

FEEDING BLEND OPTIMIZATION FOR LIVESTOCK BY USING GOAL PROGRAMMING APPROACH

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ABSTRACT

Feed blend formulation is an important process in the livestock industry. This process will help the livestock industry nowadays to keep providing continuous supply of animal protein food to cater for the expanding and increasing demand as Malaysia is undergoing a rapid growth in economic and human population. The formulation of feed blend involves multiple objectives to be achieved through the decision making process. In this project, Goal Programming (GP) method is used to formulate the livestock feed blend for a farm situated in Negeri Sembilan, Malaysia. This method is an approach of assisting the decision makers to solve multiple objectives for livestock feed blend in determining an optimal combination of ingredients to meet the nutritional requirements. This will lead to a rational use of available resources by minimizing the production cost and maximizing the nutritional value required for the growth of livestock. The nutrition for the livestock contains dry matter (DM), metabolism energy (ME), crude protein (CP) and crude fibre (CF). Then, the preemptive model is tested using LINGO software and the results have been validated by using Mean Absolute Percentage Error (MAPE). All of the multiple objectives have been fully achieved which represents the ability of the goal programming model to comply with optimizing the feed blend formulation.

Keywords: Feed Blend, Goal Programming, Livestock, Optimization

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1. Introduction

Livestock are any breed or population of domestic animals that are raised for home use or making profit normally in farm for instance cattle, sheep, goats, swine, poultry and any other animals that are involved in food production. The primary challenge of livestock industry nowadays is to keep providing continuous supply of animal protein food to cater for the expanding and increasing demand as every country including Malaysia is undergoing a rapid growth in economic and human population. Efficient livestock production plays a significant role for a profitable and sustainable livestock industry, which can be achieved by increasing the quantity and quality of livestock feed (Babić & Perić, 2010). Livestock feed formulation involves the blending of raw ingredients to satisfy the nutritional requirements for the maximum growth of livestock as well as minimizing its production cost that can be attained only by an optimal blending of ingredients from available resources. The problem of over

formulation or under formulation of livestock feed blend that does not meet the requirement will not support for the maximum livestock growth (Annets & Audsley, 2002).

The focus of this research is to find the optimal blending of ingredients to produce livestock feed, that is significant for a farm in Negeri Sembilan, Malaysia. The company businesses primarily engaged in manufacturing livestock feed blend, halal meat production, frozen food processing, slaughtering service, fresh milk production, feedlot and breed lot, and some other products and services. In this research, the optimization of livestock feed blend involves multiple research objectives, which are cost minimization and nutritional value maximization in term of dry matter (DM), metabolism energy (ME), crude protein (CP) and crude fibre (CF). The beef cattle feed has been chosen as the subject of input data. All objectives could be reached by applying mathematical optimization methods that can verify an optimal mixture of ingredients to achieve the nutritional requirements of livestock leading to cost reduction and rational use of existing resource.

Waugh (1951) has defined livestock feed blend in mathematical formulation that is linear programming (LP). However, LP has many limitations due to the restriction of the decisions maker's preferences as well as this method only form a singular objective function (Lara, 1993). Therefore, in this research, goal programming (GP) method is applied as it involves multiple objectives to be achieved. Goal programming was introduced by Charnes and Cooper in 1955 where it is one of the techniques in Operational Research (OR) that has widely been used to solve multi criteria decision making problems (Jenal *et al.*, 2011). This method defines a target level for each of the objectives or goals and assigns relative priorities to achieve those goals. GP has been widely used in many fields where it can minimize the variance for each objective from the desired target value (Orumie & Ebong, 2014).

GP also has the capability of simultaneously satisfying numerous conflicting goals with different applicable means to the decision making situation as the real problem of the world actually involves various undisputed objectives. This contribute to the huge number of goal programming applications in many and various areas such as in solid waste management, quality control, accountancy, marketing, human resources, farming, forestry, transportation, site selection, telecommunication, aviation and space studies (Aouni & Kettani, 2001). Some of other research are optimization in library funding (Hassan & Loon, 2012), tourism activities (Hassan & Halim, 2012), the management of pineapple nutrient (Hassan & Sahrin, 2012), optimization of staff scheduling problem (Rashid *et al.*, 2018), marketing strategy (Dendere & Masache, 2013), supplier selection (Rashid *et al.*, 2019) as well as managing forest diversity (Bertomeu & Romero, 2001).

2. Methodology

This section presents the data that has been taken from a farm situated in Negeri Sembilan, Malaysia to find the optimal blending of ingredients per feeding for male beef cattle weighted about 500 kilograms. The data for price and nutritional content in term of dry matter (DM), metabolism energy (ME), crude protein (CP) and crude fibre (CF) from eight sort of feed is shown in Table 1. Table 2 shows the cost and the nutritional content needed per feeding. In order to obtain the optimal feeding blend, the constraints in the model must fulfill the requirements in Table 2. The targeted values for each sort of feed are shown in Table 3.

Table 1. Livestock feed blend

Sort of feed	Cost (RM/kg)	DM (%)	ME(MJ/kg)	CP (%)	CF (%)
Palm oil sludge	0.09	91.00	5.99	10.00	15.00
Palm kernel cake	0.70	91.00	8.91	16.00	15.00
Rice bran	0.45	92.00	8.78	13.00	49.00
Corn gluten	0.90	90.00	10.57	8.00	3.00
Soybean waste	0.30	50.00	5.15	13.00	13.00
Coconut husk	0.06	80.00	5.98	5.00	26.00
Molases	1.20	76.00	8.83	4.00	0.00
Dicalcium phosphate	3.60	91.00	10.11	15.00	11.00

Table 2. Requirement for cost and nutrients for daily feeding

Nutrients	Constraint Type	Max Requirement
Cost	\leq	4.16 (RM)
Dry Matter (DM)	\geq	7.90 (kg)
Metabolism Energy (ME)	\geq	74.90 (MJ)
Crude Protein (CP)	\geq	0.95 (kg)
Crude Fibre (CF)	\geq	0.05 (kg)

Table 3. Targeted values for each sort of feed

Type of Feed	Targeted Value Per Feeding (Kg)
Palm oil sludge (x_1)	$1.50 \leq x_1 \leq 2.00$
Palm kernel cake (x_2)	$2.00 \leq x_2 \leq 2.50$
Rice bran (x_3)	$1.40 \leq x_3 \leq 1.60$
Corn gluten feed (x_4)	$0.40 \leq x_4 \leq 0.60$
Soybean waste (x_5)	$1.50 \leq x_5 \leq 3.50$
Coconut husk (x_6)	$1.40 \leq x_6 \leq 1.60$
Molases (x_7)	$0.40 \leq x_7 \leq 0.60$
Dicalcium Phosphate (x_8)	$0.03 \leq x_8 \leq 0.06$

2.1 Model Development

Listed below are the input parameters, decision variables, constraints, and the objective function in the mathematical model for optimization of livestock feed blend.

2.1.1 Input Parameters

The following notations are used to construct the mathematical model in this study:

n = Number of sorts of feed in the model, $n = 8$

i = Index for sort of feed in the model, $i = 1 \dots n$

A_i = Lower limit value in kilograms for sort of feed i , $i = 1 \dots 8$

B_i = Upper limit value in kilograms for sort of feed i , $i = 1 \dots 8$

C_i = Cost per kilograms for sort of feed i , $i = 1 \dots 8$

D_i = The percentage of dry matter content for sort of feed i , $i = 1 \dots 8$

E_i = Metabolism energy content in MJ/kilograms for sort of feed i , $i = 1 \dots 8$

F_i = The percentage of crude protein content for sort of feed i , $i = 1 \dots 8$

G_i = The percentage of crude fibre content for sort of feed i , $i = 1 \dots 8$

d_i^+ = The positive deviation variable of the goal constraints i , $i = 1 \dots 5$

d_i^- = The negative deviation variable of the goal constraints i , $i = 1 \dots 5$

2.1.2 Decision Variable

The decision variables are defined as follow:

x_i = Type of the sorts of feed, $i = 1 \dots 8$

2.1.3 Hard Constraints

The hard constraints that are constructed for this model which must be fulfilled are the targeted values for each sort of feed per feeding. There are eight types of sort of feed that are measured in kilograms in this study which should have values between the lower and upper limit as follow:

$$A_j \leq \sum_{j=1}^n X_j \leq B_j, j = 1 \dots 8 \quad (1)$$

2.1.4 Soft Constraints

The soft constraints in this model are shown in Eq. (2)-(6). The aspiration values are the right-hand side value of the soft constraints which are the cost and the requirement of nutrients per feeding. The set of soft constraints in the model formulation will have positive deviation, d_i^+ and negative deviation, d_i^- where this model will attempt to fulfill these soft constraints by minimizing the deviations of the soft constraints from the aspiration values. The value of these deviations' variables will be explained in the next section.

2.1.5 Goals and Priorities

The set of soft constraints are then constructed in the model formulation as the goals. Then the goals will be organized according to the highest to the lowest priority that has been decided by the owner of the farm. The priority of each goal is defined as follows:

Goal 1 (P1): This goal is to minimize the cost per feeding where the owner of the farm has set up a cost which should not exceed RM4.16. The overachievement of the cost must be minimized and the goal constraint is as follow:

$$\sum_{j=1}^n C_j X_j + d_1^- - d_1^+ = 4.16, j = 1 \dots n \quad (2)$$

Minimum: d_1^+

Goal 2 (P2): This goal is to maximize the content of dry matter in each sort of feed so that the total amount of dry matter per feeding is greater than 7.90 kilograms. The underachievement of total dry matter content must be minimized and the goal constraint is as follow:

$$\sum_{j=1}^n D_j X_j + d_2^- - d_2^+ = 7.90, j = 1 \dots n \quad (3)$$

Minimum: d_2^-

Goal 3 (P3): This goal is to maximize the content of metabolism energy in each sort of feed so that the total amount of metabolism energy per feeding is greater than 74.90 MJ. The underachievement of the total metabolism energy content must be minimized and the goal constraint is as follow:

$$\sum_{j=1}^n E_j X_j + d_3^- - d_3^+ = 74.90, j = 1 \dots n \quad (4)$$

Minimum: d_3^-

Goal 4 (P4): This goal is to maximize the content of crude protein in each sort of feed so that the total amount of crude protein per feeding is greater than 0.947 kilograms. The underachievement of total crude protein content must be minimized and the goal constraint is as follow:

$$\sum_{j=1}^n F_j X_j + d_4^- - d_4^+ = 0.947, j = 1 \dots n \quad (5)$$

Minimum: d_4^-

Goal 5 (P5): This goal is to maximize the content of crude fiber in each sort of feed so that the total amount of crude fiber per feeding is greater than 1.422 kilograms. The underachievement of total crude fiber content must be minimized and the goal constraint is as follow:

$$\sum_{j=1}^n G_j X_j + d_5^- - d_5^+ = 1.422, j = 1 \dots n \quad (6)$$

Minimum: d_5^-

2.1.6 Objective Functions

In this study the objective functions are to minimize all of the deviation variables that have been set up in the goal constraints as shown below:

Minimize $P1 + P2 + P3 + P4 + P5$ where,

$$P1 = d_1^+ \quad (7)$$

$$P2 = d_2^- \tag{8}$$

$$P3 = d_3^- \tag{9}$$

$$P4 = d_4^- \tag{10}$$

$$P5 = d_5^- \tag{11}$$

The final preemptive goal programming model as in (Hassan & Sahrin, 2012), will be as follows:

Minimize $P1 + P2 + P3 + P4 + P5$

Subject to

Equations (1)-(11);

$$d_1^-, d_1^+, d_2^-, d_2^+, d_3^-, d_3^+, d_4^-, d_4^+, d_5^-, d_5^+ \geq 0$$

3. Result and Discussion

The preemptive goal programming model for the optimization of livestock feed blend has been tested using LINGO software. LINGO software is a simple tool which helps to apply linear and nonlinear optimization which will find the answer that yields the best result. LINGO includes a set of built-in solvers to tackle a wide variety of optimization problems where the solvers are directly linked to the modeling environment (Krishnaraj et al., 2015). There are five goals that were assigned with priorities in this research. Table 4 shows the current amount of the sorts of feed per feeding and the result from the preemptive model while Table 5 shows the result of the deviation variables.

Table 4. Current values and the preemptive values for the sorts of feed

Current	Preemptive
$x_1 = 1.70$	$x_1 = 1.98$
$x_2 = 2.50$	$x_2 = 2.00$
$x_3 = 1.50$	$x_3 = 1.60$
$x_4 = 0.50$	$x_4 = 0.40$
$x_5 = 3.50$	$x_1 = 2.60$
$x_6 = 1.50$	$x_6 = 1.60$
$x_7 = 0.30$	$x_7 = 0.40$
$x_8 = 0.05$	$x_8 = 0.04$

Table 5. The deviation variables

Priority	Deviation Variables	
P1: Cost	$d_1^- = 0$	$d_1^+ = 0$
P2: Dry Matter (DM)	$d_2^- = 0$	$d_2^+ = 0.48$
P3: Metabolize Energy (ME)	$d_3^- = 0$	$d_3^+ = 0$
P4: Crude Protein (CP)	$d_4^- = 0$	$d_4^+ = 0.25$
P5: Crude Fibre (CF)	$d_5^- = 0$	$d_5^+ = 0.73$

The values of $d_1^+ = 0, d_2^- = 0, d_3^- = 0, d_4^- = 0, d_5^- = 0$ show that all of the goal has been fully achieved. P1 with the of value of $d_1^+ = 0$ indicates that the production cost has achieved the minimum cost. The value of $d_2^+ = 0.480$ for P2 shows that dry matter content can be increased by 0.480 kilograms in each feeding. The value of $d_3^+ = 0$ for P3 shows that the metabolism energy has achieved the maximum value. The value of $d_4^+ = 0.252$ for P4 indicates that the crude protein requirement can be increased by 0.252 kilograms than the expected value while the value of $d_5^+ = 0.731$ for P5 shows that the crude fiber requirement can be increased up to 0.731 kilograms from the available sort of feed. In order to validate the results, error calculation is established based on the error deviations from the aspired target of the preemptive model and also those form current values as indicated in Table 6 by using Mean Absolute Percentage Error (MAPE) analysis (Hassan, 2016). MAPE is an average percentage error measurement that is calculated using the absolute error in each period divided by the observed value for that period (Khair et al., 2017). The formulation for MAPE is as follow:

$$\frac{\sum \left| \frac{e_i}{x_i} \right|}{\sum x} \times 100 \tag{12}$$

Table 6. Error calculation for the preemptive goal programming model

Priority	Aspiration (x)	Preemptive	Error $\left \frac{e_i}{x_i} \right $	Current	Error $\left \frac{e_i}{x_i} \right $
P1	4.16	4.16	0.00	4.71	0.13
P2	7.90	8.37	0.06	8.88	0.12
P3	74.90	74.85	0.0007	81.06	0.08
P4	0.95	1.20	0.26	1.36	0.43
P5	1.42	2.15	0.51	2.23	0.57
Total	89.33	90.73	0.84	98.24	1.33

The MAPE calculation of the preemptive model is as follow:

$$\frac{\sum \left| \frac{e_i}{x_i} \right|}{\sum x} \times 100 = \frac{0.84}{89.33} \times 100 = 0.94\% \quad (13)$$

Then the MAPE calculation of the current value is as follow:

$$\frac{\sum \left| \frac{e_i}{x_i} \right|}{\sum x} \times 100 = \frac{1.33}{89.33} \times 100 = 1.49\% \quad (14)$$

Both MAPE value for preemptive model and current value is less than 10% of percentage error. However, it can be seen that the error of preemptive model is less than the error of the current value which indicates that the preemptive model gives better result which is closer to the aspiration value.

4. Conclusion

The preemptive goal programming model using LINGO software successfully obtained the good results, and error analyses using mean absolute percentage Error (MAPE) verified its optimality. Thus, it is shown that the mathematical programming model can be used for decision maker to plan and obtain optimized livestock feed blend. It is recommended for future work to consider factors such as the weight of the livestock as well as apply integrated method such as GP and Analytic Hierarchy Process in the model formulation.

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