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Research Article

A GOAL PROGRAMMING APPROACH TO RATION FORMULATION PROBLEM FOR INDIAN DAIRY COWS

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A B S T R A C T

Due to limitation of feedstuffs in Mandya, district of Karnataka, small dairy farmers faced many problems to feed balanced, least cost diet to dairy cattle's. From earlier research it was clear that the productivity of cattle's maintained by different dairy farmers was lower and this is mainly due tolimited resources for feeding and small farmers are not having proper knowledge as well as resources to provide low cost balanced ration to cattle's. Therefore, there is a need to focus on minimizing the diet cost by upgrading the scientific dairy farming practices. However, several techniques are in use for animal diet formulation but a successful application of soft computing technique to improve the quality of the solution is always preferred as the rigidity of the functions in Linear Programming Problem (LPP) can be easily handled. Hence, to meet the nutrient requirement,a Primitive Goal programming model for three category of dairy cattle's weighing 500kg each and yielding 10lit of milk with 4% fat content during 7th, 8th and 9th month of pregnancy is been formulated by dividing the goals into set of priorities. In our earlier work [10], LP models for three categories of dairy cattle's has been formulated and solved by Simplex-method, GRG Nonlinear, EA-method and RGA. In the present work, a goal programming model (GP model) has been developed by dividing each goal into set of priorities for all the three categories of animal as there are two high priority objectives i.e. least cost and dry matter intake, to be achieved if possible. This GP model is solved by real coded genetic algorithm with hybrid function, which shows thatfive goals are overachieved whereas one goal is fully achieved and one is underachieved for Cattle 1& 2. It could be concluded that real coded genetic algorithm (RGA) with hybrid function can effectively be used to formulate least cost diet such that the feed requirements of the animals are met without any nutrients deficiency.

INTRODUCTION

India has largest livestock population in world. Livestock is one of the important economic activities especially in the rural areas of country providing income for most of the family. In dairy farming, feeding cost accounts about seventy percent of total operation cost. Even though dairying Programme have attained considerable importance in various Five Year Plans and the States and the Centre for the development of this sector have taken up several schemes/projects but different diet plan is needed for different categories of dairy cows in which while calculating the low cost balanced diet it requires an understanding of nutrient requirement of dairy cow's at different condition.

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As per the 19th livestock census report the population of cows is been increased by 6.52% over previous census report (2007) and the total number of cows estimated in 2012 was 122.9 million. The total number of milking animal in India is 116.77 million, in which the 12% contribution is from cattle [13]. Also as per the Basic animal husbandry & Fisheries statistic 2017, the per capita availability of average milk in Karnataka was 291 gram per day during 2016-17, which are less than 12 top milk-producing states in India like Uttar Pradesh. [14] Karnataka has only 4% share in milk production in year 2016-17. From 2012 to 2016, the cattle population is increased from 1142.62 to 1370.69 (in 000 nos.) which estimate the milk production of milk production of 5718.22 to 6562.15 (in 000 nos.) in which the Average Yield per In-Milk Animal of Non-Descript/Indigenous Cows during 2012-13 to 2016-17 in Karnataka was 2.32- 2.43 kg/day. Area under Fodder Crops is increased from 35 thousand hectares to 2006-07 to 36 thousand hectares and Permanent Pastures and other Grazing lands is decreased from 930 thousand hectares to -906 thousand hectares since 2006-07 to 2013-14 [4]. According to past survey, it was clear that farmers are not feeding the dairy cattle's properly due to high feed cost and unavailability of proper feedstuffs [5].

Therefore, it is necessary to supply least cost balanced diet to dairy cattle's especially during pregnancy andmilking period. Since 1991 many researcher studied feeding practices in which small farmers have limited resources for feeding practice [6]. As livestock, industry plays an important role in development of Indian Economy as the share of Livestock in agriculture GDP is increased from 13.88% to 29.20% since 1990 to 2013.Livestock also contributes to 4% of the National Gross Domestic Product [1,2]. Hence, by considering the economic importance and difficulties of Indian farmers an improvement in feeding practice is required, which results in least cost feed plan for dairy cows at different hypothetical condition.

Linear programming is one of the most commonly used methods followed by many commercial and noncommercial feed formulation programs but Rehman and Romero addressed the limitation of LP while formulating ration in practice. The assumption in LP restricts objective function to be single and constraints to be fixed-RHS, which means the reduction of goal programming model consists of constraints and sets of goals, which are prioritized sometimes. The objective of goal programming is to find the solution, which satisfies the constraints, and come close to the stated goals of respective problem. Theoretically, goals could be satisfied completely, partly, or in some extreme cases, some of them might also not be met. This violence is measured using positive and negative deviation variables that are defined for each goal separately, commonly known as over- or under-achievement of the goal. Since the objective function of the WGP formulation minimizes the sum of total deviation from set goals, the obtained result might yield compromise solution between contradictory goals [11]. Zoran babic *et.al*, applied goal programming method to determine a an optimal blend of ingredients for livestock feed in which, goal programming model proves to be a use full procedure in determining the optimal livestock feed blend [13]. Evolutionary Algorithms (EA) consist of Genetic algorithm, Genetic programming and their hybrid functions [3] and EA highly depend upon its operators [7]. Furuya *et.al* in 1997 used genetic algorithms in which the ratio of ingredients has evolved. Sahman *et al*., used GA to find least cost diet for a livestock, which results in good solution with few constraints [8]. Shilpa Jain *et al*., done the comparative analysis of real and binary coded genetic algorithm on fuzzy time series prediction. Author concluded that the real coded GA runs much faster than binary coded GA [12].

In our earlier research, Linear programming model of dairy cows weighing 500 kg which are pregnant at three different months (7th ,8th ,9th mnts) is formulated and solved using LP simplex, GRG nonlinear, EA and different parameters of Real coded Genetic algorithm based on primary data. This study resulted in "no significance difference between techniques" ($p>0.05$) and concluded that RGA can be used to formulate the least cost diet.Hence, in present study we have extended the work and formulated the Goal programming model of dairy cows, which are pregnant at third trimester i.e. 7th, 8th, and 9thmonth, which required balanced diet to maintain health and to produce milk with 4% fat [10] and is solved using real coded hybrid Genetic Algorithm.

Goal programming model

In agreement with the decision maker (nutritionist), it was decided to try the linear model developed by [10], by formulating it into goal programming models. In earlier work, a linear model for cattle 1, cattle 2 and cattle 3 is been developed for cows with body weight of 500 kg, which is pregnant at third trimester and they need balanced ration for body maintenance, and 10 liter of milk production with 4% fat. Hence three goal programming models for above mentioned cattle's is formulated by considering several goals, where all the constraints except dry matter intake (DMI) are given priority in which least cost is highly prioritized.

In earlier work, the upper and lower bounds for each constraint is been set by the decision maker as per the Indian Council of Agricultural Research-ICAR 2013 and NRC 2001 standard. In this paper, the constraints are converted to goals and their target values on dry matter basis are as follows:

1. To determine the diet plan the cost will be Rs 126.71for cattle-1, Rs 131.82 for cattle-2 and Rs 136.65 for cattle-3.
2. To determine the diet plan total dry matter (DM) intake will be 16.75 kg for cattle-1, 16.89 for cattle-2 and 17.03 for cattle-3.
3. To determine the diet plan the share of Crude protein (CP) will be 1.644 kg for cattle 1, 1.691kg for cattle 2 and 1.738 kg for cattle 3.
4. To determine the diet plan the share of Total Digestible Nutrients (TDN) will be 8.5425 kg for cattle 1, 8.6139 kg for cattle 2 and 8.6853 for cattle 3.
5. To determine the diet plan the share of Calcium (Ca) willbe 0.1176 kg for cattle 1, 0.1223 kg for cattle 2 and 0.1207 kg for cattle 3.
6. To determine the diet plan the share of phosphorus will be 0.04193 kg for cattle 1, 0.04 for cattle 2 and 3.
7. To determine the diet plan the share of roughage will be 12.2858 kg for cattle 1, 12.2076 kg for cattle 2 and 12.1495 kg for cattle 3.
8. To determine the diet plan the share of concentrates will be 4.4642 kg for cattle 1, 4.6824 kg for cattle 2 and 4.8805 kg for cattle 3.

This establishes the goal-programming model in which seven goal functions except DM intake have been formulated asgoals. Eventually, it is difficult to achieve all the seven goals, thereforedeviational variables are introduced.The achievement function of the GP model becomes the sum of the square root of deviation variables, which has to be minimized. This goal-programming model is solved by real coded hybrid genetic algorithm.

GP model 1

$$Min\ Z = \sqrt{p_1\left(d_{cost}^{+}\right)^2 + p_2\left(d_{CP}^{-}\right)^2 + p_3\left(d_{TDN}^{-}\right)^2 + p_4\left(d_{Ca}^{-}\right)^2 + p_5\left(d_{Ph}^{-}\right)^2 + p_6\left(d_{Rough}^{-}\right)^2 + p_7\left(d_{Conc}^{-}\right)^2}$$

Subjected to:

1. Goal1(Minimize Least Cost): $\sum_{i=1}^{17} C_i x_i + d_{cost}^{-} - d_{cost}^{+} = 126.71$
2. Goal 2(Maximize Crude Protein): $\sum_{i=1}^{17} CP_i + d_{CP}^{-} - d_{CP}^{+} = 1.644$ Kg
3. Goal 3(Maximize Total Digestible Nutrient): $\sum_{i=1}^{17} TDN_i + d_{TDN}^{-} - d_{TDN}^{+} = 8.5425$ Kg
4. Goal 4(Maximize Calcium): $\sum_{i=1}^{17} Ca_i + d_{Ca}^{-} - d_{Ca}^{+} = 0.1176$ Kg

5. Goal 5(Maximize Phosphorus): $\sum_{i=1}^{17} Ph_i + d_{Ph}^- - d_{Ph}^+ = 0.04193$ Kg
6. Goal 6(Maximize Roughages): $\sum_{i=1}^{5} Rough_i + d_{Rough}^- - d_{Rough}^+ = 12.2858$ Kg
7. Goal 7(Maximize Concentrates): $\sum_{i=6}^{17} Conc_i + d_{Conc}^- - d_{Conc}^+ = 4.4642$ Kg
8. $\sum_{i=1}^{17} x_i = 16.75$ Kg

GP Model 2

$$MinZ=\sqrt{p_1(d_{cost}^+)^2+p_2(d_{CP}^-)^2+p_3(d_{TDN}^-)^2+p_4(d_{Ca}^-)^2+p_5(d_{Ph}^-)^2+p_6(d_{Rough}^-)^2+p_7(d_{Conc}^-)^2}$$

Subjected to:

1. Goal1(Minimize Least Cost): $\sum_{i=1}^{17} C_i x_i + d_{cost}^- - d_{cost}^+ = 131.8234$
2. Goal 2(Maximize Crude Protein): $\sum_{i=1}^{17} CP_i + d_{CP}^- - d_{CP}^+ = 1.691$ Kg
3. Goal 3(Maximize Total Digestible Nutrient) $$\sum_{i=1}^{17} TDN_i + d_{TDN}^- - d_{TDN}^+ = 8.6139 \text{ Kg}$$
4. Goal 4(Maximize Calcium): $\sum_{i=1}^{17} Ca_i + d_{Ca}^- - d_{Ca}^+ = 0.1223$ Kg
5. Goal 5(Maximize Phosphorus): $\sum_{i=1}^{17} Ph_i + d_{Ph}^- - d_{Ph}^+ = 0.04$ Kg
6. Goal 6(Maximize Roughages): $\sum_{i=1}^{5} Rough_i + d_{Rough}^- - d_{Rough}^+ = 12.2076$ Kg
7. Goal 7(Maximize Concentrates): $\sum_{i=6}^{17} Conc_i + d_{Conc}^- - d_{Conc}^+ = 4.6824$Kg
8. $\sum_{i=1}^{17} x_i = 16.89$ Kg

GP Model 3

$$MinZ=\sqrt{p_1(d_{cost}^+)^2+p_2(d_{CP}^-)^2+p_3(d_{TDN}^-)^2+p_4(d_{Ca}^-)^2+p_5(d_{Ph}^-)^2+p_6(d_{Rough}^-)^2+p_7(d_{Conc}^-)^2}$$

Subjected to:

1. Goal1(Minimize Least Cost): $\sum_{i=1}^{17} C_i x_i + d_{cost}^- - d_{cost}^+ = 136.65$
2. Goal 2(Maximize Crude Protein): $\sum_{i=1}^{17} CP_i + d_{CP}^- - d_{CP}^+ = 1.738$ Kg
3. Goal 3(Maximize Total Digestible Nutrient): $$\sum_{i=1}^{17} TDN_i + d_{TDN}^- - d_{TDN}^+ = 8.6853 \text{ Kg}$$
4. Goal 4(Maximize Calcium): $\sum_{i=1}^{17} Ca_i + d_{Ca}^- - d_{Ca}^+ = 0.1207$ Kg
5. Goal 5(Maximize Phosphorus): $\sum_{i=1}^{17} Ph_i + d_{Ph}^- - d_{Ph}^+ = 0.04$ Kg
6. Goal 6(Maximize Roughages): $\sum_{i=1}^{5} Rough_i + d_{Rough}^- - d_{Rough}^+ = 12.1495$ Kg
7. Goal 7(Maximize Concentrates): $\sum_{i=6}^{17} Conc_i + d_{Conc}^- - d_{Conc}^+ = 4.8805$ Kg
8. $\sum_{i=1}^{17} x_i = 17.03$ Kg
9. where p_i $(i = 1,2..7)$ are positive number between $(0,1)$ Such that $p_1 > p_2 > \ldots p_7$.

Real Coded Genetic Algorithm with hybrid function

Genetic algorithm is a search-based technique, which is based on evolution theory. The difference between binary and real coded GA is that in binary coded GA, variables arerepresented by bits of zeros and ones while GA based on real number representation are called real coded GAs (RGA). GA works on solution space instead of state space, where it builds new solutions based on existing one. We first created initial population then decided the gene representation, we choose default population type "double vector" to represent genes. After representation of genes, it undergoes three main operators such as selection, crossover and mutation to create next generations. Matlab provides gaoptimset to create or modify the GA option structure. Matlab does not provide every method available in literature but provides lot of options to find the optimal solution. The selection procedure decides how an individual is selected to become parents. We used tournament selection procedure of size 2 where an individualcan be selected more than once as a parent. Crossover combines two parents to create new offspring for next generation. Crossover heuristic returns offspring because it moves from worst parents to past best parent. Default value of ratio is 1.2. If P1 and P2 are parents where P1 has better fitness then offspring=P2+1.2*(P1-P2). Mutation decides how algorithm makes small changes in the individual randomly to create new mutation offspring's. Mutation is important operator as a diversity point of view, which allows GA to search in broader space. We have linear constraints and bounds; hence, adaptive feasible mutation is used which generates a direction that is adaptive with respect to last successful or unsuccessful generation. The feasible region is bounded by the constraints and inequality constraints. A step length is chosen along each direction so that linear constraints and bounds are satisfied. After specifying above genetic algorithm options for linear models, Genetic algorithm sometimes return a local minimum instead of global minimum, i.e. a point where the objective function value is less than the nearby points but possibly greater than the distant point in solution space. Therefore, to overcome this deficiency of Genetic algorithm we have introduced hybrid command "fmincon" inside Genetic algorithm, in which we allow GA to find the valley that contains global minimum and after last generation, it takes the last value of GA as the initial value of fmincon to converge quickly. Another way to make GA explore the wider range of points is to increase the diversity of the population, and it can be done by setting initial range of population. However, we have rigid constraints and bounds so we want to search the point in the specified lower and upper bounds only. Based on GP model, we have 31 decision variables and 7 goals (1- Equality constraint). We have to find the minimum cost of diet based on Dry matter, hence, we set the no of variables to 31 from which we have developed three goal-programming models with different priorities for cows with body wt. 500 kg, which is pregnant at third trimester.

Result in Dry matter and Fresh basis

Table 1 Least cost and Deviation value solved by Hybrid RGA for Goal Programming models

Variables	Feed Stuffs	GP model 1	GP model 2	GP model 3
x_1	Paddy straw	0.0000	0	0
x_2	Co-4 grass	0.0000	0	0
x_3	Maize fodder	12.2802	12.2014	12.1431
x_4	Co FS 29 sorghum fodder	0.0000	0	0
x_5	Ragi straw	0.0000	0	0
x_6	Maize	0.0000	0	0
x_7	Soya DOC	0.0000	0	0
x_8	Copra DOC	0.0480	0	0

	x_9	Cotton DOC	0.6099	0.7691	0.908
	x_{10}	Wheat Bran	3.7989	3.9052	3.9654
	x_{11}	Gram chunnie	0.0000	0	0
	x_{12}	Cotton seed	0.0000	0	0
	x_{13}	Concentrate Mix Type I	0.0000	0	0
	x_{14}	Calcite	0.0000	0	0
	x_{15}	MM	0.0000	0.0095	0.006
	x_{16}	DCP	0.0131	0.0048	0.0074
	x_{17}	Salt	0.0000	0	0
		d_{cost}^-	9.7909	10.5312	11.4146
		d_{cost}^+	0.0000	0	0
		d_{CP}^-	0.0000	0.0002	0.0001
		d_{CP}^+	0.0000	0	0
		d_{TDN}^-	0.0000	0	0
		d_{TDN}^+	1.9453	1.9789	2.012
		d_{Ca}^-	0.0086	0.0115	0.01
Deviations		d_{Ca}^+	0.0000	0	0
		d_{Ph}^-	0.0132	0.011	0.0096
		d_{Ph}^+	0.0000	0	0
		d_{Rough}^-	0.0056	0.0062	0.0054
		d_{Rough}^+	0.0000	0	0
		d_{Conc}^-	0.0074	0.0081	0.0071
		d_{Conc}^+	0.0000	0	0
		Dry Matter Intake (DMI)	16.75	16.89	17.03
		Crude Protein (CP)	2.3524	2.395	2.4401
Constraints		Total Digestible Nutrient (TDN)	10.4878	10.5928	10.6973
		Calcium (Ca)	0.109	0.1108	0.1107
		Phosphorus (P)	0.0287	0.029	0.0304
		Roughage	12.2802	12.2014	12.1431
		Concentrates	4.4568	4.6743	4.8734
		Least Cost (z) on DM Basis	116.9191	121.2922	125.2354
		Objective function value	0.0127	0.0132	0.0115

RESULTS AND DISCUSSION

Table 1 shows the results obtained for all the goal-programming models.

On assigning the weights P_1 (goal1 : cost), P_2 (goal 2 : CP) , P_3 (goal3 : TDN), P_4 (goal 4 : Ca) , P_5 (goal5 : Ph), P_6 (goal6 : Roughage), P_7 (goal7 : Concentate) as $0.9, 0.8, 0.7, 0.6, 0.5, 0.4, 0.3$ and solving the GP Model 1, using RGA with hybrid function, we obtain $d_{cost}^- = 9.7909$, $, d_{TDN}^+ = 1.9453$, $d_{Ca}^- = 0.0086$, $d_{Ph}^- = 0.0132$, $d_{Rough}^- = 0.0056$, $d_{Conc}^- = 0.0074$ and rest of the variables $d_{cost}^+, d_{CP}^+, d_{CP}^-, d_{TDN}^-, d_{Ca}^+, d_{Ph}^+, d_{Rough}^+, d_{Conc}^+$ as zero.We observe that goals 1, 4, 5, 6, 7 are overacheived and goal 3 is underachieved whereas goal 2 is fully achieved without any deviation obtaining $Minimum\ Z = 0.0127$.

Similarly on assigning the same weights P_1 (goal1 : cost), P_2 (goal 2 : CP) , P_3 (goal3 : TDN), P_4 (goal 4 : Ca) , P_5 (goal5 : Ph), P_6 (goal6 : Roughage), P_7 (goal7 : Concentate) as $0.9, 0.8, 0.7, 0.6, 0.5, 0.4, 0.3$ and solving the GP Model 2, using RGA with hybrid function, we obtain $d_{cost}^- = 10.5312$, $d_{CP}^- = 0.0002$, $d_{TDN}^+ = 1.9789$, $d_{Ca}^- = 0.0115$, $d_{Ph}^- = 0.011$, $d_{Rough}^- = 0.0062$, $d_{Conc}^- = 0.0081$ and rest of the variables $d_{cost}^+, d_{CP}^+, d_{TDN}^-, d_{Ca}^+, d_{Ph}^+, d_{Rough}^+, d_{Conc}^+$ as zero. Here also we observe that goals 1, 4, 5, 6, 7 are overacheived and goal 3 is underachieved whereas goal 2 is slightly over achieved with $d_{CP}^- = 0.0002$ obtaining $Minimum\ Z = 0.0132$.

But On assigning the same weights P_1 (goal1 : cost), P_2 (goal 2 : CP) , P_3 (goal3 : TDN), P_4 (goal 4 : Ca) , P_5 (goal5 : Ph), P_6 (goal6 : Roughage), P_7 (goal7 : Concentate) as $0.9, 0.8, 0.7, 0.6, 0.5, 0.4, 0.3$ and solving the GP Model 3, using RGA with hybrid function, we obtain $d_{cost}^- = 11.4146$, $d_{CP}^- = 0.0001$, $d_{TDN}^+ = 2.012$, $d_{Ca}^- = 0.01$, $d_{Ph}^- = 0.0096$, $d_{Rough}^- = 0.0054$, $d_{Conc}^- = 0.0071$ and rest of the variables $d_{cost}^+, d_{CP}^+, d_{TDN}^-, d_{Ca}^+, d_{Ph}^+, d_{Rough}^+, d_{Conc}^+$ as zero.Here it is seen that goals 1, 5, 6, 7 are overacheived and goal 3 is underachieved whereas goals 2 and 4 is slightly overachieved with deviation $d_{CP}^- = 0.0001$ and $d_{Ca}^- = 0.01$ obtaining $Minimum\ Z = 0.0115$.

The obtained solution does not completely satisfy the decision maker; hence, decision maker has to work on overacheived targets. First, third, fourth, fifth, sixth and seventh goal are analyzed and the reason for the overachievement can be searched in the diet plan. The choice of the final solution depends on the decision maker. In our case, we have shown three different GP-models representing the diet plan that decision maker may make. All possibilities is not considered, as the LP model developed in [10] allows introduction of additional constraints anytime which results new set of solutions, whereas some constraints (if added) can also lead to "no solution" which means that additional constraints are too complex that it is necessary to mediate in the model by increasing some of the requirements. However, for better output we need a further discussion with qualified cattle nutritionist

CONCLUSION

The present works focused on improving the results of LP model developed by Ravinder *et.al.* [10], by formulating it into goal programming models. The GP models are solved by real coded genetic algorithm with hybrid function to improve the quality of feed mix to the dairy cows. The goal programming method proves to be a useful method in determining the optimal diet plan for dairy cows at three different body conditions. As the results obtained reveals that RGA with hybrid function can be applied to formulate least cost ration, however fixing the constraints and use of code for making software is considered while choosing the technique for making least cost diet plan. Further detailed research with various additional constraints needs to fine-tune the technique.

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