ISSN: 2277-9655
Impact Factor: 1.852

IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

A study of Livestock Ration Formulation using Goal programming and Random Search Technique for Global optimization

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Abstract

The aim of this paper is to present a non-linear weighted sum Goal Programming Approach for the formulation of a daily dairy cow ration. The basis of its construction lies in the models developed by earlier researchers on the Excel Solver platform. It merges the single objective linear programming model and the weighted goal programming model with linear objective of minimizing the deviations. The single objective linear model helps in making an estimation of least-cost magnitude that might be expected. The obtained result is used in the goal programming model to set the targets for each of the goals that should be achieved as closely as possible. In this study, the construction of the non linear model of Goal programming approach is done by formulation of non-linear objective function as square root of the sum of the squares of the deviations in which weight is assigned to each goal according to its priority. This new model was tested at three values of preferential weights for dairy cows with a 10L daily milk yield, using a controlled Random Search Technique for Global optimization. The result obtained depicts the benefit of applied approach & probabilistic solution technique. In contrast to the linear models, which gives only one solution, this model & solution technique provides many possible solution sets to reduce the cost of the diet without compromising its nutritional quality, by allowing for harmless deviations from the goals, using under & over achievements.

Keywords: Linear programming, Goal programming, Livestock ration formulation, Controlled Random Search Technique (RST2).

Introduction

Diet formulation is the major driving factor for animals. Objective of diet formulation is to provide necessary energy at different stages of production of growth, reproduction, metabolism and lactation. It produces an effective diet at minimum cost to provide appropriate energy to animals. As animal feed is indirect human food, it is necessary to improve animal diet formulation.

Formulation of an efficient ration is a complex process. It should take into consideration nutritional, economic and environmental factors. However, rations are most often constructed by experience, textbook-based knowledge, or by trial and error method. In all these cases, non-nutritional factors, such as economic and the environment might be neglected, which deteriorates the efficiency of diets.

Waugh (1951), applied the linear programming (LP) paradigm in order to formulate rations on a least-cost basis. This approach has been very popular in the past, especially after the rapid development of personal computers. In the 1960s, it became a classical approach to formulate animal diets as well as feed-mixes (Black & Hlubik, 1980). More recently, Castrodeza et al. (2005) stressed that the daily routine of ration formulation is one of the fields in which LP is most widely used. Though LP is suitable for solving animal diet problems efficiently, exclusive reliance just on one objective (cost function) as the only and the most important decision criteria is one of the reasons why the LP paradigm may be a deficient method in the process of ration formulation (Rehman & Romero, 1984; 1987). Lara & Romero (1994) stress that in practice decision makers never formulate rations exclusively on the basis of a single objective, but rather on the basis of several different objectives, where economic issues are only one of many concerns.

In the present study, we have focused on non-linear weighted sum Goal Programming Approach for the formulation of a daily dairy cow ration. For this purpose we considered the models developed by Shrabani (2011) on the Excel Solver. The first model is a single objective linear programming model which helps in making an estimation of least-cost magnitude that might be

ISSN: 2277-9655
Impact Factor: 1.852

expected. The results obtained from this model is used in setting the targets for each of the goals while formulating the weighted goal programming model with linear objective of minimizing the deviations. The aim was to achieve the targets as closely as possible using Excel solver. Manasa et al [2013:volume3,issue2,] tried solving the linear as well as non-linear programming problems with single objective using a probabilistic technique viz. “Controlled Random search Technique for Global optimization”, proposed by Shanker et al [ ]. In the present work, we have considered the non linear model of Goal programming approach by formulating the non-linear objective function as square root of the sum of the squares of the deviations in which weight is assigned to each goal according to its priority. Further we tested the linear as well as non linear weighted sum Goal Programming models for dairy cows with a 10kg daily milk yield, using a controlled Random Search Technique for Global optimization. The results obtained depicts the benefit of applied approach & probabilistic solution technique. In contrast to the linear models, which gives only one solution, this model & solution technique provides many possible solution sets to reduce the cost of the diet without compromising its nutritional quality, by allowing for harmless deviations from the goals, using under & over achievements.

2.Literature Survey

The live stock ration formulation problem is postulated within the framework of multiple-criteria decision making techniques by Rehman and Romero (1984).They made an attempt to show the importance of goal programming by introducing these techniques to agricultural systems modellers and then demonstrating their use in livestock ration formulation. The multiple criteria decision making techniques covered included goal programming and its variants such as weighted and lexicographic approaches and multiple objective programming. Zgajnar,et.al(2009) presented the paper in the developed spreadsheet tool for the formulation of a daily cow ration. It is constructed on the basis of two linked sub-models developed on the Ms-Excel platform. It merges the common linear programming model and weighted goal programming model with penalty function.

2.1. Goal Programming in Animal Diet Problem

Goal programming, a powerful and effective methodology for the modelling, solution, and analysis of problems having multiple and conflicting goals and objectives, has often been cited as being the “workhorse” of multiple objective optimization (i.e., the solution to problems having multiple, conflicting goals and objectives) as based on its extensive list of successful applications in actual practice. Goal programming problems can be categorized according to the type of Mathematical programming model (linear programming, non-linear programming, integer programming etc.) that it fits except for having multiple goals instead of a single objective.

Goal programming is a pragmatic and flexible method for resolving multiple criteria decision making problems that ration formulation need. The basic approach of goal programming is to establish a specific numeric goal and formulate an objective function for each objective, and then seek a solution that minimizes the (weighted) sum of deviations of these objective functions from their respective goals. Important aspect of weighted goal programming is that one has to set target and their values and set weights to belonging to goals. One of many possibilities could be sensitivity analysis where only binding goals should be considered. Rehman and Romero (1993) strongly recommend its application when one is not sure about the priorities of the goals. The quality of the result is strongly dependent on the selection of preferential weights in weighted Goal programming. To reduce bias of obtained results sometimes additional technique should be used to define the weights (Gass 1987)

There are three possible types of goals.

1.A lower, one-sided goal sets a lower limit that we do not want to fall under (but exceeding the limit is fine).
2. An upper, one-sided goal sets an upper limit that we do not want to exceed (but falling under the limit is fine).
3.A two-sided goal sets a specified target that we do not want to miss on either side.
The general GP models are as follows assuming that there are m goals, p structural constraints, n decision variables and k priority levels. Goal programming is an extension of linear or non-linear optimization problem involving an objective function with multiple objectives.

Minimize

$$Z = \sum_{i=1}^{m} \sum_{k=1}^{K} P_k \left(w_{i,k}^{+} d_i^{+} + w_{i,k}^{-} d_i^{-} \right)$$

$$\sum_{j=1}^{n} a_{ij} x_j + d_i^{-} - d_i^{+} = b_i \quad for \;\; i = 1,2.....m$$

ISSN: 2277-9655
Impact Factor: 1.852

$$\sum_{j=1}^{n} a_{ij} x_j (\le, =, \ge) b_i \ \ for \ \ i = m+1, ...m$$

$x_j, d_i^+, d_i^- \ge 0$ for j=1,......n

i=1,......m.

Where P_k = the priority coefficient for the k^{th} priority

$W_{i,k}^+$ = the relative weight of the d_i^+ variable in the k^{th} priority level.

$W_{i,k}^-$ = the relative weight of the d_i^- variable in the k^{th} priority level

Objective of goal programming is to minimize the deviation (d_i) so as to find the solution for which the deviation is minimum.

3. Materials and Methods

3.1.1 Solution by Excel solver

Ms Excel, familiar to a large number of people, provides a rich environment for solving linear goal programming problems in a structured way. The solver is a simple but effective tool for solving goal programs. It can be used for optimizing linear models containing hundreds of variables and constraints. Once a problem is written in the form of LGP model it can be quickly solved using solver.

3.1.2. Controlled Random Search Technique

A controlled Random search technique for global optimization based on quadratic approximation has been developed by C.Mohan and Shanker K (1994) to solve Mathematical models of real life optimization problems. This technique can be applied to obtain global optimal solutions of an optimization problem of the type:

Minimize:

$$f(X), \ \ X = (x_1, x_2, x_{3,} ....x_n)$$

Subject to

$$g_j(X) \ge (or \ \le) \ (or \ =) \ \lambda_j, \qquad j = 1, 2, ..., m$$

With bound on $a_i \le x_i \le b_i, \quad i = 1, 2, ..., n.$

These algorithms are probabilistic in nature and do not require any initial point for initiation. Theoretically though there is no guarantee that global optimal solution will be obtained but in vast majority of the problems tried, the algorithms locate the global optimal solutions. Even in situations where the algorithms do not locate the global optimal solution they at least provide a solution which is best amongst the hundreds of feasible solutions simulated by the algorithm during the search process.

3.2.1 Non Linear Goal Programming Model

The present study is based on the secondary data of GP model of livestock ration of Shrabani (2011). The brief description of the model is as follows:

Farmers would encounter three different physiological conditions if a fully grown up cow having body weight of 500 kg is considered wherein

a) Animal does not produce milk.
b) Produce different levels of milk with certain amount of fat.
c) Is in 3rd trimester of pregnancy it needs extra nutrient supplements

Looking into the need of ration for all of the above categories, three hypothetical animal models were selected for this study in which animal 1 needed ration for maintaining body function (Maintenance ration). In Indian condition since the high producing cows yield about 10L milk with maximum 4% fat content, the animal 2 was selected which needed ration not only for maintenance but for 10L milk with 4% fat production. The animal 3 was selected considering that it needed ration for 3rd trimester of pregnancy.

This study is the proof that optimization of ration formulation at cheaper cost is possible in three different animal models combining linear and simple weighted non linear goal programming with priority function as compared with only linear goal programming approach. By applying GP model in this study, the cost could be reduced to a reasonable extent satisfying the exact requirement of dry matter. Further reduction of cost using goal programming was possible only by reducing the amount of dry matter level. Therefore one way to adjust the ration cost would by reducing the dry matter to the acceptable lowest limit and then achieves the actual goals.

3.2.2. Formulation of Non-linear Goal programming Model:

Non-linear Goal programming model with priority ranked goals for ration formulation of hypothetical

ISSN: 2277-9655
Impact Factor: 1.852

animal 1 to 3 indicating constraints variables on left hand side (LHS) and right hand side(RHS) of the equation with objective function (Z) to different goals which needs to be minimized . Targets set in the RHS is based on 1 Kg feed formulation considering dry matter (DM) requirement of 10 Kg for animal -1&3 and 18 Kg for animal -2.

Table 1: Priority values for all the three Animals

Priorities	Animal 1	Animal 2	Animal 3
P_1	0.48	0.51	1.17031
P_2	0	0	0
P_3	0	0	0
P_4	15.5	0	23.164
P_5	369	12.435	229.35
P_6	-0.62	0	1.5490
P_7	16.044	1.61255	3.745
P_8	0	-0.06	0
P_9	0	0.26275	0.06
P_{10}	0.21	0.06725	0.21
P_{11}	0	0	0
P_{12}	0	0	0
P_{13}	0	0	0
P_{14}	0	0	0
P_{15}	0.16	-0.116	0
P_{16}	0.16	-0.116	0

By using the value of priorities, the construction of the non-linear model of goal programming approach is done by using the above priorities and the formulation of non-linear objective function as square root of the sum of the squares of the deviations in which weight is assigned to each goal according to its priority.

Table 2: Objective function for all the three animals:

$$\sqrt{\begin{array}{c} P_1 d_{lc}^{+2} + P_2 d_t^{-2} + P_3 d_t^{+2} + P_4 d_{cp}^{-2} + P_5 d_{tdn}^{-2} + P_6 d_{ca}^{-2} + P_7 d_p^{-2} + P_8 d_g^{+2} + P_9 d_b^{+2} + P_{10} d_{ck}^{+2} \\ + P_{11} d_{\frac{r}{c}}^{-2} + P_{12} d_{\frac{r}{c}}^{+2} + P_{13} d_{\frac{d}{g}}^{-2} + P_{14} d_{\frac{d}{g}}^{+2} + P_{15} d_{\frac{c}{h}}^{-2} + P_{16} d_{\frac{c}{h}}^{+2} \end{array}}$$

The value of the P_i's for all the three animals mentioned in the table 1.

Table 2: Constraints for all the three animals

Constraints	LHS	RHS		
		Animal 1	Animal 2	Animal 3
Least cost (Rs/Kg)	$4x_1+2x_2+4x_3+10x_4+9x_5+12x_6+12x_7+14x_8+20x_9+d_{1c}^- - d_{1c}^+$	≤ 7.48	≤9.01	≤8.17
Total (Kg)	$x_1+x_2+x_3+x_4+x_5+x_6+x_7+x_8+x_9+d_t^- - d_t^+$	=1	=1	=1
Protein (g/Kg)	$30x_1+102x_2+180x_3+80x_4+110x_5+120x_6+120x_7+450x_8+300x_9+d_{cp}^- - d_{cp}^+$	≥31	≥108	≥46.53
Energy/TDN (g/Kg)	$450x_1+550x_2+600x_3+880x_4+850x_4+660x_6+650x_7+790x_8+790x_9+d_{tdn}^- - d_{tdn}^+$	≥297	≥693	≥445
Calcium(g/Kg)	$2x_1+5.6x_2+12.8x_3+2.7x_4+3x_5+2.4x_6+2.6x_7+3.8x_8+7.4x_9+d_{ca}^- - d_{ca}^+$	≥3.8	≥5.15	≥3.1
Phosphorus(g/Kg)	$1.1x_1+3.8x_2+5.7x_3+4.2x_4+3.9x_5+17.3x_6+13.4x_7+8.4x_8+13.2x_9+d_p^- - d_p^+$	≥2.3	≥3.78	≥2.3
Grain max@7% ofconcentrate (Kg)	$(x_4+x_5)+d_g^- - d_g^+$	≤0.36	≤0.36	≤0.36
Bran max @50% of concentrate(Kg)	$(x_6+x_7)+d_b^- - d_b^+$	≤0.30	≤0.30	≤0.30
Cake max @50% of concentrate (Kg)	$(x_8+x_9)+d_{ck}^- - d_{ck}^+$	≤0.21	≤0.21	≤0.21
Roughage /Concentrate	$3(x_1+x_2+x_3)-2(x_4+x_5+x_6+x_7+x_8)+d_{r/c}^- - d_{r/c}^+$	=0	=0	=0
Dry/green roughages	$3x_1-2(x_2+x_3)+d_{d/g}^- - d_{d/g}^+$	=0	=0	=0
Legume/non-legume greens	$(x_2-x_3)+d_{c/h}^- - d_{c/h}^+$	=0	=0	=0

ISSN: 2277-9655
Impact Factor: 1.852

Table 3: Result sheet of Animal 1

2 / 1	100	500	1000	2000	3000	4000	5000	Conclusion
x_1	0.193	0.107	0.107	0.196	0.118	0.1	0.115	-
x_2	0.216	0.125	0.101	0.202	0.196	0.125	0.127	-
x_3	0.036	0.094	0.017	0.060	0.083	0.084	0.038	-
x_4	0.058	0.066	0.069	0.052	0.068	0.088	0.054	
x_5	0.316	0.386	0.323	0.338	0.313	0.309	0.342	-
x_6	0.068	0.062	0.050	0.086	0.061	0.058	0.062	-
x_7	0.217	0.204	0.318	0.209	0.242	0.227	0.243	-
x_8	0.062	0.083	0.089	0.059	0.089	0.059	0.092	-
x_9	0.050	0.062	0.088	0.062	0.054	0.062	0.072	-
d_{1c}^-	0.099	0.078	0.081	0.072	0.058	0.097	0.070	A
d_{1c}^+	0.238	0.287	0.254	0.275	0.252	0.250	0.280	A
dt^-	0.059	0.093	0.077	0.087	0.086	0.056	0.051	A
dt^+	0.051	0.070	0.099	0.093	0.086	0.060	0.067	A
d_{cp}^-	0.056	0.092	0.075	0.058	0.093	0.062	0.074	A
d_{cp}^+	53.112	53.406	51.81	54.232	52.981	50.253	50.248	O.A
d_{tdn}^-	0.052	0.067	0.086	0.082	0.053	0.062	0.077	A
d_{tdn}^+	0.060	0.060	0.090	0.055	0.087	0.05	0.082	A
d_{ca}^-	0.088	0.090	0.078	0.088	0.075	0.062	0.055	A
d_{ca}^+	0.180	0.182	0.187	0.181	0.188	0.190	0.187	A
d_p^-	0.069	0.072	0.075	0.062	0.073	0.094	0.062	A
d_p^+	0.082	0.067	0.056	0.054	0.097	0.061	0.084	A
d_g^-	0.079	0.093	0.050	0.090	0.062	0.050	0.095	A
d_g^+	0.095	0.062	0.066	0.097	0.053	0.055	0.074	A
d_b^-	0.064	0.080	0.053	0.080	0.058	0.062	0.072	A
d_b^+	0.071	0.062	0.065	0.084	0.074	0.072	0.085	A
d_{ck}^-	0.071	0.099	0.052	0.096	0.065	0.075	0.091	A
d_{ck}^+	0.085	0.090	0.083	0.062	0.050	0.093	0.055	A
$d_{r/c}^-$	0.060	0.053	0.053	0.091	0.059	0.059	0.082	A
$d_{r/c}^+$	0.066	0.052	0.095	0.082	0.067	0.062	0.080	A
d_{dg}^-	0.067	0.070	0.060	0.095	0.094	0.062	0.050	A
d_{dg}^+	0.055	0.062	0.084	0.057	0.071	0.083	0.062	A
$d_{c/h}^-$	0.236	0.262	0.250	0.252	0.226	0.276	0.222	A
$d_{c/h}^+$	0.083	0.092	0.093	0.093	0.078	0.086	0.096	A
Obj	1.081	1.389	1.717	1.632	1.131	1.287	1.534	
No.of .itr	133	533	1033	2033	3033	4033	5033	

Table 4: Result sheet of Animal 2

2 / 1	100	500	1000	2000	3000	4000	5000	Conclusion
x_1	0.139	0.102	0.124	0.118	0.146	0.112	0.144	-
x_2	0.044	0.049	0.053	0.068	0.050	0.029	0.027	-
x_3	0.149	0.153	0.145	0.151	0.152	0.141	0.143	-
x_4	0.076	0.075	0.067	0.090	0.062	0.075	0.074	
x_5	0.340	0.314	0.314	0.389	0.327	0.344	0.317	-
x_6	0.074	0.086	0.073	0.062	0.059	0.070	0.060	-
x_7	0.012	0.012	0.019	0.019	0.047	0.031	0.018	-
x_8	0.058	0.083	0.091	0.050	0.061	0.058	0.087	-
x_9	0.129	0.114	0.125	0.101	0.103	0.153	0.148	-
d_{1c}^-	0.073	0.071	0.080	0.083	0.050	0.089	0.074	A
d_{1c}^+	0.068	0.074	0.076	0.094	0.060	0.071	0.062	A
dt^-	0.086	0.083	0.074	0.074	0.065	0.075	0.063	A
dt^+	0.090	0.076	0.084	0.076	0.077	0.092	0.084	A
d_{cp}^-	0.085	0.059	0.070	0.084	0.063	0.059	0.071	A
d_{cp}^+	27.099	30	30	26.716	29.214	27.408	26.919	U.A
d_{tdn}^-	0.079	0.070	0.076	0.063	0.055	0.074	0.054	A
d_{tdn}^+	0.057	0.068	0.079	0.090	0.074	0.054	0.089	A
d_{ca}^-	0.084	0.072	0.085	0.095	0.064	0.074	0.086	A
d_{ca}^+	0.060	0.081	0.071	0.077	0.055	0.084	0.071	A
d_p^-	0.087	0.069	0.095	0.068	0.089	0.077	0.065	A
d_p^+	0.088	0.085	0.076	0.052	0.074	0.068	0.063	A
d_g^-	0.090	0.078	0.083	0.056	0.087	0.079	0.088	A
d_g^+	0.074	0.089	0.077	0.077	0.074	0.081	0.061	A
d_b^-	0.084	0.064	0.1	0.066	0.070	0.062	0.066	A
d_b^+	0.091	0.077	0.073	0.059	0.084	0.093	0.071	A
d_{ck}^-	0.099	0.092	0.051	0.090	0.072	0.064	0.065	A
d_{ck}^+	0.083	0.076	0.062	0.079	0.085	0.067	0.058	A
$d_{r/c}^-$	0.083	0.089	0.056	0.076	0.093	0.092	0.062	A
$d_{r/c}^+$	0.099	0.095	0.056	0.079	0.081	0.065	0.079	A
d_{dg}^-	0.065	0.082	0.081	0.095	0.065	0.080	0.081	A
d_{dg}^+	0.084	0.060	0.087	0.072	0.051	0.087	0.058	A
$d_{c/h}^-$	0.079	0.076	0.093	0.093	0.077	0.096	0.067	A
$d_{c/h}^+$	0.096	0.074	0.057	0.080	0.088	0.073	0.067	A
obj	0.303	0.270	0.300	0.249	0.232	0.284	0.214	
No .of .itr	133	533	1033	2033	3033	4033	5033	

ISSN: 2277-9655
Impact Factor: 1.852

Table 5 : Result sheet of Animal 3

2 / 1	100	500	1000	2000	3000	4000	5000	Conclusion
x_1	0.104	0.108	0.158	0.102	0.129	0.141	0.103	-
x_2	0.077	0.068	0.063	0.055	0.057	0.070	0.059	-
x_3	0.187	0.155	0.151	0.150	0.161	0.169	0.187	-
x_4	0.055	0.064	0.092	0.098	0.070	0.092	0.052	
x_5	0.395	0.304	0.374	0.302	0.332	0.395	0.301	-
x_6	0.067	0.085	0.057	0.085	0.068	0.091	0.095	-
x_7	0.229	0.247	0.226	0.299	0.217	0.201	0.263	-
x_8	0.076	0.068	0.053	0.050	0.075	0.055	0.056	-
x_9	0.053	0.088	0.050	0.070	0.055	0.055	0.068	-
d_{1c}^-	0.070	0.050	0.075	0.092	0.067	0.089	0.084	A
d_{1c}^+	0.530	0.649	0.530	0.514	0.534	0.636	0.514	A
dt^-	0.053	0.072	0.059	0.063	0.077	0.064	0.063	A
dt^+	0.072	0.074	0.081	0.079	0.090	0.082	0.090	A
d_{cp}^-	0.098	0.052	0.070	0.091	0.099	0.063	0.082	A
d_{cp}^+	43.645	44.145	41.607	41.575	40.990	41.306	42.301	U.A
d_{tdn}^-	0.065	0.052	0.068	0.055	0.052	0.053	0.069	A
d_{tdn}^+	0.089	0.053	0.093	0.082	0.057	0.098	0.066	A
d_{ca}^-	0.099	0.084	0.087	0.059	0.083	0.071	0.064	A
d_{ca}^+	0.069	0.084	0.066	0.057	0.051	0.073	0.083	A
d_p^-	0.090	0.078	0.064	0.085	0.085	0.056	0.089	A
d_p^+	0.063	0.071	0.053	0.072	0.084	0.070	0.055	A
d_g^-	0.099	0.085	0.089	0.066	0.090	0.059	0.076	A
d_g^+	0.063	0.066	0.060	0.095	0.089	0.072	0.084	A
d_b^-	0.089	0.066	0.087	0.095	0.061	0.089	0.051	A
d_b^+	0.071	0.073	0.070	0.099	0.067	0.096	0.075	A
d_{ck}^-	0.060	0.065	0.060	0.098	0.078	0.061	0.069	A
d_{ck}^+	0.053	0.056	0.058	0.068	0.064	0.077	0.076	A
$d_{r/c}^-$	0.097	0.072	0.066	0.051	0.079	0.063	0.090	A
$d_{r/c}^+$	0.058	0.086	0.072	0.080	0.069	0.081	0.085	A
d_{dg}^-	0.093	0.064	0.060	0.099	0.078	0.074	0.050	A
d_{dg}^+	0.057	0.092	0.088	0.064	0.069	0.052	0.056	A
$d_{c/h}^-$	0.058	0.064	0.084	0.079	0.061	0.069	0.091	A
$d_{c/h}^+$	0.109	0.115	0.119	0.149	0.119	0.116	0.135	A
Obj	1.254	1.111	1.244	1.113	1.106	1.115	1.264	
No. of .itr	133	533	1033	2033	3033	4033	5033	

1-Variables and deviations

2-No.of.iterations

A-Achieved

O.A-Over achieved, U.A-under achieved.

Obj- Objective function

Goal 1:

d_{1c}^+ , d_{1c}^- — The overachievement of the least cost ration d_{1c}^+ needs to be minimized (≤7.48 (animal 1), ≤9.01 (animal2), ≤8.17 (animal 3)),hence both the goals d_{1c}^+ , d_{1c}^- are for all the three animals achieved.

Goal 2 :

d_{1t}^+,d_{1t}^- — Total weights desired in the ration were equal to 1kg for animal 1,2 & 3 hence theunder achievement and the over achievement goals are achieved

Goal 3:

d_{cp}^+,d_{cp}^- — Crude protein desired in the ration needs need to be minimized (≥31 (animal1), ≥108 (animal2), ≥46.53 (animal 3), but it is over achieved by approximately 62% for animal 1,and underachieved for animal 2 & 3 approximately 75% and 12% , hence the goals are over and under achieved for animal 1,2&3

Goal 4:

d_{tdn}^+,d_{tdn}^- — TDN desired in the ration need to be minimized(≥297(animal1),≥693(animal2),≥445(animal3)) for the underachievement and hence it met the target , so they achieved their goals.

Goal 5:

d_{ca}^+,d_{ca}^- — calcium desired in the ration needs to be minimized(≥3.8(animal1),≥5.15(animal 2) ,≥3.1 (animal 3)) for the underachievement, hence it is met the requirement and the goals are achieved.

Goal 6:

d_p^+,d_p^- — Phosphorous desired in the ration need to be minimize (≥2.3(animal 1&3),≥3.78(animal2))
the underachievement, hence it is minimized and met the target.

Goal 7:

d_g^+, d_g^- ─Maximum grain inclusion in the ration needs to minimize (≤0.36 for animal 1,2&3) for the overachievement , hence the target and the goals are achieved.

Goal 8:

d_b^+, d_b^- ─Maximum bran inclusion in the ration needs to be minimize the overachievement (≤ 0.30 for animal 1,2&3) , hence the target and the goals are achieved.

Goal 9:

d_{ck}^+, d_{ck}^- ─ Maximum cake inculsion in the ration needs to reduce the overachievement (≤ 0.21for animal 1,2&3), hence they met the target and achieved their goals.

Goal 10:

$d_{r/c}^+, d_{r/c}^-$ ─ The ratio of roughage- concentrate in the ration need to minimize(=0 for animal 1,2&3) both the under and over achievements and hence it is minimized for both and achieved their goals.

Goal 11:

$d_{d/g}^+, d_{d/g}^-$ ─ The ratio of dry-green in the ratio needs to be minimize(=0 for animal 1,2&3) for both the under and over achievements and hence it is minimized for both and achieved their goals.

Goal 12:

$d_{c/h}^+, d_{c/h}^-$ ─The ratio of cowpea-hybrid Napier ratio needs to be minimize (=0 for animal 1,2&3)for both

the under and over achievement and hence it minimized for both and achieved their goals.

From the above discussion it is clear that all the goals are achieved and the goal 3 is over achieved for animal 1 with the least possible deviations that lie in the range of (1.081,1.717) practically which is well acceptable. For animal 2 &3 Goal 3 is under achieved with the deviations in the range of (0.214,0.303) and (1.106, 1.264) respectively. In case Goal 3 is more important to be achieved by the planner, first priority can be given to this goal, so that this goal can be achieved first that can happen with the slight compromise on some other goals. In fact any of the obtained solutions mentioned in the table 3,4&5 can be suggested to the planner for application purpose.

Conclusion:

The result of this study revealed that the non-linear weighted sum goal programming approach problem for livestock ration formulation of three kinds of animals is well structured and more acceptable as compared to linear Goal programming problem. The "Controlled Random search Technique" used to solve non-linear goal programming problem provides many possible solutions in achieving most of the goals by allowing for harmless deviations using under and over achievements. Hence, it is concluded that this technique can be used effectively in solving non-linear weighted sum goal programming problem of animal diet formulation.

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