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Least cost diet plan of cows for small dairy farmers of Central India

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Small dairy farmers of Central India (Madhya Pradesh, Vidarbha region of Maharashtra and Chhattisgarh) "are constrained by inadequate supply of protein source during the dry season" is extracted from Chakeredza et al. (2007). Poor economic conditions of the dairy farmers do not allow them to purchase commercial protein concentrates. Locally available non-conventional protein sources can be used as alternative cheaper protein sources. Formulation of a cost efficient diet balanced for key nutrients has emerged as the biggest problem to the farmers. The present study presents a least cost balanced diet formulation plan for the small dairy farmers. The Linear Programming Technique was applied to formulate the least cost ration plan for daily feeding for the cross bred and local dairy cows separately. The least cost ration plan formulated for daily feeding for cross bred dairy cows yielding 5 to 10 L of milk per day included 3.50 kg paddy straw, 10.60 kg Napier grass, 1.35 kg soybean cake, 2.08 kg wheat bran, and 0.06 kg mineral mixture, costing 19% less in comparison to the routine feeding plan followed by the farmers. Similarly, the least cost daily feeding ration plan formulated for the local lactating cows yielding 3 L of milk per day included 3.06 kg paddy straw, 7.60 kg Napier grass, 0.86 kg soybean cake, 1.20 kg wheat bran, and 0.05 kg mineral mixture, reducing the feed cost by 22% as compared to the existing ration plan followed by the farmers . The least cost ration plan formulated through this study is recommended for use by the small dairy farmers of Central India to reduce the feed cost of dairy animals.

Key words: Least cost, fodder, dairy feed, small scale, linear programming.

INTRODUCTION

Cost of feeding is the single most important factor affecting the profitability of a dairy enterprise. The economical feeding of cows is a major component of a dairy farmer's decision making. Feed typically accounts for 60-80 per cent of variable cost of milk production (Webster, 1993; Patil, 2010). Without good feeding programmes, the benefits of good breeding and management programmes cannot be realized (Chakeredza et al., 2008).

The economical feeding of dairy cows is a relatively complex problem as it has to cater for the nutritional requirement to maintain the health of the cow and milk production. The nutrients to be supplied in a feeding programme include energy, protein, minerals and vitamins (Pond et al., 1995). Carbohydrates and fats are the major source of energy. In Central India (Madhya Pradesh, Vidarbha region of Maharashtra and Chhattisgarh) sorghum, maize, paddy straw, and wheat

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bran are the major sources of energy. Minerals and vitamins are incorporated in the diet as pre-mixes. Protein is included in the dairy meal concentrate and mainly supplied through soybean cake.

Composition of the ration currently fed to the cows is decided based on dry matter intake required for getting a required level of milk production per day. Due to high cost and non-availability of concentrates and protein sources, locally available supplements are required to optimally feed dairy cows. These should be supplied in higher quantities as a replacement to concentrates to reduce the feed cost. However, there is a problem to formulate diets that are balanced with respect to protein, energy, vitamins, and minerals and at the same time being low cost.

Review of existing literature offers numerous examples of utilizing operation research technique for solving nutrition management problem. The most common is the least cost ration optimization based on linear programming technique. It has been widely used in modeling the least cost ration problem (O'Coner et al., 1989; Munford, 1996; Alexander et al., 2006; Chakeredza et al., 2007). No study has until now been reported from Central India that emphasizes cost minimization for feeding dairy cows under constraints faced by the dairy farmers. Therefore, an attempt is made in the present study to formulate a least cost ration plan for the dairy farmers of Central India.

MATERIALS AND METHODS

A total of 200 small dairy farmers, 100 each having cross bred and local lactating cows, were randomly selected through guidance from animal nutrition experts from different parts of Madhya Pradesh, the Vidarbha region of Maharashtra, and Chhattisgarh in such a way so that they could represent a homogeneity regarding type of animal rearing, feeding, and management situation of dairy farmers of Central India. Data were collected during 2009 to 10 through pre-tested questionnaire by interview method.

For each breed/type maintained in the farm, an individual lactating animal was selected, whose per day milk yield was the nearest to the average milk yield per day 5 L for cross bred and 3 L for local during lactation period. Major sources of dietary energy in the study area include wheat bran, broken wheat, maize, soybean cake and roughages (dry fodder). The source of nutrients provided by the majority of dairy farmers was retained in the existing plan to ensure minimum switch over or changes and utilization of locally available material. One method that can be used to derive least-cost rationing is linear programming (Torez, 2000). The linear programming technique was used to work out the least-cost combination of feeds and fodders under the specified nutrient restrictions, which were estimated from the actual feeding of the lactating animal. The following situations were identified for programming least cost combination of feeds and fodder:

Situation I: Cross-bred cows (jersey) yielding 5 to 10 L of milk per day. Situation II: Local cows (mix of breeds) yielding below 3 L of milk per day.

The cost minimizing model used in this study was of the following form:

Minimize $$Z = \sum_{j=1}^{n} C_j X_j$$

Subjected to linear constraints such as:

i. $$\sum_{j=1}^{n} a_{1j} x_j \le B_1$$

ii. $$\sum_{J=1} a_{2j} x_j \le B_2$$

iii. $$\sum_{J=1}^{n} a_{3j} x_j \ge B_3$$

iv. $$\sum_{J=1}^{n} a_{4j} x_j \ge B_4$$

v. $$\sum_{J=1}^{n} a_{5j} x_j \ge B_5$$

vi. $$\sum_{J=1}^{n} a_{6j} x_j \ge B_6$$

And non-negativity constraints $x_j \ge 0$ where, z = total cost of feed mix in rupees; x_j = quantity of j^{th} feed material in the feed mix in kg; c_j = unit cost of feed material x_j in rupees per kg; a_{ij} = amount of i^{th} nutrient available in one kg of x_j feed material; i = 1, 2, 3, 4, 5, and 6.

B_1, B_2, B_3, B_4, B_5, and B_6 are required levels of nutrients such as dry matter supplied by roughages, dry matter supplied by concentrates, total digestible nutrients (TDN), digestible crude protein (DCP), calcium (Ca) and phosphorus (P) for specific level of milk yield per day per lactating animal. Recommended level of nutrients suggested by the animal nutrition experts for maintaining optimum daily milk yield were estimated from the collected data based on average body weight of animal. INRA (France) feeding standard was used.

Objective function

The objective function was to minimize the cost of feed and fodders fed to the milch cows for the specified two programming situations.

Technological matrix

The initial technological matrices for cost minimization problems under the above mentioned two situations were formulated by using the simplex method of linear programming (Anderson et al., 2000). Initial matrices were formulated with nutrient restrictions, purchase price of feeds and fodders, alternative feeds and fodders (or) real activities, disposal activities and artificial activities. These components of initial matrix are discussed below:

Nutrient restrictions

In the present study, two types of nutrient restrictions' were used namely, maximum restrictions and minimum restrictions.

Maximum restrictions

Maximum restrictions were applied to dry matter as the belly capacity of the animal is fixed under an assumption that, the animals are being fed full belly capacity and thus, the dry matter intake was calculated based on actual amount of roughages and concentrates fed to the lactating cows at the specified level of milk production. The dry matter restrictions were imposed separately for roughages and concentrate fed to the lactating animals at the specified level of milk production. Thus, it was ensured that the optimal plan does not violate the requirements of existing nutritional norms.

Minimum restrictions

Minimum restrictions were applied to:

(i) Total digestible nutrients (TDN) which is the system of measuring available energy of feed and energy requirement of animals involving a complete formula of measured nutrients and it is estimated as digestible energy/0.044,
(ii) Digestible crude protein (DCP) which is the amount of crude protein actually absorbed by the animal (NDDB, 2012),
(iii) Calcium (Ca) and,
(iv) Phosphorus (P) that was estimated on the basis of actual feeding for different situations specified and imposed as requirements to satisfy optimal conditions.

Real activities (alternate nutrient sources)

Real activities are alternative nutrient sources available in the locality (Chandler and Walkir, 1972). While selecting the alternative nutrient sources (real activities), the following points were taken into account:

(i) It should be sufficiently available in the locality throughout the year,
(ii) It must be palatable to the dairy animals,
(iii) The information about the digestibility coefficient and chemical composition of feeds and fodders should be available. Based on the above criteria, feeds and fodders considered as real activities included paddy straw, sorghum straw, sorghum fodder, Napier grass, berseem fodder and other fodder, soybean cake, wheat bran, maize, tapioca chips, wheat protein, molasses and mineral mixtures.

Disposal activities

Disposal activities are also termed as non-use activities or slack activities (Babbar, 1956). These are activities to deal with the inequalities of linear programming. In the present study, the inequalities problem was solved by introducing six disposal activities such as dry matter supplied by roughages, dry matter supplied by concentrates, TDN, DCP, Ca and P.

Artificial activities

Artificial activities are used to get a better feasible plan (Anderson et al., 2000) and are used for each restriction which has the disposal activity with minus coefficient. Artificial activity has a positive coefficient for the restriction, denoting that it uses the restrictions. In the present study, four artificial activities were introduced for the four restrictions viz. TDN, DCP, Ca and P.

C_J values

C_j values are the purchase value (cost) per unit of real activity. For farm produced fodders, the cost of production in rupees per unit was used as C_j values. In the case of fodders supplied by other agencies, the market price was considered as the C_j value. For the concentrate activities, the prevailing market prices in the study area in rupees per unit were considered as C_j values as it was observed that, the prices of concentrates did not vary because of its supply from government agencies.

Input coefficients

The specified nutrients viz. dry matter, TDN, DCP, Ca, and P available in different feeds and fodders were obtained from the animal nutrition experts of the study area. The optimal plans for feeding the dairy cows were developed for the two specified programming situations.

RESULTS

Situation 1

The least cost feeding plan reduced the ration cost for cross bred cows from 111.12 to 90 Rupees (Table 1). The least cost ration only used 5 ingredients compared with 13 in the original feed plan, and 10 kg less was needed to meet calculated requirements than what was originally fed to the cows. The principle component of the least cost ration was Napier grass, compared with sorghum fodder in the original diet.

Paddy straw and Napier grass were the principal components of energy, while soybean cake supplied protein. Mineral mixture is essential for lactating cows as it contains Ca, P, Mg, Fe, and Zn. Thus, the feed cost was reduced while keeping the essential source of nutrients for supplying energy, protein and minerals.

Marginal cost of nutrients

Marginal cost of nutrients or shadow price under the given set of conditions indicates the potentiality of nutrients (Table 2). It could be observed that, the activities in the solution at non-zero values have zero shadow prices; those reported at zero level have a negative shadow price indicating reduction in cost by that amount when one unit of the particular nutrient is decreased.

The level of slack activity for phosphorus was 0.068 kg, which indicated that phosphorus restriction was ineffective. This means that the least cost combination of feeds and fodders which meets the dry matter, TDN, DCP and calcium requirements also exceeds the phosphorus requirement by 0.068 kg without any cost implication.

The shadow prices on the slack activities at zero level indicate by how much the cost of the ration would be reduced when the constraint is relaxed by one unit. A decrease in one unit (kg) of dry matter supplied by

Table 1. Optimal plan compared with existing plan for daily feeding 5 L-yielding cross bred cows.

S/N	Source of nutrients	Existing plan		Optimum plan	
		Quantity (Kg)	Cost (Rs)	Quantity (Kg)	Cost (Rs)
1	Paddy straw	4.00	8.00	3.50	7.00
2	Sorghum straw	1.00	2.00	-	-
3	Sorghum fodder	10.00	30.00	-	-
4	Napier grass	3.00	12.00	10.60	42.40
5	Berseem (*Trifolium alexandrinum* L.)	2.00	4.00	-	-
6	Other fodder	3.00	6.00	-	-
7	Soybean cake	1.20	13.03	1.35	21.10
8	Wheat bran	1.25	7.70	2.08	13.35
9	Maize	0.70	8.09	-	-
10	Tapioca chip	0.50	3.33	-	-
11	Wheat broken	0.75	4.82	-	-
12	Molasses	0.25	2.15	-	-
13	Mineral mixture	0.10	10.00	0.06	6.00
		-	111.12 (100.00)	-	90.00 (81.00)

Figures in bracket show the percentage of the total feed cost of the existing plan.

Table 2. Level of slack activity and shadow price for cross-bred cow diet nutrients.

S/N	Particulars	Level of slack activity (kg)	Shadow price (Rs/d)
1	Dry matter from roughages	0	-2.58
2	Dry matter from concentrates	0	-126.81
3	Total digestible nutrients (TDN)	0	-9.35
4	Digestible crude protein (DCP)	0	-270.40
5	Calcium	0	-950.78
6	Phosphorus	0.068	0

roughages constraints reduced the cost of optimal plan by Rs 2.58. For the dry matter supplied by concentrate constraints, one unit decrease will result in a reduction of cost by Rs 126.81 in the optimum plan. The marginal cost of TDN was Rs. 9.35. That is, for every decrease in one unit of restrictions, cost will decrease by Rs 9.35 and vice versa. The marginal cost of DCP and calcium were Rs 270.40 and Rs. 950.38. This means that for every decrease in one unit of these restrictions, the cost will reduce by Rs 270.40 for DCP and Rs 950.38 for calcium

Situation II

The least cost feeding plan reduced the ration cost for local cows from 75.57 to 58.56 rupees (Table 3). The least cost ration only used 5 ingredients compared with 13 in the original feed plan, and 7 kg less was needed to meet calculated requirements than what was originally fed to the cows. The principle component of the least cost ration was Napier grass, compared with sorghum fodder in the original diet.

Marginal cost of nutrients

It can be observed in Table 4 that, supply of P is surplus, amounting to 0.061 kg with zero shadow price. Marginal cost of dry matter supplied from roughages is Rs 2.36 and it is 120.10 for dry matter supplied by concentrates. For both of these restrictions, shadow prices imply that every decrease in one unit of the activity will result in reduced cost of their respective shadow prices. In the case of TDN, DCP, and Ca, the marginal costs estimated are Rs 10.25, Rs 251.20, and Rs.845.32, respectively. Every decrease in one unit of these three constraints will cause a decline in cost of their respective shadow prices.

Table 3. Optimal plan compared with existing plan for daily feeding 3 liter-yielding local cows.

S/N	Source of nutrients	Existing plan		Optimum plan	
		Quantity (Kg)	Cost (Rs)	Quantity (Kg)	Cost (Rs)
1	Paddy straw	4.00	8.00	3.06	6.12
2	Sorghum straw	1.00	2.00	-	-
3	Sorghum fodder	8.00	24.00	-	-
4	Napier grass	3.00	12.00	7.60	30.40
5	Berseem (*Trifolium alexandrinum* L.)	1.50	3.00	-	-
6	Other fodder	0.00	-	-	-
7	Soybean cake	0.70	7.60	0.86	9.34
8	Wheat bran	0.75	4.81	1.20	7.70
9	Maize	0.40	4.62	-	-
10	Tapioca chip	0.30	2.00	-	-
11	Wheat broken	0.35	2.25	-	-
12	Molasses	0.15	1.29	-	-
13	Mineral mixture	0.04	4.00	0.05	5.00
		-	75.57 (100.00)	-	58.56 (77.49)

Figures in bracket show the percentage to the total feed cost of the existing plan.

Table 4. Level of slack activity and shadow price for local cow diet nutrients.

S/N	Particulars	Level of slack activity (kg)	Shadow price (Rs/d)
1	Dry matter from roughages	0	-2.36
2	Dry matter from concentrates	0	-120.10
3	Total digestible nutrients (TDN)	0	-10.25
4	Digestible crude protein (DCP)	0	-251.20
5	Calcium	0	-845.32
6	Phosphorus	0.061	0

DISCUSSION

The existing feeding plan followed by the dairy farmers contained large number of ingredients due to which the feed cost was observed to be high. The animal nutritionists are of the opinion that there is scope to reduce the feed cost by formulating an optimum feeding plan by minimizing the number of ingredients and suitably reallocating their quantities. Therefore, there is a need to formulate an optimum least cost ration plan to reduce the feed cost. Least cost feed formulation is combining many feed ingredients in a certain proportion to provide the target animal (both crossbred and local lactating cows) with a balanced nutritional feed at the least possible cost.

This paper suggested an optimum ration plan through incorporation of locally available feed resources at recommended level for minimization of cost for cross bred and local lactating cows. Through the adoption of the plans it is possible to reduce the food cost while maintaining a balanced diet for the crossbred and local lactating cows. A number of workers, for example Munford (1996), Torez (2000), Djumaera et al. (2009) and Griffith (2010), have advanced the use of linear programming in formulation of least cost diet plans for dairy animals. The optimum plans for crossbred and local lactating cows presented here are user friendly as the user is quite familiar with the ingredients incorporated into the plan. In the optimum plans high cost concentrates are replaced by Napier grass. The higher quantity of Napier grass entered into the final plan is mainly because of its higher production, thereby reducing the per unit cost of production and at the same time providing the essential nutrients required for increased milk production.

The preference to Napier grass in both the plans is due to high dry matter production, reasonably good fodder quality, drought tolerance and its persistence under frequent harvesting. Incorporation of soybean cake into both the optimal feeding plans increased substantially thereby supplying more protein. Soybean cake has a high crude protein content of 44 to 50% and a balanced amino acid composition for feed formulation (FAO, 2004). A high level of inclusion (30 to 40%) is used in high performance monogastric diets (FAO, 2004).

Paddy is the dominant crop of the region and experience has shown that, paddy straw can be used in rations to provide dry matter. Paddy straw can provide neutral detergent fiber, acid detergent fiber and crude protein. Inclusion of wheat bran concentrates in both the optimum ration plans is required, in spite of having a higher price per kg than per kg price of wheat broken and molasses, because it is high in total digestible nutrients. Increase in the cost due to increase in the quantity of wheat bran in the two optimal plans is compensated by the entry of low cost locally available feed resources like Napier grass. Incorporation of mineral mixture in the optimal plan is essential to provide minerals like Ca, P, Na, Cl, K, S and Mg which are essential for increasing milk production. The dairy animal is more likely to suffer from lack of both Ca and P than from a lack of any other mineral, with the possible exception of salt (www.agriculture.kzntl). Paddy straw and Napier grass supplied mainly the energy; soybean cake provided the protein and mineral mixtures supplied minerals like Ca, P, Mg, Zn, Fe, Cu, Iodine etc.

The shadow price of nutrient constraints included in both the models implied that, every increase in one unit of the nutrient will result in reduction of their respective shadow prices. In this study all the nutrient constraints except P have positive shadow prices when the minimum constraint has been reached. The least cost will be increased by the amount of the shadow price if the minimum constraint is forced to be one unit higher. The zero shadow price of P reveals that, the least cost combination of feeds and fodder after meeting all the requirements also exceed the P requirement by 0.068 kg without any cost implication. Similar feed ingredients are incorporated into both the optimum ration plans of cross bred and local dairy cows.

Cost reduction to the extent of 19 and 23% is noticed in the optimum plans for cross bred and local cows as compared to the existing plans. The least-cost feeding plan once formulated through the model will continue for a reasonably long time as there are no frequent changes in price of the ration items as a result of which dairy farmers are continuing the same feeding plan for a sufficient long time. The model does a reasonably good job as the feed ingredients included in the least cost plan are not new to the farmers as these are already used by them in their present feeding plan. The extension workers should try to implement the optimum plans suggested through this study for reduction of feed cost, and feedback from farmers should be obtained for further improvement. However, long term studies on the effect of using higher quantities of Napier in production rations for reducing feed cost need to be carried out.

Conclusion

The optimal plan showed how the locally available cheap ingredients can be combined to formulate a least cost feed plan. The results suggested that, in both situations, there was considerable reduction in total feed cost in the optimal plan while supplying all the nutritional requirements to the animals. This indicates that, there is considerable scope for minimizing the cost, under the given situations and restrictions. Confronted with the situation of growing resource scarcities at farm level, formulation and adoption of optimal plans should form an integral part of farm planning for these farms. In both situations p is available in excess quantities. The marginal quantities of feed items observed in the optimal plans act as a guide for efficient use of existing resources.

The results of this study can be of significant value to dairy farmers of the region. The amount of savings in dairy feed cost could have a large positive impact on reducing animal maintenance cost and thus, the profitability of dairy cooperation.

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