Function 1)}$$

and

$$DMI = (-0.293 + 0.372 * FCM + 0.0968 * [BW.\text{sup}0.75]) * (1 - \exp(-0.192 * (WIM + 3.67))) \qquad \text{(Function 2)}$$

Predictive functions from the NRC (2001), CP: P ratio and research observations where;

MY= Milk yield

FCM= Fat corrected milk

BF= Butter fat

DMI= Dry matter intake

$BW^{0.75}$= Metabolic body weight

WIM= Weeks in milk

2.5 Optimising Multi-Objective Predictive Functions

Specifications of a multi-objective programming approach necessitate target values for cost, milk yield, and excess nutrients (Heard et al., 2004). The feed cost target (C) the milk yield target (M) and the phosphorus target (P) were obtained through separate linear and non-linear programming models described by Morse et al. (1992), Varela-Alverez and Church (1998) and Tozer and Stokes (2001). Figure 3 presents sample potential ingredients available from June to August 2011at Naku Modern-Feed Mill, Nakuru (Kenya).

Available	Ingred_ID	Ingred_Name	Ingred_Group	Must_Include	DM	TDN	CP	RUP	RDP	CF	ADF	NDF	Ca
☑	3	Fish Meal	P	☑	895.00	67.55	48.73	0.00	0.00	11.27	0.00	3.00	0.17
☑	4	Cotton Meal	P	☐	958.60	58.63	29.29	0.00	0.00	9.47	0.00	34.50	0.2
☑	5	Sunflower Meal	P	☐	900.90	58.66	26.88	0.00	0.00	12.63	0.00	33.07	1.73
☑	6	Maize Germ	E	☐	886.20	90.68	10.53	0.00	0.00	10.30	0.00	5.52	0.02
☑	7	Wheat Bran	E	☐	918.00	60.76	15.15	0.00	0.00	5.22	0.00	12.17	0.0
☑	8	Wheat Pollard	E	☐	887.50	75.87	13.96	0.00	0.00	3.80	0.00	5.87	0.1
☑	9	Dairy Premix	M	☑	980.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.65
☑	10	Limestone	M	☑	1000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.
☑	11	DCP	M	☑	970.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	13.4
☑	12	Magadi Soda	M	☑	210.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.1
☑	13	Molasses	E	☑	750.00	71.00	2.30	0.00	0.00	0.00	0.00	0.00	0.42

Figure 3. Printout image from the MoF-Dairy Edition-2010 program indicating the ingredients, nutritive values and unit prices. Data adapted from Naku Modern-Feed Mill, Nakuru (Kenya)

2.5.1 Crude Protein: Phosphorous Ratios and Ingredient Groupings

Typically feed concentrates are incorporated in dairy feeds because of their relatively high nutrient contents (Energy (E) or Protein (P) or Minerals (M)), but so long as there prices are cost-attractive. However, some by-products contain quite high concentrations of P. The primary aim of feeding a dairy supplement is to provide protein, not phosphorous. In order to achieve a good balance between feed quality and minimum nutrient excretion in manure, it is necessary to utilise protein sources with high crude protein (CP) to phosphorous (P) ratios as a selection criterion for an ingredient to be included into the final formula. Therefore, using feed ingredients with higher CP:P ratios provide the much needed protein with less P; whilst continued utilisation of protein sources or ingredient by-products with lower CP:P ratios (Dave, 2004) may even be more costly in the long-term. To simplify the formulation process, available concentrate ingredients were therefore categorised into three groups: Energy (E); Protein (P); and Minerals (M) rich concentrates as shown in Figure 4; for their step-by-step nutrient contribution to the calculated ration totals.

Ingred_ID	Ingred_Name	Ingred_Group	Must_Include	CP_per_P_Ratio	UnitPrice	Price_per_TDN	Price_per_CP	Safe_Max
3	Fish Meal	P	☑	64.97	58.00	0.85	1.19	0.50
4	Cotton Meal	P	☐	47.24	51.00	0.86	1.74	15.00
5	Sunflower Meal	P	☐	47.15	9.00	0.15	0.33	8.00
6	Maize Germ	E	☐	19.86	23.00	0.25	2.18	30.00
7	Wheat Bran	E	☐	16.46	17.50	0.28	1.15	20.00
8	Wheat Pollard	E	☐	25.38	23.50	0.30	1.68	10.00
9	Dairy Premix	M	☑	0.00	250.00	0.00	0.00	0.50
10	Limestone	M	☐	0.00	6.00	0.00	0.00	0.10
11	DCP	M	☐	0.00	80.00	0.00	0.00	0.10
12	Magadi Soda	M	☐	0.00	14.00	0.00	0.00	0.10
13	Molasses	E	☑	1.69	17.50	0.24	7.60	5.00

Figure 4. Printout image from the MoF-Dairy Edition-2010 program showing crude protein and phosphorous ratios and grouping of some ingredients. Data adapted from Naku Modern-Feed Mill, Nakuru (Kenya)

2.5.2 Least Cost Function

The objective function specified by Equation 1 depicts the summation of the prices of the i feed ingredients (π_i) multiplied by their proportional use (X_i) in the optimal feed. The minimum cost target C is expressed as:

$$\min \quad C = \sum_{i=1}^{I} \pi_i X_i \qquad \text{(Equation 1)}$$

The inclusion rate of every ingredient is subject to a safe minimum and safe maximum in order to guard against nutritional deficiencies and excesses. Equations 2 and 3 present typical nutritional upper and lower bound constraints of inclusion rates;

$$\sum_{i=1}^{I} a_{ij} X_i \geq b_j \forall J = 1,2,\ldots J-1 \qquad \text{(Equation 2)}$$

$$\sum_{i=1}^{I} a_{ij} X_i \leq b_j \qquad \text{(Equation 3)}$$

$$\sum_{i=1}^{I} a_{ij} X_i \leq J \qquad \text{(Equation 4)}$$

The technical coefficients a_{ij} measure the amount of the *jth* nutrient in the *ith* feed ingredient while the right hand sides' b_j give the minimum or maximum amount of the *jth* nutrient allowable in the feed depending on the indicated sign of the inequality. There are a total of I feed ingredients and J nutrients and j=J refers to dry matter (DM) as indicated by the constraint Equation 4.

2.5.3 Minimum P-excretion Function

Target phosphorous excretion, *P*, is found by minimizing a non-linear Function 3 by Morse et al. (1992), subject to Equations 2 and 3, and an equality relation that determines the optimal feed's total phosphorous intake. The non-linear function is expressed as:

$$\min\ p = k(14.67 + 0.678\,p + 0.00196\,p^2 - 0.317\,m) \qquad \text{(Function 3)}$$

Subject to Equations 2 and 3;

$$\sum_{i=1}^{I} a_{ij} X_i = P \qquad \text{(Equation 5)}$$

$$\sum_{i=1}^{I} a_{ij} X_i \leq J \qquad \text{(Equation 6)}$$

Phosphorous excretion in manure was calculated using the equality relation (3) and is denoted by *p*.

2.5.4 Model Functions and Imposed Constraints

A summary of the formulation model activities, imposed constraints and model notations are presented in Tables 1 and 2.

Table 1. Summary of formulation model activities and imposed constraints

Activity	Model Function	Imposed Constraints
Feed quality	CP:P ratio	High CP:P ratio ingredients
Least cost feed	$\min\ C = \sum_{i=1}^{I} \pi_i X_i$	Minimum ingredient cost (C X_i)
Minimum P-excretion	$(14.67 + 0.678\,p + 0.00196\,p^2 - 0.317\,m)$	Minimum nutrient excretion (P-level ≤ NRC values)

Source: Adapted from Waugh (1951); Morse et al. (1992) and Tozer and Stokes (2001).

Table 2. Summary of model notations

Indices	Definition
I	Ingredient
J	Nutrient
Parameters	
π_m	Price of milk (Kshs/kg of milk)
π_i	Price of ingredients (Kshs/kg as fed)
a_{ij}	Amount of nutrients j in ingredients i (% or g/kg DM)
b_j	Required amount of nutrient j (%, kg, Mcal)
k	Phosphorus intake efficiency (%)
C	Target feed cost (Kshs/cow/day)
M	Target milk production (kg/cow/day)
P	Target phosphorus excretion (kg/cow/day)
Variables	
x_i	Required level of ingredients i in feed (kg/cow/day)
Functions	
C (x_i)	Feed cost in Kenya shillings (Kshs/cow/day)
M (x_i)	Optimum Milk yield (kg/cow/day)
P (x_i)	Phosphorus excretion (kg/cow/day)

Source: Adapted from Waugh (1951); Morse et al. (1992) and Tozer and Stokes (2001).

2.6 Feed Formulation Process

2.6.1 Listing of Available Ingredients and Their Nutritive Values

Formulation of the dairy feed entailed listing available ingredients (Table 3) for inclusion in the concentrate feed and presented them in a schedule as follows:

- Dry matter content (DM %)
- Total digestible nutrient (TDN %)
- Crude protein (CP %)
- Rumen undegradable protein (RUP%)
- Rumen degradable protein (RDP%)
- Crude fibre (CF %)
- Acid detergent fibre (ADF%)
- Neutral detergent fibre (NDF%)
- Calcium (Ca %)
- Phosphorous (P %)
- Protein: Phosphorous ratio
- Price per kg of ingredient
- Price per unit TDN %
- Price per unit CP %
- Safe minimum inclusion level (%)
- Safe maximum inclusion level (%)

Table 3. Ingredient constraints

CP_per_P_Ratio	UnitPrice	Price_per_TDN	Price_per_CP	Safe_Max
0.00	250.00	0.00	0.00	1.00
0.00	5.00	0.00	0.00	2.00
21.50	15.00	0.22	1.07	50.00
212.00	17.00	0.21	1.60	40.00
175.00	20.00	0.27	0.57	35.00
120.00	17.00	0.24	0.47	25.00
0.00	60.00	0.00	0.00	5.00
40.00	18.00	0.25	1.13	40.00
46.50	12.00	0.18	0.47	35.00
35.00	40.00	0.56	11.43	10.00
17.00	60.00	0.81	1.09	0.50

2.6.2 Fixing Ingredient and Nutrient Constraints

Fixing of the TDN % and CP % levels is based on the nutritional analysis of available ingredients (Bouwman, 1999). When fixing the safe minimum and safe maximum inclusion rates, the following feed factors were put into consideration; toxic matters, influence on palatability, milk quality, digestive tract, and also ingredient availability. The requirements (Table 4) of the feed to be composed were fixed under the following considerations:

- A minimum TDN % (considering prices per unit TDN)
- A minimum percentage of digestible crude protein (DCP)
- A maximum percentage of digestible crude protein (DCP)
- A maximum percentage of crude fat (CF)
- A maximum percentage of calcium (Ca)
- A maximum percentage of phosphorous (P)

2.6.3 Fixing Formulation Constraints

In composing the dairy feed proper, the following reserved inclusion proportions were considered in building the feed up to 50 percent level.

- About 1 to 4 % for the inclusion of any dairy premixes and vitamin-mineral concentrates
- 30 % of ingredient(s) which are higher in TDN % than the required optimum level of the feed; specifically take those ingredients that have the highest CP: P ratio and lowest price per percentage TDN, but no more that the safe maximum percentage.
- About 16 to 18 % of ingredient (s) which are higher in CP % than the required optimum level of the feed; specifically take those ingredients that have the highest CP: P ratio and lowest price per percentage CP, but no more that the safe maximum percentage.

Having 50 % then, continue building further on step-by-step; adding 10 % at a time but within the safe maximum levels. At 50, 60, 70, 80, 90 and 100 %, always check for TDN and CP levels and select on the basis of 10 % ingredients which are balancing the feed and which have the highest CP: P ratios and cheapest.

2.7 Model Inputs and Validation Process

The developed software formulation package was tested for technical as well as dynamic functionalities according to the Software Engineering Best Practices guidelines of 1998. Overall system technical functionality testing was performed to capture and correct errors before the final implementation. User feedbacks were used to perform model re-design and capability enhancements in readiness for the program operational validation under practical on-station condition at Egerton University, Ngongongeri Farm.

To perform technical program validation, users interacted with the program by firstly registering with the system by providing necessary user details: name, contact address and farm number including; additional farm management variables needed for software program reports like the customer herd size (HS), milking times (MT), and prevailing market milk price (MP), after which an instance of each user profile was created. The system further required users to select available ingredients from the ingredients DB, set appropriate ingredient and nutrient constraints, and provide cow production performance details upon which the formulation of a balanced multi-objective dairy diet was based. User data were entered through a VB form linked to the core simulation model (standard NRC 2001, Table 4) which automatically calculated and generated nutrient requirements for the particular cow or cow production groups under the specified constraints; for that customer instance. The MoF-Dairy Edition program is equipped with powerful queries to calculate the dairy feed formula.

Table 4. Nutrient constraints outlined in the dairy cattle standard requirements

STD_ID	DM_MIN	DM_MAX	BW_MIN	BW_MAX	BF_MIN	BF_MAX	TDN	CP	RUP	RDP	CF	ADF	NDF	Ca	P	A	D	PMY	NoL_GT3
1	8	18	400	499	5.00	6.00	63.00	12.00	4.40	7.80	17.00	21.00	28.00	0.43	0.28	3200.00	1000.00	7.00	☐
2	8	18	400	499	4.50	4.90	63.00	12.00	4.40	7.80	17.00	21.00	28.00	0.43	0.28	3200.00	1000.00	8.00	☐
3	8	18	400	499	4.00	4.40	63.00	12.00	4.40	7.80	17.00	21.00	28.00	0.43	0.28	3200.00	1000.00	10.00	☐
4	8	18	400	499	3.50	3.90	63.00	12.00	4.40	7.80	17.00	21.00	28.00	0.43	0.28	3200.00	1000.00	12.00	☐
5	8	18	400	499	3.50	3.90	63.00	12.00	4.40	7.80	17.00	21.00	28.00	0.43	0.28	3200.00	1000.00	13.00	☑
6	10	19	500	599	5.00	6.00	67.00	15.00	5.20	8.70	17.00	21.00	28.00	0.51	0.33	3200.00	1000.00	13.00	☐
7	10	19	500	599	4.50	4.90	67.00	15.00	5.20	8.70	17.00	21.00	28.00	0.51	0.33	3200.00	1000.00	17.00	☐
8	10	19	500	599	4.00	4.40	67.00	15.00	5.20	8.70	17.00	21.00	28.00	0.51	0.33	3200.00	1000.00	20.00	☐
9	10	19	500	599	3.50	3.90	67.00	15.00	5.20	8.70	17.00	21.00	28.00	0.51	0.33	3200.00	1000.00	24.00	☐
10	10	19	500	599	3.50	3.90	67.00	15.00	5.20	8.70	17.00	21.00	28.00	0.51	0.33	3200.00	1000.00	27.00	☑
11	12	20	600	699	5.00	6.00	71.00	16.00	5.70	9.60	17.00	21.00	28.00	0.58	0.37	3200.00	1000.00	20.00	☐
12	12	20	600	699	4.50	4.90	71.00	16.00	5.70	9.60	17.00	21.00	28.00	0.58	0.37	3200.00	1000.00	25.00	☐
13	12	20	600	699	4.00	4.40	71.00	16.00	5.70	9.60	17.00	21.00	28.00	0.58	0.37	3200.00	1000.00	30.00	☐
14	12	20	600	699	3.50	3.90	71.00	16.00	5.70	9.60	17.00	21.00	28.00	0.58	0.37	3200.00	1000.00	36.00	☐
15	12	20	600	699	3.50	3.90	71.00	16.00	5.70	9.60	17.00	21.00	28.00	0.58	0.37	3200.00	1000.00	40.00	☑
16	14	20	700	799	5.00	6.00	75.00	17.00	5.90	10.30	15.00	19.00	25.00	0.64	0.41	3200.00	1000.00	26.00	☐
17	14	20	700	799	4.50	4.90	75.00	17.00	5.90	10.30	15.00	19.00	25.00	0.64	0.41	3200.00	1000.00	33.00	☐
18	14	20	700	799	4.00	4.40	75.00	17.00	5.90	10.30	15.00	19.00	25.00	0.64	0.41	3200.00	1000.00	40.00	☐
19	14	20	700	799	3.50	3.90	75.00	17.00	5.90	10.30	15.00	19.00	25.00	0.64	0.41	3200.00	1000.00	48.00	☐
20	14	20	700	799	3.50	3.90	75.00	17.00	5.90	10.30	15.00	19.00	25.00	0.64	0.41	3200.00	1000.00	53.00	☑
																			☐

Source: NRC (2001).

3. Results

3.1 Calculations by Predictive Functions

3.1.1 Milk Yield and Dry Matter Intake

The NRC (2001) MY and DMI modelling approach that recommends use of only animal factors that are measurable on an individual basis including; 4 % FCM rather than MY, $BW^{0.75}$ rather than live body weight (LBW), and weeks in milk were utilised. Figure 5 illustrates data set for Holstein-Friesian lactating cows from Egerton University's Ngongongeri Farm with the following production performance parameters: LBW = 400 kg; MY = 12 kg; BF = 3.61, and WIM = 10, obtained from June 26th to August 22nd, 2011. These were used in the determination of the herd FCM and hence DMI.

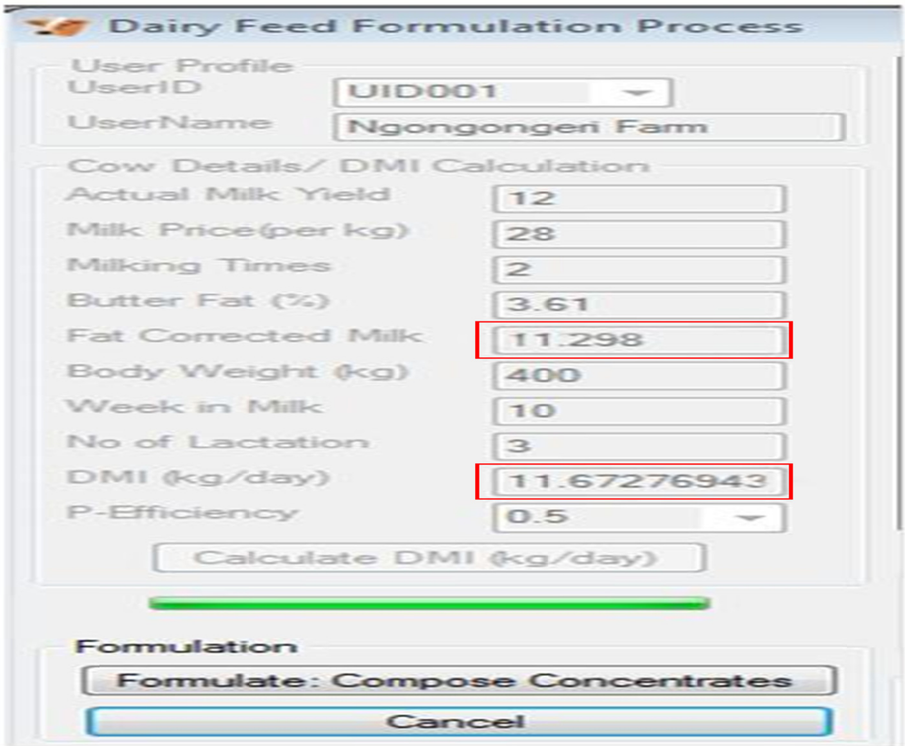

Figure 5. Printout image from the MoF-Dairy Edition-2010 program showing predicted milk yield (4 % FCM) and daily dry matter intake (DMI) in kg per day

3.1.2 Minimum P-excretion in Manure

Under normal conditions, urinary P excretion is negligible and, therefore, the P-manure balance of dairy cows (Function 3) is determined by P intake, intestinal absorption and secretion in milk. Milk P output is directly related to milk yield, since milk P concentration is constant (NRC, 2001; Valk et al., 2002; Valk and Beynen, 2003). The optimised minimum P-excretion (Function 3) where; k is the efficiency of *P* digestibility which ranges from 0.1 to 1.0; and *p* is the value of formulated feed phosphorous per kg DM feed (e.g. F % *P* is equivalent to 10F g of phosphorous per kg DM feed). Meaning that for a cow supplemented at (Read as Daily Total in the program report analysis (Table 21) X kg of feed per day, then the value of P above would be (10 F g of *P* per kg DM feed * X kg DM feed) 10FXg of *P* on DM basis per day. Consequently, the value of p^2 would be $(10FX * 10FX)^2$ is $(100FFXX)^2$ g of *P* on DM basis. The *m* is the total potential milk production per day (PMY) in the program and since, 1 kg milk contains 0.9 g of *p* (Morse et al., 1992; NRC, 2001; Dave, 2004), a cow whose PMY is Y_{max} kg of milk per day (from the average of experimental lactating cows), then the total *P* content in her milk would be given by 0.9 g per kg milk * PMY, hence the value of *m* in the equation would be dynamically substituted thus: 0.9 g of *P* * Y_{max} kg of milk per day on DM basis. Finally, the excreted P-manure value need to be converted from DM basis into FM basis to reflect real farm feeding situations and manure excretion in published as well as regulatory values, termed “dilution factor”. Given that the formulated feed (CRT) DM value of W g per kg feed, then on FM matter basis, the value of minimum *P* would be given by (0.9 g per kg milk * PMY * W g per kg feed) g of excess P-manure per day on FM basis. The resultant DM and FM basis *P* value is thus compared with published literature (5 g /kg DM manure) as well as regulatory standard (30 mg/Litre of waste effluent) values (Table 5) for effluent discharge into public sewers of maximum permissible level as stipulated in EMCA (2006) guidelines.

Table 5. Predicted excess P-manure

Gross Environmental Components

Predicted P-Manure (g/kg)		Recommendations		P-Pollution (g/kg)	
DryMatter	FreshMatter	Literature Value	Nema Standards	DryMatter	FreshMatter
11.15	8.72	5 g/kg DM	30 mg/kg FM	6.15	8.69

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Ngongongeri Farm

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Calculated using the MoF-Dairy Edition-2010 program.

3.2 Program Reports

3.2.1 Dairy Feed Formula and Nutrient Composition Analysis

Table 6 shows a summary of a sample formulated diet expressed as percentage inclusion rate, feed nutritive values and unit ingredients price.

Table 6. Summary of feed formulation

Formulation

Summary of Ration Formulate

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Ingred_Name	%	DM	TDN	CP	RUP	RDP	CF	Ca	P	UnitPrice
Molasses	5.00	37.50	3.55	0.12	0.00	0.00	0.00	0.02	0.07	0.88
Magadi Soda	0.10	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
DCP	0.10	0.97	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.08
Limestone	0.10	1.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.01
Dairy Premix	0.50	4.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.25
Wheat Pollard	10.00	88.75	7.59	1.40	0.00	0.00	0.38	0.02	0.06	2.35
Wheat Bran	20.00	183.60	12.15	3.03	0.00	0.00	1.04	0.02	0.18	3.50
Maize Germ	10.00	88.62	9.07	1.05	0.00	0.00	1.03	0.00	0.05	2.30
Maize Germ	20.00	177.24	18.14	2.11	0.00	0.00	2.06	0.00	0.11	4.60
Sunflower Meal	5.73	51.62	3.36	1.54	0.00	0.00	0.72	0.10	0.03	0.52
Cotton Meal	1.00	9.59	0.59	0.29	0.00	0.00	0.09	0.00	0.01	0.51
Cotton Meal	14.00	134.20	8.21	4.10	0.00	0.00	1.33	0.04	0.09	7.14
Fish Meal	0.50	4.48	0.34	0.24	0.00	0.00	0.06	0.00	0.00	0.29
Fillers	12.97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ration Totals	100.00	782.68	63.00	13.88	0.00	0.00	6.71	0.23	0.61	Ksh. 23.44

3.2.2 Ration Nutrient Deviation

The NRC (2001) dairy cattle nutrient requirements are regarded as the nutritionally accepted guiding standards from which, KEBS extracts dairy cattle specifications for millers in Kenya. It therefore provides a bench-mark upon which deviations for calculated ration values can be assessed as shown in Table 7.

Table 7. Ration nutrient deviation

Ration Nutrient Variability Analysis

	%	DM	TDN	CP	RUP	RDP	CF	Ca	P	UnitPrice
Ration Totals	100.00	782.68	63.00	13.88	0.00	0.00	6.71	0.23	0.61	Ksh. 23.44
StdReq No. 5	100.00	11.67	63.00	12.00	4.40	7.80	17.00	0.43	0.28	
Deviation			0.00	1.88	-4.40	-7.80	-10.29	-0.20	0.33	

3.2.3 Predicted Manure P-Balance

For the assessment of P requirements of dairy cows, both results from controlled feeding trials and knowledge of P metabolism is required (Valk and Beynen, 2003). Manure P-balance (g/kg DM manure) is computed using Function 3. From an environmental point of view, an efficient use of ingested P by dairy cows is important to minimize fecal P output (Table 8) and, as a result, P losses to the environment. Lowering P intake can reduce P excretion, but diets for dairy cows must contain sufficient P (Valk et al., 2002) to meet milk production requirements.

Table 8. Potential excess P-manure excretion into the environment

Gross Environmental Components

Predicted P-Manure (g/kg)		Recommendations		P-Pollution (g/kg)		
Dry Matter	Fresh Matter	Literature Value	Nema Standards	Dry Matter	Fresh Matter	
						11 UID001 Ngongongeri Farm 8/10/2011 12:35:26PM
11.15	8.72	5 g/kg DM	30 mg/kg FM	6.15	8.69	
						12 UID001 Ngongongeri Farm 8/10/2011 12:38:35PM
11.15	8.72	5 g/kg DM	30 mg/kg FM	6.15	8.69	
						13 UID001 Ngongongeri Farm 8/10/2011 12:45:11PM
11.15	8.72	5 g/kg DM	30 mg/kg FM	6.15	8.69	

3.3 Feed Quality

Protein is the most limiting nutrient to milk production under tropical dairy farming conditions (Bouwman, 1999), and as such the formulated dairy feed quality calculations were therefore based on CRT for CP values. One major asumption made in milk yield calculations is that production of 1 kg of milk requires 84 grams of CP (Bouwman, 1999; Muia et al., 2005). Thus, a ration of X % CP content is equivalent to X g of CP per 100g of kg DM feed or (10Xg of CP per 1 kg DM feed), hence the feed quality (Table 9) was calculated as: ration protein value (10X g of CP) divided by 84 g of CP required to produce I kg of milk.

Table 9. Feed quality calculations

Feed Quality	
1Kg of Feed =	1.65 Kg of Milk

3.4 Supplementation Levels

Lactating dairy cattle supplementation levels are majorly dependent on the difference between potential (PMY) and actual (AMY) daily milk yield (denoted by: Y kg of milk per day), roughage quality and concentrates feed quality based on the most limiting nutrient to milk production (CP % content) as well as the number of cow milking times per day (NDDP, 1995). The resultant calculation (Table 10), for instance, assuming 2 milking times per day on average using concentrate feed quality of 10X/84 kg of milk per kg feed, is calculated as:

$$\left(\frac{Y}{10\ X\ /\ 84}\right) \div 2$$: gives the number of kg of supplement feed per milking.

Table 10. Feed supplementation level calculations

Supplementation Level				
Daily Total	0.61	Kg/Cow/Day	Milking Times	2
Per Milking	0.30	Kg/Cow/Milking		

3.5 Marginal Milk Profits

In the formulation of a diet, the objective is to maximise the difference between the income from milk and the expense on feeds. Since formulation is on DM basis, the prices of the feedstuffs are converted from as fed basis into DM basis. This was achieved by dividing as fed price by DM % for each feedstuff. Total income from milk minus total expense on feed, where: optimal milk yield/cow/day (M) multiplied by the price per kg of milk (π_m) computed the total income (M π_m); and price/kg DM feedstuff π_i multiplied by amount of consumed supplement feed per cow per day in kg (X_n) resulted in the total expense on concentrate feed per day ($X_n \pi_i$); hence the Maximum profit function (M π_m - $X_n \pi_i$) was derived. Table 11 presents milk profit margins determined by calculating: [the total revenue from milk sales (extra kg of milk (Y) multiplied by the market milk price (Kenya Shilling 28)] minus [total supplementary feed cost (84Y/10X) multiplied by cost of kg commercial feed (Kenya Shilling 23.44)]. The following assumptions were made: an average market concentrate feed cost of ksh. 23.44, and fresh milk price of kshs. 28. *(Price sources: Naku-Modern-Feed Mill, Nakuru (Kenya) and Ngongongeri-Farm-Njoro (Kenya), between June and August 2011).*

Table 11. Milk profit margin calculations

Profit Margin		
	per Kg of Feed	Ksh. 22.83
	per Cow	Ksh. 13.81
	per Herd	Ksh. 165.77

4. Discussion

4.1 Incorporation of Milk Yield, Dry Matter Intake and P-manure Predictive Functions

Prediction of feed intake by dairy cattle has received much attention for many decades, and numerous models have been developed (Brown & Chandler, 1978; Waldner, 2003; Thorne & Dijkman, 2005; Concepcion et al., 2006). The traditional motivation for this interest has been a balanced diet increases production, efficiency, and profitability of dairy enterprises (Shah & Murphy, 2006). Prediction of feed intake by lactating cows usually depends on knowing what sort of feeds they are consuming. The MY, DMI and P-manure prediction models used in the multiple objectives diet formulation are represented by Functions 1, 2, and 3. These functions provide a strong base upon which a computerised multiple ration formulation program can be built. They are particularly important when cost of extra feed is being balanced against projected returns from additional milk yields and the ability of the cow to consume extra feed in a ration for maximum profit; while guarding against excessive pollutant nutrients from manure into the environment.

4.1.1 Predicted Milk Yield and Dry Matter Intake

The positive relationship between feed intake and milk yield, where milk production increased as feed intake increased, has been previously described but at a progressively diminishing rate (Andrés & Carlos, 2006). Several approaches to modelling DMI exist, including mathematical models (Nagorcka et al., 2004) of ruminal function; the weekly average intake of a group of cows or the daily intake of an individual cow as advanced by various research reports from Agricultural Research Council (ARC), Cornell Net Carbohydrate and Protein System (CNCPS) and National Research Council (NRC) (Jensen et al., 1942; NRC, 2001; Muriuki, 2006; McEvoy, 2008; Fox et al., 2004). However, the NRC is regarded as the "bench mark" model and even where individual states or regional blocks have established their own specific models, they have always used NRC for comparison. Ironically, the NRC model was last updated in 2001, despite recent tremendous achievements by many individual research groups in the field of dairy cow nutrition and feeding; and the precision to predicting DMI and hence MY.

The voluntary DMI of the dairy cow is an important variable in dairy management since it fosters nutritional and economical accuracy in ration formulation. Together with MY, it can be used to estimate the economic value of an individual cow at any given stage of lactation and hence improve economic decisions of whole farm operations. This variable becomes crucial for nutritional reasons, especially when concentrates are formulated for either supplementary or total mixed rations (TMR) for dairy cows. Lack of accuracy in prediction may result in nutrient underfeeding or overfeeding affecting animal performance, animal health or dairy farm environment. Feed intake prediction inaccuracy may also limit the ability of different simulation and optimization techniques to improve the economic and technical efficiency of key operations in dairy farms such as feeding, breeding, or replacement (Hristov et al., 2004, 2005).

4.1.2 Prediction of Minimum Phosphorous Excretion

The underlying assumption of this study is that inclusion levels of P in dairy rations affect the inorganic phosphate (P_2O_5) content of manure excreted by lactating cows. Published results (Lekasi et al., 2001a; Ayako, 2005; Joleen, 2007; Joleen et al., 2008) only report one value for P_2O_5 content of manure excreted (5 g/kg DM manure) and do not specify the P levels in the rations used to compile the data. Therefore, calculated values of P-excretion for lactating cows were used rather than the P_2O_5 results from published sources to better account for the varying levels of P inclusion in rations. Matching feed P content (%) to the amount of milk produced by different lactating groups within a herd is absolutely critical (Valk et al., 2002; Valk and Beynen, 2003; Wu et al., 2003; Dave, 2004; Jodi, 2004). To do this effectively good knowledge about the rate of feed intake of different lactating groups is paramount. According to NRC (2001) feeding recommendations, the highest concentrations of P for high producing cows should be 0.48 % on DM basis.

Past literature has demonstrated the most accurate way to account for P-excreted in manure for lactating cows is subtracting the amount of P in milk produced from the amount of ration P (Morse et al, 1992; Lara, 1993; Wu, et al., 2003). The P excreted by lactating cows was calculated by minimising a non-linear function (Function 3) by Morse et al. (1992), subject to (Equations 2 and 3). The rate of efficiency with which dairy cows utilize P is in the range of ($0.5 > k < 1$) for supplementary concentrates and this rate of P utilisation efficiency coupled with the optimal cow milk yield per day greatly determine the level of P-manure balance. The P utilisation efficiency is an additional component that is addressed in MoF-Dairy Edition (2010) program as a system enhancement to reflect on the realities of DMI as well as P-excretion models; which are based on the assumption that there exists a direct relationship between milk P output and the percentage of apparent P digestibility for individual animals (Valk et al., 2002). Consequently, the higher the rate of P utilisation efficiency, the lower is the P-manure content since much of the dietary P is absorbed into body tissues.

4.2 Implications for Feed Policy Regulatory Mandates and Entrepreneurial Needs

In Kenya, there are about 150 animal feed millers that produce various kinds of mainly concentrate feeds of high energy and protein density (Muriuki et al., 2003; MoLD, 2009). A number of policy and institutional considerations as well as business/economic drivers need to be addressed by the various stakeholders in the dairy feed industry (MoLFD, 2006a, 2006b, 2008) so as to to match the ever emerging dairy farming regulatory challenges of the 21st century. Consequently, there is need for an elaborate policy formulation and regulatory frameworks as well as feed planning decision-making tools for the day to day running of the fast growing feed industry. Some of these issues include: measures to enhance productivity and competitiveness of dairy farming through supply of affordable and quality animal feeds, adoption of a common feed formulation approach that integrates economic, production as well as environmental needs collectively (Mutua et al., 2010), with a view to creating uniformity in feed quality for dairy; and institutional frameworks to safeguard (Mbugua, 1999; Karanja, 2003; Muriuki et al., 2003) and enforce adherence (Tozer and Stokes, 2001; Mutua et al., 2010, 2011) to multiple feed formulation methodology.

The livestock feeds industry in Kenya is regulated through the ‘Fertilisers and Animal Foodstuffs Act Chapter 345, 1963 (revised in 1977)’ and the ‘Standards Act Chapter 496, 1977’ (revised in 1981). Kenya is currently in the process of developing and formulating legislation and policies that deal explicitly with the livestock feeds sector (Muriuki et al., 2003; Technical Team, 2003; Githinji, 2006; Technical Working Group, 2006; Githinji, 2008). As part of the recently instituted countrywide economic reforms, the market for feeds has been liberalised and the feed prices decontrolled. The policy on cattle feeds is not yet finalised and a series of stakeholder consultative workshops have discussed the draft Animal Feeds Bill, 2010. The private sector has always handled the manufacturing, supply and distribution of livestock feeds. The co-operative societies have also been involved in the supply of livestock feed and their involvement is more critical in the rural areas where manufacturers and their distributors may not be present (Muriuki et al., 2003; Githinji, 2006, 2008). These industry actors present a potentially huge consumer market for dairy feed software formulation packages such as the MoF-Dairy Edition (2010) program, which is likely to provide a tailor-made tool in feed manufacturing decision-making process.

4.2.1 Feed Quality

Feed cost accounts for about 40-70 % of dairy production costs in highly intensive dairy systems (Jones et al., 1980; MoLD-NDDP, 1995; Muriuki, 2006; LPEM, 2008). However, there are concerns about the quality of cattle feeds in Kenya (Mbugua, 1999; Staal et al., 2003; Muriuki, 2006), and this is probably the reason why farmers often attribute variable milk quantities and quality to variations in feed quality. From the perspective of the dairy producers, quality of feed may be as important as cost (Technical Team, 2006; AKEFEMA, 2008; MoLD, 2009). Variable and unreliable feed quality increases risks and costs, and may dissuade prospective entrepreneurs from undertaking intensive dairy production. Variable quality may also affect smallholder producers more severely than others. In such conditions, large producers who can invest in their own feed ration formulation may be able to gain a competitive edge over smallholders, who rely entirely on available market supply of feeds of variable quality (Mbugua, 1999; Muriuki, 2003; Mutua et al., 2010). The quality problem is partially affected by low supply of the necessary ingredients, especially those that are not locally available, such as oilseed cakes and meals, fish meals, premixes, minerals, vitamins and amino acids (Muriuki et al., 2003); and also partially by the least-cost formulation approach commonly used by feed millers in Kenya (Mutua et al., 2010, 2011). Nonetheless, the MoF-Dairy Edition (2010) formulation software package potentially offers a solution since it optimises cost, production and policy regulatory frameworks step-wise by integrating the three Functions.

The cattle feeds market in Kenya is regulated by the government (i.e. MoLD and KEBS), which is also responsible for setting quality standards for all feed products sold in or imported. These standards are supposed to be reviewed every five years or as need may arise (KEBS, 1990). Unfortunately, standards for cattle feeds have not changed for a long time due to inadequate resources at KEBS to conduct regular and comprehensive reviews (Muriuki et al., 2003), and also the slow pace of the MoLD in instituting legal, institutional, policy and regulatory reforms urgently needed to foster feed industry growth and expansion. To enforce standards for cattle feeds, KEBS officials are mandated to conduct random audit visits and take samples from feed millers for analyses. However, this process alone may not necessarily guarantee sustainable feed quality since no attempts are ever made to audit the actual feed manufacturing decision-making process as well as the ration formulation methods implemented in compounding concentrate dairy feeds. It is, perhaps, time that feed quality policy regulation went beyond just checking the feed samples but also include harmonisation of the formulation methodologies followed by the feed millers; with a view to standardizing them; if any meaningful uniformity in feed quality is to be realised.

Feed millers in Kenya are registered as companies by the Registrar of Companies through the Companies Act Cap 486 and licensed by the respective Local Authorities. All together, about 150 millers have been registered and licensed to operate in Kenya (MoLD, 2009). The government has only recently developed a policy for the feed sector and a proposed Animal Feeds Bill, 2010 is yet to be tabled in Parliamnet (Muriuki et al., 2003; Githinji, 2006; Technical Team, 2006; Technical Working Group, 2006; Githinji, 2008). Policies that directly affect cattle feeds such as decontrolled prices and liberalised marketing were implemented as part of the economy-wide Structural Adjustment Programmes of government. Unfortunately, efforts to control feed quality have not been addressed in the current Animal Feeds Policy and Regulatory Framework. One way to entrench this into the proposed Draft Bill would be to champion the need to adopt a common feed formulation methodology and use of uniform software programs, such as the MoF-Dairy Edition (2010), that optimise economic, production as well as environmental policy regulatory goals collectively.

In 1996, the then Ministry of Agriculture and Livestock Development (Kenya) responded to farmer's quality concern of various farm inputs by appointing a team to act as inspectors for various farm inputs such as fertiliser and animal feeds. The teams' task was to ensure that the inputs met the prescribed minimum quality standards, however, to date the team has not been activated (Muriuki et al., 2003; Githinji, 2006; Githinji, 2008). This leaves the quality assurance function to be performed by only KEBS on behalf of the government, which is itself constrained by lack of capacity to regulate the feed sector. Government Veterinary doctors, though gazetted feed inspectors, rarely perform this duty. Weak policy and lack of a specific regulator, as well as lack of capacity to regulate (Muriuki et al., 2003; Muriuki, 2006; Technical Working Group, 2006), is believed to have created an environment that makes it possible for some manufacturers to occasionally supply substandard feeds. To arrest the current state of weak industry coordination, potential feed quality inspectors could be trained on multiple objective feed manufacturing principles as part of the efforts to strengthen the ministry's feed inspectorate unit. Consequently, a regulatory framework that encompasses auditing of both feed formulation process approach as well as concentrate feeds sampling is likely to replace the long list of potential inspectors and enhance quality control checks prior to damages being done besides saving the industry operational costs.

4.2.2 Minimum P-Excretion for Environmental Management

As Kenya enhances its readiness for the Vision 2030 industrialisation goal (Kenya Vision 2030, 2008), attention is fast shifting to the quality of service offered by state agencies charged with regulatory mandates, such as NEMA and KEBS, which have come into sharp focus against the backdrop of rising tide of entrepreneurial culture (Omondi, 2008). A primary regulatory issue associated with livestock production is manure storage and disposal. Consequently, the livestock industry is facing a number of environmental challenges and there is increased pressure on dairy producers to manage their excess manure nutrients more efficiently. One major area of concern is P and its role as an environmental pollutant (Dou et al., 2003; Dave, 2004; Jodi, 2004; Ayako, 2005).

Nutrient management has become increasingly important since NEMA waste management regulations (EMCA, 1999) were implemented in Kenya. Consequently, livestock producers, feed suppliers, and extension officers are challenged with on-going developments in waste management regulations. The government of Kenya administers policy and publishes regulations for livestock and livestock waste management through the Ministry of Livestock Development and NEMA, respectively. The NEMA, established under the Environmental Management and Coordination Act (EMCA) No. 8 of 1999, is the principal institution of the government in the implementation of all policies relating to environmental management. The NEMA farm waste management policy covers programs on improved livestock production under sustainable environmental management (EMCA, 1999; Waste Management Regulations, 2006; MoLD, 2009). Currently, the NEMA waste and nutrient management planning is focused on crop nutrient management and waste treatment. However, efforts on how to deal with manure as a waste and/or fertilizer are weak (Waste Management Regulations, 2006; Lekasi et al., 2001a; Lekasi et al., 2001b; Ayako, 2005). Therefore, additional environmental regulations specific to excess manure pollutant nutrients will continue to be developed and implemented in Kenya, since NEMA regulations on dairy farm manure storage and disposal have implications on how livestock, milk and dairy products are produced and marketed.

Diet plays a very important part in the overall farm balance of P. Excretion of P-manure is directly related to P consumption by the cow. Research has shown that reducing dietary P concentration can have a tremendous impact on the overall P management on farms (Tozer & Stokes, 2001; Liu, 2003; Dave, 2004; Arriaga et al., 2009). The fourth schedule of EMCA (2006), Regulation 22, Y37 sections a, b, and c stipulates the levels of organic phosphates wastes considered hazardous; and none for inorganic phosphates which are considered critical environmental aquatic pollutants from manure. Whilst the livestock waste regulations are promulgated and enforced by NEMA, it is not yet clear which regulations specifically address concentrate feeding operations in Kenya. Since cow manure entering waterways does not go through municipal treatment system processes, it presents a potential constraint to MoF-Dairy Edition (2010) package in its attempt to determine potential P-manure environmental pollution. Consequently, the MoF-Dairy Edition (2010) program potential manure P-balance reports were based on both published literature (5 g/kg DM manure) as well as the EMCA (2006) guidelines on waste management for phosphates (30 mg/Litre Waste Effluent). Hence, manure nutrient management guidelines in Kenya are not yet comprehensive and as such will continue to be developed further with a view to explicitly addressing the ever emerging industry regulatory issues.

4.2.3 Business Economic Analysis

The multiple objectives feed formulation approach can be used in different situations to assist livestock managers to plan diets and/or feeding strategies that may allow them to best meet their dairy economic and business objectives as well as policy requirements (Tozer & Stokes, 2001; Thorne & Dijkman, 2001; Mutua et al., 2010, 2011); such as the MoF dairy cattle supplementary feeding. Dairy ration formulation aims at minimizing costs while maintaining a specified milk production level. The production function for milk yield can be represented as:

$Y = f(L, F, \theta)$,

Where: Y is the milk yield, L is labor input, F is feed input, and θ is defined as random states of nature that affect milk production, such as weather conditions and stress levels on cows.

The dairy producer evaluates different methods to decrease the cost of production dependent on input levels. In particular, they evaluate the nutrient composition of different feeds to determine if a less expensive feedstuff can be substituted in the ration to decrease input costs while maintaining nutritional requirements for a specified milk production level (Joleen, 2007; Joleen et al., 2008). Standard dairy cattle nutritional requirements and specific cow production performance were considered in the MoF-Dairy Edition (2010) program development. The formulation contained all known feeding and nutritional inputs and animal production outputs. The methodology utilised feedstuffs based on cost and composition, animal performance (kg of milk) as a function of nutrients and total animal product output (Varela-Alverez & Church, 1998; Tozer & Stokes, 2001). The produced milk gave the calculated revenues while the price of feed was an expense. The objective was to maximise on milk profits; within the confines of sustainable dairy production. The formulation used predicted MY and DMI of the cow, production response to nutrients intake, and daily nutrients requirements for lactating cows based on NRC (2001) specifications.

Smallholder dairy production in Kenya contributes about 56% and 70% of total and marketed milk production, respectively (Omore et al., 1999). The productivity per animal from these farms remains low; partly due to quality variation (MoLD, 2009) of available commercial concentrate supplementary feeds. From the public point of view, the role of cattle feed manufacturers is mainly to make feeds available to dairy producers at affordable prices, at the right time and most importantly, to ensure consistent quality in conformity with set standards (Muriuki et al., 2003; MoLD, 2007, 2009; Mutua et al., 2010). They are expected to be efficient in their manufacturing, keeping pace with new technologies and global feed standards as well as emerging regulatory guidelines and be able to translate their efficiency into competitive prices, and also promote proper use of concentrate feeds within the dairy industry. Therefore, adoption of a feed formulation program; such as MoF, that attempts to offer economic predictions per unit input into dairy farming is probably one of the best tools for transforming the feed industry.

While milk production is important, it is the average cost of milk production which is the key driver of marginal milk profits (Omore et al., 1999; Staal, et al., 2003; Thorne & Dijkman, 2005; Newman and Savage, 2009). Additionally, the choice of breed and management aspects is synergetic to supplementary feeding and hence the relevance of the MoF-dairy Edition (2010) to modern dairy feed manufacturing process. In effect, supplements should be used to manage pasture, and should not be complete feed for the animal. Supplementary feeding is only beneficial when there are insufficient pastures. The quality of harvested and eaten pastures explains the majority of the variations in milk revenues between farms (Newman and Savage, 2009; Mutua et al., 2010; Tarrant et al., 2010). To guarantee sustainable dairy profitability, supplements should therefore be used only to fill a true concentrate feed nutritional deficit so that generated liquidity and cash flow can ensure business survival and provide opportunities for future growth and expansion.

5. Conclusion

The current rate of development in desktop computing facilities and availability of programming tools for rapid development of user-friendly interfaces; and the availability of reliable data on MY, DMI, and P-manure functions, can result in successful delivery of tailored-software products suitable for providing decision support tools in feed manufacturing. There is need to entrench a common multiple objectives feed formulation methodology into the proposed Animal Feeds Draft Bill 2010 in Kenya, for effective policy formulation and regulatory framework that are responsive to a wide range of circumstances. Emerging global economic, production as well as environmental regulations are driving the need for broader policy, institutional as well as regulatory framework that include auditing of both feed formulation and manufacturing process approach as well as concentrate feeds sampling. Thus, the need for the MoF-Dairy Edition (2010), that optimise economic, production as well as environmental policy regulatory goals collectively.

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