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Design and Validation of Ration Formulation of Cattle – A Research Investigation

Vishal Patil[a] Radha Gupta[b] Rajendran D[c] and Ravinder Singh Kuntal[d]

[a]*Department of Mathematics, Jain University, Bangalore, Karnataka, India*
E-mail: vishal.patil33@rediffmail.com, ravindercertain@gmail.com
[b]*Department of Mathematics, DSCE, Bangalore, Karnataka, India*
E-mail: radha.gaurav.gupta@gmail.com
[c]*National Institutes of Animal Nutrient and Psychologist, Bangalore, Karnataka, India.*
E-mail: rajnutri@yahoo.com
[d]*Department of Mathematics, Jain University, Bangalore, Karnataka, India*
E-mail: ravindercertain@gmail.com

Abstract: Ration formulation is one of the basic needs of animal yield industries. In an attempt to optimising the ration formulation many mathematical models have been used with varying success. Among all the models, Linear Programming Model (LP) is used adequately for least cost ration formulation for many years. In this paper linear models are prepared for minimum cost for three different cow livestock named as Model1, Model2 and Model3. The constraints are designed with utmost care using specially designed Total Mixed ration (TMR) calculator. Its solution is found using two different techniques in Excel Solver and Controlled Random Search Technique (RST) the results obtained shows that there is "no significance difference in the techniques used to solve these linear models".
Keywords: *Ration formulation, Linear Programming Model, Excel Solver, Random Search Technique.*

1. INTRODUCTION

Livestock plays an important role in Indian economy. About 20.5 million people depend upon livestock for their livelihood. Livestock contributed 16% to the income of small farm households as against an average of 14% for all rural households. It also provides employment to about 8.8 % of the population in India. Livestock sector contributes 4.11% GDP and 25.6% of total Agriculture GDP as in [1].

Dairy industries have a different resources and objectives; in which animal diet formulation and nutrient utilization with minimum cost are important ones. There are many techniques are in use for animal ration formulation for more than hundred years. For an effective ration formulation, different nutrient ingredients are mixed together in such a way that it provides all necessary nutrition at different stages of production. Different category of animals has different requirements of energy, protein to maintain growth as well as production. The objective of ration formulation is to provide set of nutrient Ingredients to animal, which fulfil the nutrient requirement of animal in the best way.

In 2008 MS Excel spread sheet based procedure of ration formulation is formulated for smallholder dairy production of sub-Saharan Africa, which ensures that the ration is balanced for all the required nutrients which is low-cost as well as user has significant control over the process. By this method, the authors incorporated the fodder legumes Leucaena diversifolia, Leucaena pallida, Leucaena esculenta, Acacia angustissima and Calliandra calothyrsus, which results in, cost reduction from 10 % on C. calothyrsus to 30% on L [6].

In 2014, the mathematical model was developed in What's Best 9 (WB! 9) for Excel to optimise a fodder for dairy cows which results in minimizing the ration cost, which is one of the way to prepare fodder meal (ration) for dairy cows with nutrient requirements [7].

In 2013 The Random Search Technique and Genetic algorithm is used to formulate the least cost ration for sahiwal cows of second to fifth lactation number to maximize the milk yield based on secondary data Results obtained shows that the performance of both the techniques can be implemented for nonlinear livestock ration formulation problem as in [4].

By using Microsoft Excel feed formulation model has been developed which is user friendly and it don't require repeated calculation at different levels. It only require cueing-in of feeds and their quantity and on one click it will show protein and energy level as in [8].

Recently in 2016 a Real Coded Genetic Algorithm (RGA) is applied to find Least Cost Feedstuffs for Dairy Cattle during Pregnancy, in which the obtained results concluded that real coded genetic algorithm can also be used for ration formulation to find least cost feedstuffs in dairy cattle. They also economize the total mixed ration cost such that the feed requirements of the animals are met without any nutrients deficiency [9].

Different category of cattle's have different requirements for energy like carbohydrates and fats, proteins, minerals and vitamins in order to maintain its various functions like reproduction, maintenance, and milk production.

Main objectives of this paper are as follows :

1. To point out the requirements of cow livestock at the minimum cost.
2. To develop Linear Programming model for livestock at different Stages
3. To set the Null Hypothesis: there is no significant difference among the solution techniques
4. To compare the results obtained through different techniques by performing Analysis of Variation (ANOVA) test

The LP Problem is solved by two techniques Excel Solver, Random Search Technique (RST) which are discussed below

1.1. Excel Solver

MS-EXCEL 2010 is most commonly and universally available spread sheet, which provides a rich environment to user for solving LLP & NLP problems in a systematic way. MS-EXCEL comes with MS Office and hence no extra cost is involved to use this method. In the main men solver option is available in which there are different tools like GRG Non-linear, Simplex Method and Evolutionary. It is a simple and effective tool for solving LLP & NLP problems.

1.2. Controlled Random Search Technique

A "Controlled Random Search Technique (RST)" for Global Optimization, it is heuristic in nature, does not take mathematical nature of the functions into account and also gives same time gives acceptable results. The technique is an iterative procedure, based on quadratic approximation, works in two phases, local as well as global, and depends only on function evaluation without making "aprori" presumptions regarding the mathematical nature of the functions present in the objective function or constraints. In the local phase, the objective function is evaluated at a number of randomly sampled feasible points. And in the global phase, these points are manipulated by local searches to yield a possible candidate for the global minima as in [4] & [5]

The Linear Programming model of ration formulation used for this study has 16 decision variables and 08 constraints. The minimum requirement of specified nutrients viz. CP, TDN and Dry matter used in diet considered from NRC 2001 standards. And the minimum and maximum bounds for the constraints are calculated by TMR Calculator (Total Mineral Mixture) which is developed by Dr. Rajendran. D, Sr. Scientist NIANP (National Institute of Animal Nutrient Proteins).

The paper is classified as follows: First section, composition of different ingredients with cost, Crude Protein (CP), Total Digestible Nutrient (TDN), Phosphorus (P), Calcium (CA) with minimum and maximum quantity, is given in tabular form. In the second section, three models are formulated for three different cow livestock. In the third section, these three models are solved using three different techniques: Excel Solver and Controlled Random Search Technique (RST). The last section comprises of setting up the Hypothesis and its testing using ANOVA test.

Table 1
Composition Feed Ingredient with CP, TDN, CA, P, Min, Max in (%) and Cost in (Rs)

Variables (X_i)	*Ingredients*	$COST_i$	DM_i	CP_i	TDN_i	CA_i	P_i	MIN_i	$MAX1_i$	$MAX2_i$	$MAX3_i$
X_1	Paddy straw	5	90	5.13	40	0.18	0.08	0	3	4	4
X_2	CO-4 grass	3	25	8	52	0.14	0.09	0	2.4	3.2	3.2
X_3	Maize fodder	3	25	8	60	0.53	0.14	0	3.6	4.8	4.8
X_4	Co Fs 29 sorghum fodder	3	90	7	50	0.12	0.09	0	1.2	1.6	1.6
X_5	Ragi Straw	3	90	6	42	0.15	0.09	0	1.2	1.6	1.6
X_6	Maize	17	90	8	79	0	0	0	4.8	6.4	6.4
X_7	Soya DOC	38	90	42	70	0	0	0	2.4	3.2	3.2
X_8	Copra DOC	23	90	22	70	0	1	0	3	4	4
X_9	Cotton DOC	23	90	32	70	0	1	0	2.4	3.2	3.2
X_{10}	Wheat Bran	17	90	12	70	1	0	0	1.2	1.6	1.6
X_{11}	cotton seed	21	90	16	110	0	1	0	0.6	0.8	0.8
X_{12}	Concentrate Mix Type I	17	90	22	70	1	0	0	2.4	3.2	3.2
X_{13}	Calcite	4	97	0	0	36	0	0	0.12	0.16	0.16
X_{14}	MM	50	90	0	0	32	6	0	0.06	0.08	0.08
X_{15}	DCP	28	90	0	0	24	16	0	0.024	0.032	0.032
X_{16}	Salt	5	90	0	0	0	0	0	0.12	0.16	0.16

2. LINEAR PROGRAMMING MODELS

Earlier many other mathematical models have been used in formulating ration of livestock like Goal programming to minimize the cost as in [3], linear programming as in [2].In this paper, Linear programming models are prepared for optimization of feed stuff for minimization of costs of ration. All the three LP models are prepared based on the data given in Table 1. The coefficients of the objective function are taken from above table. The minimum and maximum values of constraints given in Table 1 are calculated using TMR calculator. In three models three different cow livestock are considered depending upon their requirement of food. First category of cow named as "Model1" in which weight of the cow is 500kg, age is 4 years, and Pregnant. Second category of cow is named as "Model2" in which weight of the cow is 500kg, milk yield is 10 litres, and fat is 4 %, not pregnant, age is 4 years. Third category of cow is named as "Model3" in which weight of the cow is 500kg, milk yield is 10 litres, fat is 4%, pregnant, age is 4 years, as shown in Table 2.

Table 2
Three Different Models and their Specification

Models	*Model 1*	*Model 2*	*Model 3*
Weight (in kgs)	500	500	500
Milk Yield (in litres)	0	10	10
Milk Fat (%)	0	4	4
Age (in years)	4	4	4
Pregnancy status	Yes	No	Yes

Notations:

Z : Objective function,
$COST_i$: Per unit cost of feed ingredient,
X_i : Variables of feed ingredient in the feed mix,
DM_i : Per unit dry matter of feed ingredient,
CP_i : Per unit crude protein of feed ingredient,
TDN_i : Per unit total digestible nutrient of feed ingredient,
CA_i : Per unit calcium of feed ingredient,
P_i : Per unit Phosphorus of feed ingredient,
MIN_i : Minimum requirement of i^{th} nutrient,
$MAX1_i$: Maximum requirement of i^{th} nutrient in Model 1,
$MAX2_i$: Maximum requirement of i^{th} nutrient in Model 2,
$MAX3_i$: Maximum requirement of i^{th} nutrient in Model 3,

The following three models consist of 16 feed ingredients for optimization of ration. Input data for feeds with cost, and nutritional composition are shown in Table 1.

2.1. Model 1

Objective Function

Minimize $Z = \sum x_i \times \text{Cost}_i \; [i = 1,2,..16]$

Constraints

$$\begin{aligned}
\text{DM} &: \sum x_i \times DM_i = 10 [i = 1,2,..16] \\
\text{CP} &: 1.2216 \le \sum x_i \times CP_i \; \& \; \le 1.404 && [i = 1,2,..16] \\
\text{TDN} &: 5.6844 \; \le \sum x_i \times TDN_i \; \le 6.54 && [i = 1,2,..16] \\
\text{CA} &: 0.0384 \le \sum x_i \times CA_i \le 0.048 && [i = 1,2,..16] \\
\text{P} &: 0.024 \le \sum x_i \times P_i \le 0.027 && [i = 1,2,..16] \\
\text{Roughages} &: 4.8 \le \sum x_i \le 9.6 && [i = 1,2,..5] \\
\text{Concentrate} &: 2.4 \le \sum x_i \le 8.4 && [i = 6,7,..16] \\
\text{Daily Intake} &: 11 \le \sum x_i \le 12 && [i = 1,2,..16] \\
\text{Variables} &: \text{Min} \le {}_i \sum x_i \le MAX1_i && [i = 1,2,..16]
\end{aligned}$$

2.2. Model 2

Objective Function

Minimize $Z = \sum x_i \times \text{Cost}_i \quad [i = 1,2,..16]$

Constraints

DM	:	$\sum x_i \times DM_i = 14$	$[i = 1,2,..16]$
CP	:	$1.488 \le \sum x_i \times CP_i \le 1.712$	$[i = 1,2,..16]$
TDN	:	$8.3392 \le \sum x_i \times TDN_i \le 9.584$	$[i = 1,2,..16]$
CA	:	$0.0624 \le \sum x_i \times CA_i \le 0.064$	$[i = 1,2,..16]$
P	:	$0.0416 \le \sum x_i \times P_i \le 0.048$	$[i = 1,2,..16]$
Roughages	:	$6.4 \le \sum x_i \le 12.8$	$[i = 1,2,..5]$
Concentrate	:	$3.2 \le \sum x_i \le 11.2$	$[i = 6,7,..16]$
Daily Intake	:	$\sum x_i = 16$	$[i = 1,2,..16]$
Variables	:	$MIN_i \le \sum x_i \le MAX2_i$	$[i = 1,2,..16]$

2.3. Model 3

Objective Function

Minimize	Z	$= \sum x_i \times Cost_i$	$[i = 1,2,..16]$

Constraints

DM	:	$\sum x_i \times DM_i = 14$	$[i = 1,2,..16]$
CP	:	$2.224 \le \sum x_i \times CP_i \le 2.56$	$[i = 1,2,..16]$
TDN	:	$9.2512 \le \sum x_i \times TDN_i \le 10.64$	$[i = 1,2,..16]$
CA	:	$0.0752 \le \sum x_i \times CA_i \le 0.08$	$[i = 1,2,..16]$
P	:	$0.0464 \le \sum x_i \times P_i \le 0.048$	$[i = 1,2,..16]$
Roughages	:	$6.4 \le \sum x_i \le 12.8$	$[i = 1,2,..5]$
Concentrate	:	$3.2 \le \sum x_i \le 11.2$	$[i = 6,7,..16]$
Daily Intake	:	$\sum x_i = 16$	$[i = 1,2,..16]$
Variables	:	$MIN_i \le \sum x_i \le MIN3_i$	$[i = 1,2,..16]$

3. RESULTS

The results obtained by various techniques viz., LP Excel solver, Random Search Technique (RST) for least cost ration are presented in Table 3-4 for Model 1, 2 and 3, respectively. The least cost of total ration mixture obtained on Dry Mater Basis for Model 1 is Rs 110.49 using Excel solver, Rs 108.64 by RST. Similarly, the least cost of total ration mixture obtained on Dry Mater Basis for Model 2 is Rs 163.9159 using Excel solver, Rs 162.47 by RST. Also, the least cost of total ration mixture obtained on Dry Mater Basis for Model 3 is Rs 166.94 using Excel solver, Rs 166.64 by RST.

Table 3
Results for optimum value of feed ingredients by Excel Solver (LP)

	Model1	*Model2*	*Model3*
Z	110.4957 Rs	163.9159 Rs	166.9401 Rs
X_1	3	4	4
X_2	0.874015	0.628523	0
X_3	0	0	0.623349
X_4	1.2	1.6	1.6
X_5	1.2	1.6	1.6

	Model1	*Model2*	*Model3*
X_6	0.605353	4.874044	1.390675
X_7	0	0	0
X_8	0.905581	0.952135	0
X_9	0.575757	1.415622	2.632731
X_{10}	1.2	0	0
X_{11}	0	0.615676	0.8
X_{12}	2.037638	0	3.087291
X_{13}	0	0.122	0.073954
X_{14}	0	0	0
X_{15}	0.024	0.032	0.032
X_{16}	0.12	0.16	0.16

Table 4
Results for optimum value of feed ingredients by Random Search Technique (RST)

	Model1	*Model2*	*Model3*
Z	108.6408 Rs	162.4752 Rs	166.6437 Rs
X_1	2.9969	3.9923	3.9879
X_2	0.879609	0.627	0
X_3	0	0	0.61851
X_4	1.19711	1.5927	1.5979
X_5	1.1998	1.598	1.59332
X_6	0.59831	4.8252	1.390917
X_7	0	0	0
X_8	0.8836	0.9505	0
X_9	0.5608	1.4069	2.631224
X_{10}	1.1941	0	0
X_{11}	0	0.60171	0.793055
X_{12}	2.0075	0	3.083216
X_{13}	0	0.11825	0.072069
X_{14}	0	0	0
X_{15}	0.0169	0.031	0.031956
X_{16}	0.10367	0.15931	0.15977

Table 5 shows the total cost of ration for three cattle's by both techniques. One-way ANOVA test at 5% level of significance has been performed for the "Null hypothesis: there is no significant difference between techniques". The test reveals that since *p* value is greater than 0.05, and there is no significance difference between the techniques. Hence, it is observed that mathematical models which are developed in this study can be used effectively for ration formulation to find least cost feed stuffs in dairy cattle.

Table 5
Annova table for testing the hypothesis

Category	*Cost of ration by Excel Solver in RS*	*Cost of ration by RST in RS*
Model 1	110.4957	108.640
Model 2	163.91	162.475
Model 3	166.94	166.643
Mean ± SE	147.11523 ± 18.331	145.919 ± 18.678
P-value	0.9656^{NS}	

NS: Non-significance, $p > 0.05$, No significance difference exists between methods

In Model 1, for cattle we need to feed on an average 11.5 kg of ration as required on dry matter basis satisfying the nutrient requirements. The estimated cost of the ration is 109.568Rs.

In Model 2 for cattle we need to feed on an average 16kg of ration as required on dry matter basis satisfying the nutrient requirements. The estimated cost of the ration is 163.19 Rs.

In Model 3 for cattle we need to feed on an average 16 kg of ration as required on dry matter basis satisfying the nutrient requirements. The estimated cost of the ration is 166.7915Rs.

4. CONCLUSION

One of the major problems while formulating animal diet is to deal with linear constraints which are rigid in nature. Slight variation in the constraint formulation might reduce the solution space and getting a balanced diet without nutrient deficiency will be difficult. Therefore, the formulation of appropriate mathematical model with accurate bounds on constraints is the most important and critical aspect of any feed formulation problem. This being the focus of this study, three linear programming models are prepared for three different stages of cattle and are solved by two different techniques. Both the techniques LP Excel solver, Random Search Technique (RST) are performing well and the results obtained are acceptable since the feed requirements of the animals are met without causing any deficiency in the nutrient intake**.**

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