

HEURISTIC APPROACHES IN SOLVING NON LINEAR MODEL OF LIVESTOCK RATION FORMULATION

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ABSTRACT

A nonlinear formulation of optimum livestock diets, though very practical, has seen a limited research since classical techniques like Kuhn Tucker theory used by some researchers has its own limitations due to the rigidity of mathematical characteristics that should hold good to apply this technique. The present study deals with the importance of linear livestock ration formulation for sahiwal cows of second to fifth lactation number to maximize the milk yield[28]. Its solution is found using heuristic approaches viz. Controlled Random Search Technique(RST2) and Genetic Algorithm. We observe that the results obtained are well acceptable with slight deviations, takes less time due to computer usage, gives more flexibility to the decision maker. The techniques do not guarantee optimal solution but at least gives a solution which is best amongst the many solutions generated during the simulation process. The performance of both the techniques indicates that they can be well implemented for nonlinear livestock ration formulation problem.

KEYWORDS: *Animal diet problem, Controlled Random Search Technique (RST2), Genetic Algorithm (GA), Non-linear Programming (NLP).*

I. INTRODUCTION

Ration can be termed as the form of food given to the animals on daily basis and the ration formulation is a process by which different ingredients are combined in a proportion to provide animals with a consumable quantity of feed stuffs that will supply all required nutrients in adequate amounts. It is very much essential to formulate ration as it is one of the major requirements in animal yield industries. An efficient ration formulation requires the proper knowledge of the feedstuffs, nutrients contained in the feedstuff as well as the type of animal to be fed with such ration to ensure an optimal production at reasonable cost. Different species of animals have different requirements for energy (carbohydrates and fats), proteins, minerals and vitamins in order to maintain its various functions like maintenance, reproduction, egg production, milk production and so on.

There are several methods in formulating diet for animals. All of them have the same objectives of providing the required balanced nutrients at least possible cost. Some of them are Pearson's square method, two by two matrix method, trial and error method and so on. Mathematical programming techniques are being used to formulate the ration such as linear programming, multiple-objective programming, goal programming, separable programming, quadratic programming, non linear programming, genetic algorithm and so on.

In the present study,

1. We have used Controlled Random Search Technique developed in C++ [13] to solve non linear programming model of animal diet quoted by Pratiksha [28] and compared the results obtained with that of classical approach
2. An attempt has been made to solve the same problem using Genetic Algorithm developed in Matlab 7.0 [4] and the results are compared with the other two techniques.

Section 2 describes the literature survey of both linear programming and non linear programming techniques in animal diet problem. Section 3 focus on the methodologies used to solve non linear programming problems (NLPP).

Results obtained using heuristic approaches are discussed in detail in the section 4. Section 5 concludes the results depicted in case study of maximizing the milk yield of sahiwal cows.

II. LITERATURE SURVEY

The livestock ration formulation is not a simple exercise and the following factors should be taken into consideration in order to make better feed formulation:

1. The diet being formulated has to be palatable to stimulate enough consumption by the animals. To do this, we need to know animal requirements for specific nutrients and nutrient composition of feeds which may be used to formulate the ration.
2. The nutrients in the feed should be digestible. For example rations with high fibre cannot be easily digested by poultry.
3. The feed should be formulated in such a way that it shouldn't cause any serious digestive disturbance or adverse effects on the animal. Other factors that should be considered in feed formulation are texture, moisture and the processing, the feed has to undergo.

2.1 LINEAR PROGRAMMING IN ANIMAL DIET PROBLEM

Linear programming (LP) is the common method of least cost feed formulation and for the last fifty years it has been used as an efficient technique in ration formulation. While formulating ration by linear programming, first and foremost all available raw material and feed ingredients are selected which are to be included in ration and then a set of constraints on feed ingredient is set up. Objective function is then formulated as per the available feed ingredients and constraint to achieve the objective. While constructing linear programming model, the following assumptions are made:

1. Linearity: Feed formulation by LP is mainly based on the linearity between animal yield and nutrient ingredients included in the diet. Linearity means, the amount of each resource used and its contribution to the objective function is proportional to the value of each decision variable.
2. Simple objective: There is single objective (can be either maximization of animal yield or minimization of cost of the diet) which is a mathematical function.
3. Additivity: This means that the sum of resources used by different activities must be equal to the total quantity of resources used by each activity for all the resources [5].
4. Certainty: While formulating linear model for animal ration, it is assumed that all parameters of the model and consumption of resources are known with certainty.
5. Divisibility: It is assumed that all inputs into the ration are infinitely divisible. Perfect divisibility of outputs and resources must exist.
6. Non-negativity: Decision variables cannot be added to the final objective function in a negative way. More precisely, the solution values of decision variables are allowed to assume continuous and non-negative values.
7. Finiteness: The constraints and the variables must be finite so that it can be programmed. Hence, a finite number of activities and constraints must be employed.
8. Proportionality: This implies that the contribution of each variable to the objective function is directly proportional to each variable [1].

All these assumptions indicate that the objective function and all the constraints must be characterized by linear relationship among decision variables in LP model.

Although LP has been used widely in practice with noticeable success the assumptions considered while formulating the linear model remain its weakness. Linear programming based optimal solutions are based on linearity assumption which in practice may not be true [2]. Since varying constraints need to be considered, the feed mixing problem has become increasingly difficult to be solved by linear programming alone.

In varying situations LP is found not sufficient to overcome all of the complexities of problem. It suffers unnecessarily from over-rigid specification of nutritional and other requirements. Some relaxation of the constraints imposed would not seriously affect on animal's physical and animal's performance.

Over the years several issues arisen in feed mixing problems such as ingredients variability i.e. nutrients level of feed ingredients is unstable and fluctuates nutrients imbalance in the final solution [12].

Mitani and Nakayama [11] pointed out three limitations in LP:

1. LP models assume nutrients levels are fixed, however nutrients levels in feed ingredients are unstable and fluctuating. When the variability among ingredients is neglected, the probability in meeting nutrient restriction is only 50%.
2. It is hard to determine good balance of nutrients in the final solution of linear programming method. If only the minimum levels of nutrient requirements are placed, there is a probability for nutrients imbalance to arise in the final solution. When the variation is small, the quality of balance nutrients improves.
3. The constraints over rigidity of nutritional specification and requirement, which means no constraints violation is allowed in LP. This normally leads to infeasible solution

2.2 Non Linear Programming in Animal Diet Problem

Mathematically, optimal solution from an LP model solves primarily a technical problem which might have a loose relationship with the economic problem of maximizing the difference between costs and returns of feeding over time. To overcome the limitations of LP, various types of methodologies in ration formulation such as goal programming, quadratic programming, risk formulation, genetic algorithm, multi objective programming, multi objective fractional programming, chance constrained programming, non linear programming and integration of two different programming are being used since many years. Introduction of non linear programming to optimize yield and minimize feed cost in broiler feed formulation may lead to better approximation as compared to those of linear cases[9].

A general optimization problem is to select n decision variables from a given feasible region in such a way as to optimize (minimize or maximize) a given objective function of the decision variables. The problem is called a nonlinear programming problem (NLPP) if the objective function is nonlinear and/or the feasible region is determined by nonlinear constraints.

Every linear programming problem can be solved by simplex method, but there is no single technique which can be claimed to efficiently solve each and every non-linear optimization problem. In fact, a technique which is efficient for one non-linear optimization problem may be highly inefficient for solving another NLPP. A variety of computational techniques for solving NLPP are available. However, an efficient method for the solution of general NLPP is still a subject of research.

There are classical techniques like Kuhn Tucker theory used by some researchers to solve certain Non Linear Programming Problems (NLPP), but has its own limitations since one has to take care of a lot of mathematical characteristics to hold good before applying this technique.

III. MATERIALS AND METHODS

3.1.1 CONTROLLED RANDOM SEARCH TECHNIQUE

A “Controlled Random Search Technique (RST2) for Global optimization” developed by C. Mohan and Shanker [13] is heuristic in nature, does not take into account the mathematical nature of the functions and at the same time gives promising 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 “apriori” assumptions regarding the mathematical nature of the functions appearing 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.

An attempt has been made by Radha and Manasa [21] to use RST2 for global optimization [12] with slight modifications to meet the requirements of animal diet formulation. Further it is used to solve the linear livestock ration formulation quoted by Pratiksha [28] and results were found to be comparable.

3.1.2 GENETIC ALGORITHM

A Genetic Algorithm (GA) is a method for solving both constrained and unconstrained optimization problems based on a natural selection process that mimics biological evolution. Genetic Algorithms are adaptive heuristic search algorithm premised on the Darwin’s evolutionary ideas of natural selection and genetic.

The basic concept of GA is designed to simulate processes in natural system necessary for evolution. As such they represent an intelligent exploitation of a random search within a defined search space to solve a problem. Not only does Genetic Algorithm provide an alternative method to solving problem, it consistently outperforms other traditional methods in most of the problems link. Many of the real world problems which involve finding optimal parameters might prove difficult for traditional methods but are ideal for Genetic Algorithms [20].

The algorithm begins with a set of solutions (represented as chromosomes) called population. Solutions from one population are taken and used to form a new population. This is motivated by a hope, that the new population will be better than old one. Solutions which are then selected to form new solutions (offspring) are chosen according to their fitness. A fitness value is assigned to each individual in the population, where the fitness computation depends upon the application. For each generation individuals are selected from population for reproduction, the individuals are crossed to generate new individuals and new individuals are mutating with low mutation probability. The new individuals may completely replace the individual in the population. Though the selection is based on high fit individuals, but the average fitness of the population tends to improve from one generation to next generation. The fitness of the best individuals is expected to improve over time and the best fit individual may be chosen as a solution after several generations (Kusum Deep, RAOTA, 2009)

Due to its random nature, the Genetic Algorithm improves the chances of finding a global solution. Thus they prove to be very efficient and stable in searching for global optimum solutions. It helps to solve unconstrained, bound constrained and general optimization problems, and does not require the functions to be differentiable or continuous [4].

GA and RST2 techniques can be applied to obtain global optimal solutions of an optimization problem of the type:

Minimize:

$$f(X), X = (x_1, x_2, x_3, \dots, x_n)$$

Subject to

$$g_j(X) \geq (\text{or } \leq) (\text{or } =) \lambda_j, \quad j = 1, 2, \dots, m$$

$$\text{With bounds on } a_i \leq x_i \leq b_i, \quad i = 1, 2, \dots, n.$$

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 NON LINEAR PROGRAMMING MODEL

The present study is based on the secondary data of NLP model of livestock ration of Pratiksha [28]. The brief description of the model is as follows:

Briefly, the study consists of sahiwal cows of second to fifth lactation number. They were selected from the National Dairy Research Institute herd, and divided into 4 groups, which were switched over four times in a Latin-square change over design. Each period was of 40 days duration. The 4 groups A, B, C and D were fed with isonitogeneous and isocaloric concentrate mixtures, containing ground nut cake, cotton seed cake (decorticated), respectively.

In addition to the maintenance requirements, 50 gm DCP requirement, 50% was met through the concentrate mixture. A green fodder was given ad libitum to provide rest of the DCP and also to meet the dry matter and energy requirements.

The various concentrate mixtures containing groundnut cake cotton seed and the two types of cotton seed cakes (undecorticated and decorticated) were analyzed for crude protein, crude fibre, ether extract, organic matter, nitrogen-free extract and total ash.

The study was carried out to maximize the milk yield. The milk yield and the efficiency with which the nutrients are utilized mainly depend on three factors, which may be used to maximize it. Accounting all these facts, milk yield of an animal depends upon:

1. Digestible crude protein (DCP).
2. Total digestible nutrient (TDN).

3. Digestible dry matter (DDM).

Objective function is formulated using the appropriate relations of the variables according to their weight age on milk yield of the cows and the constraints are applied according to feeding standards of NRC recommendations (NRC, 1981).

$$Y = 4.1792442 x_2^2 - 4.082239204 \times 10^{-6} x_3^2 - 0.114836671 x_1 - 560.0786654 x_2 + 4.145857585 \times 10^{-3} x_3 + 19255.68675.$$

such that

$$608.6718 \leq x_1 \leq 782.978$$

$$60.641 \leq x_2 \leq 75.943$$

$$366.0412 \leq x_3 \leq 508.9343 \tag{1}$$

IV. RESULTS AND DISCUSSIONS

4.1 SOLUTION OF NLP BY CONTROLLED RANDOM SEARCH TECHNIQUE

The solution set for NLP model of animal diet by Controlled Random Search Technique is given in table 1. And the graphical representation of maximum milk yield is as shown in figure 1.

The wide range of solutions obtained for original bounds as mentioned in (1) is,

$$x_1 = 608 - 680, x_2 = 66 - 68, x_3 = 400 - 512.$$

All the values are in gm/kg. metabolic body weight.

The solution set for NLP model of animal diet by RST2 is as shown in table 1.

TABLE 1: Solution Set for NLP Model of Animal Diet by Controlled Random Search Technique for Original bounds

No of iterations.	x_1 in gm/kg.metabolic weight	x_2 in gm/kg.metabolic weight	x_3 in gm/kg.metabolic weight	Value of the function
100	643.75	67	482.73	566.070
200	609.48	66.82	433.62	562.206
300	639.15	66.77	442.47	565.691
400	608.27	66.91	488.97	562.030
500	642.87	66.873	388.55	565.938
600	640.11	66.91	417.47	565.606
700	671.92	66.60	511.13	569.909
800	611.85	66.69	437.28	562.748
900	609.93	67.48	467.53	563.075
1000	623.68	67.012	367.819	563.637
2000	608.67	66.79	390.36	562.121
3000	619.44	66.71	366	563.50
4000	657.01	67.19	368.76	567.712
5000	646.22	67.18	479.46	566.456

The graphical representation of maximum milk yield is shown in figure 1.

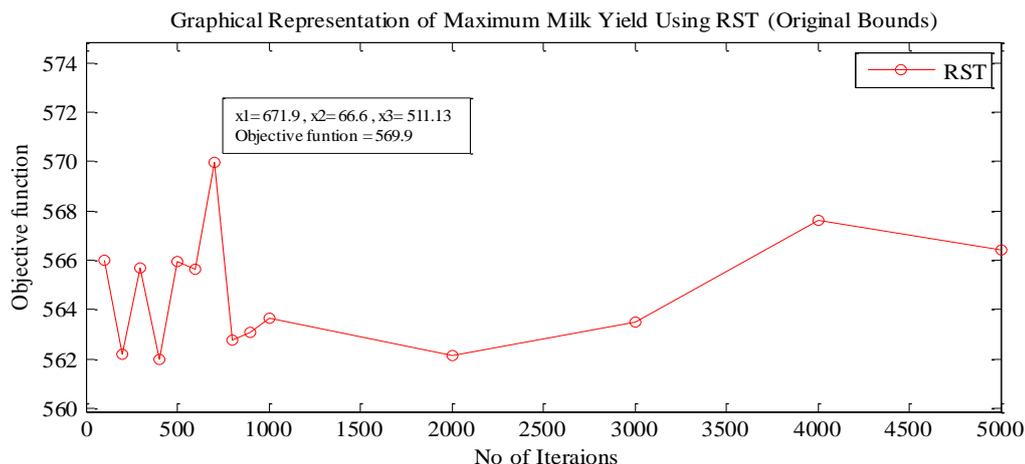


Figure 1: maximum milk yield

To avoid the possibility of getting the solution trapped in local minima we have reduced the bounds as follows:

$$630 \leq x_1 \leq 682; 66 \leq x_2 \leq 70; 366 \leq x_3 \leq 480 \quad (2)$$

The wide range of solutions obtained for reduced bounds is,

$$x_1 = 630 - 642.95, x_2 = 66.82 - 67.215, x_3 = 380.714 - 438.50$$

The global maxima obtained using a Controlled Random Search Technique for global optimization is 566. The solution set of the NLP is in table 2.

TABLE 2: Solution Set for NLP Model of Animal Diet by Controlled Random Search Technique for reduced bounds

No of iterations.	x_1 in gm/kg.metabolic weight	x_2 in gm/kg.metabolic weight	x_3 in gm/kg.metabolic weight	Value of the function
100	634.7796	67.0718	380.714	564.92
200	630.07	67.136	432.44	564.53
300	630	67.215	366	564.54
400	632.480	67.18	421.71	564.82
600	637.69	66.99	417	565.29
700	642.95	66.82	408.011	566
800	631.97	67.222	444.4	564.84
900	632.70	66.86	426.76	564.81
1000	634.34	67.08	465	564.95
2000	638.31	67.19	454	565.5
3000	631.24	66.94	438.50	564.58
4000	632.31	67.07	424.114	564.698
5000	630	67.08	437.101	564.44

The graphical representation of maximum milk yield is shown in figure 2.

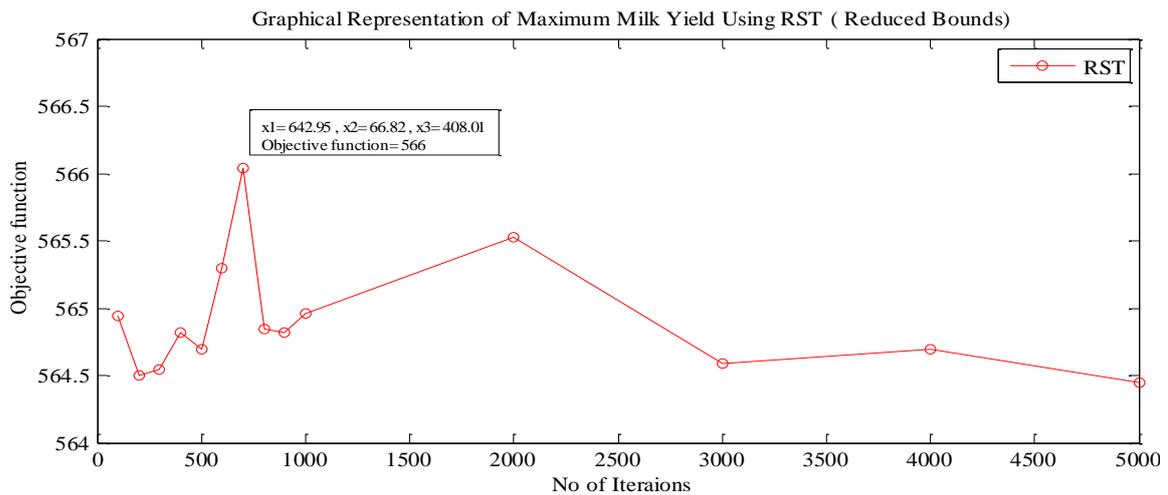


Figure 2. graphical representation of maximum milk yield as per table 2

After solving the NLPP (1) with original bounds and (2) with reduced bounds using RST2, we observe from the table 1 & 2 that the variation in the values of the decision variables x_1 , x_2 & x_3 are 4.3%, -0.19% & 20.17% respectively. This leads to the variation of 0.68% in the objective function value (maximum milk yield), which is well accepted. Hence the range of the bounds does not matter much here. Also optimal results are obtained in 700 iterations itself.

4.3 SOLUTION OF NLP BY GENETIC ALGORITHM

The solution set for NLP model of animal diet by Genetic Algorithm Technique for the bounds as in equation (1) is given in table 3. The wide range of solutions obtained with the original bounds is,

$$x_1 = 721.3220 - 747.1494, x_2 = 71.5456 - 74.6055, x_3 = 432.3138 - 474.6072$$

The global maxima obtained using Genetic Algorithm for global optimization problem is 819.1805.

Table 3: Solution Set for NLP Model of Animal Diet by Genetic Algorithm for Original Bounds

No of generations	x_1 in gm/kg.metabolic weight	x_2 in gm/kg.metabolic weight	x_3 in gm/kg.metabolic weight	Value of the function
100	749.0624	73.5973	432.3138	759.5984
200	755.6987	72.4891	495.7266	704.4718
300	744.6752	74.2517	491.5240	796.9501
400	729.9346	72.8592	457.8180	719.0342
500	750.7326	73.6261	475.2268	761.3943
600	747.5276	71.5456	472.9012	664.0140
700	748.0788	72.9356	463.3000	724.8789
800	721.3220	72.9743	465.8431	723.7324
900	759.4326	73.2797	482.3860	743.7354
1000	724.1868	73.1996	484.8339	735.5141
2000	722.4416	72.5642	482.3343	704.1149
3000	747.1494	74.6055	474.6072	819.1805
4000	724.4928	74.5268	472.6285	811.6016
5000	759.6734	73.2089	477.6959	740.0712

The graphical representation is shown in figure 3

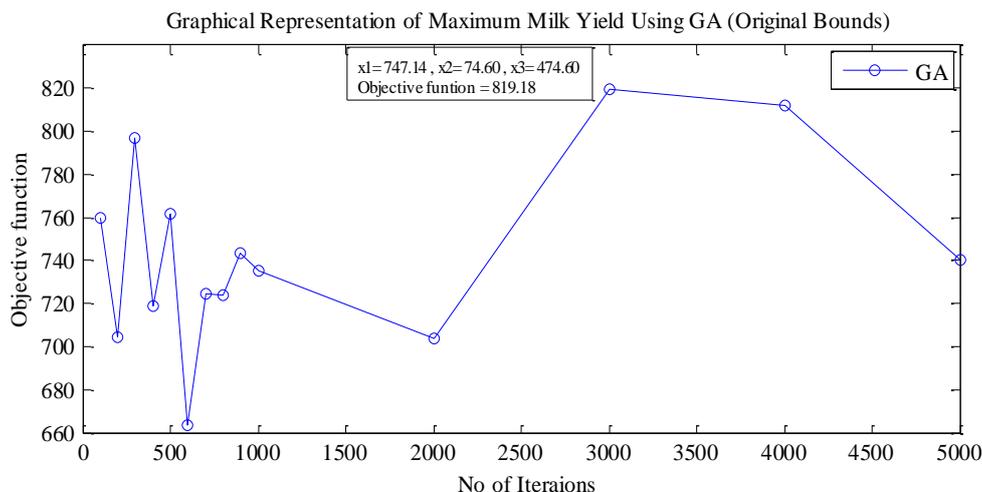


Figure 3. graphical representation of table 3

The solution set for NLP model of animal diet by Genetic Algorithm Technique for reduced bounds is given in table 4. The wide range of solutions obtained with original bounds is,

$$x_1 = 670.5081 - 677.1270, x_2 = 68.8769 - 69.4029, x_3 = 428.7671 - 463.4859$$

The global maxima obtained using a Genetic Algorithm is 593.8254.

TABLE 4: Solution Set for NLP Model of Animal Diet by Genetic Algorithm For Reduced bounds

No of generations	x_1 in gm/kg.metabolic weight	x_2 in gm/kg.metabolic weight	x_3 in gm/kg.metabolic weight	Value of the function
100	672.1468	69.3301	463.4448	591.8256
200	672.0984	68.8769	428.7671	583.8616
300	664.0533	69.3305	439.3848	590.8939
400	662.9170	68.8893	456.7290	583.0166
500	677.1270	69.4029	445.7669	593.8254
600	670.5509	69.4217	444.8161	593.4490
700	662.0822	69.4115	463.4859	592.2789
800	672.0792	69.3436	446.4769	592.0740
900	669.2510	69.1619	460.0039	588.3455
1000	674.4207	69.0258	461.6140	586.5650
2000	674.7802	69.3380	456.8179	592.2804
3000	662.8439	69.0090	453.2494	584.9496
4000	675.4472	69.3782	441.0744	593.1386
5000	670.5081	69.1511	442.2030	588.2859

The graphical representation is shown as shown in figure 4.

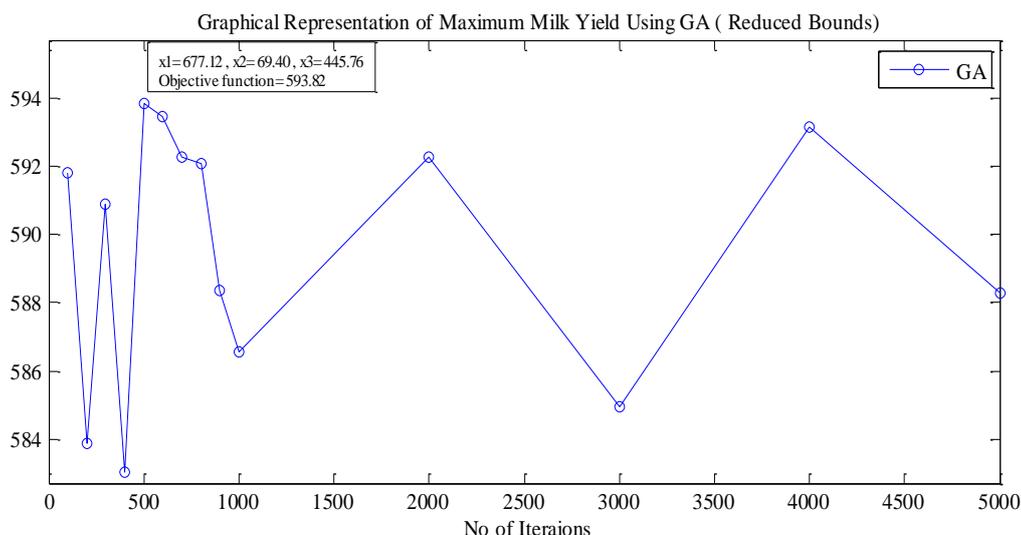


Figure 4. graphical representation of table 4

While solving the same NLPP (1) & (2) using Genetic Algorithm, it is observed from the table 3 & 4 that the variation in the values of the decision variables x_1 , x_2 & x_3 are 9.3%, 6.9% & 6.08% respectively leading to the variation of 27% in the objective function value which is more compared to the value obtained using RST2. Hence the reduction in the range of the bounds gives better results and is comparable with that of solution obtained by RST2. Also with wide range of bounds the algorithm produces best results only after 3000 generations whereas after narrowing the range of bounds the best result is produced within 500 generations itself

4.3 COMPARISON OF RST2 AND GA

The comparison between the solution obtained by RST2 and GA are shown in the table 5.

TABLE 5: Solution Set for NLP Model of Animal Diet by RST and GA

BOUNDS	RST2				GA			
	X_1	X_2	X_3	Obj Fun	X_1	X_2	X_3	Objective fun
Original Bounds	608-671	66-68	366-511	562-570	721-760	71-75	432-496	664-819
Reduced Bounds	630-642	66-67	366-465	564-566	662-677	68-69	428-463	583-594

And the graphical representation for the comparison of RST2 and GA (original bounds) is as shown in figure 5.

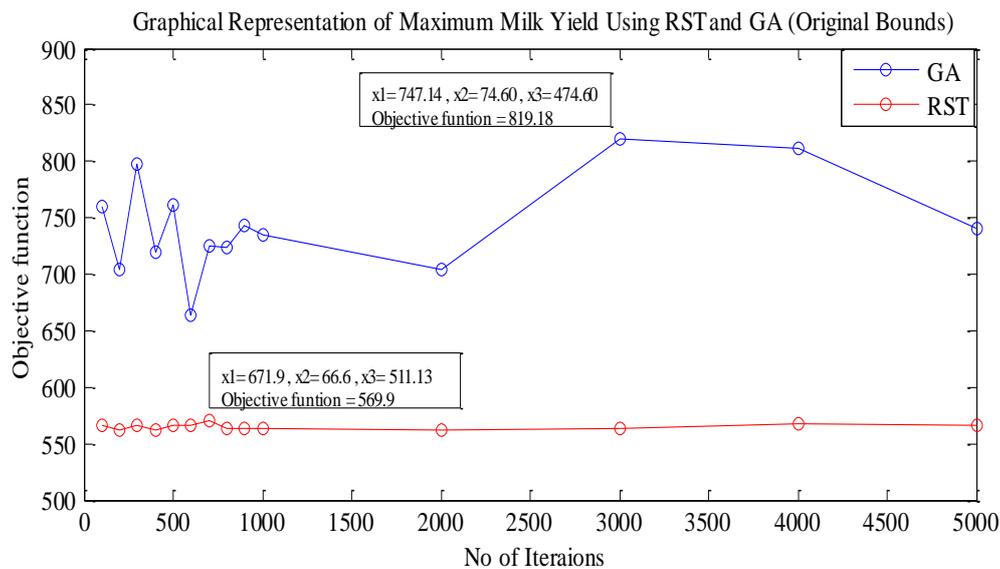


Figure 5. comparison of RST2 and GA (original bounds)

The graphical representation for the comparison of RST2 and GA (reduced bounds) is as shown in figure 6.

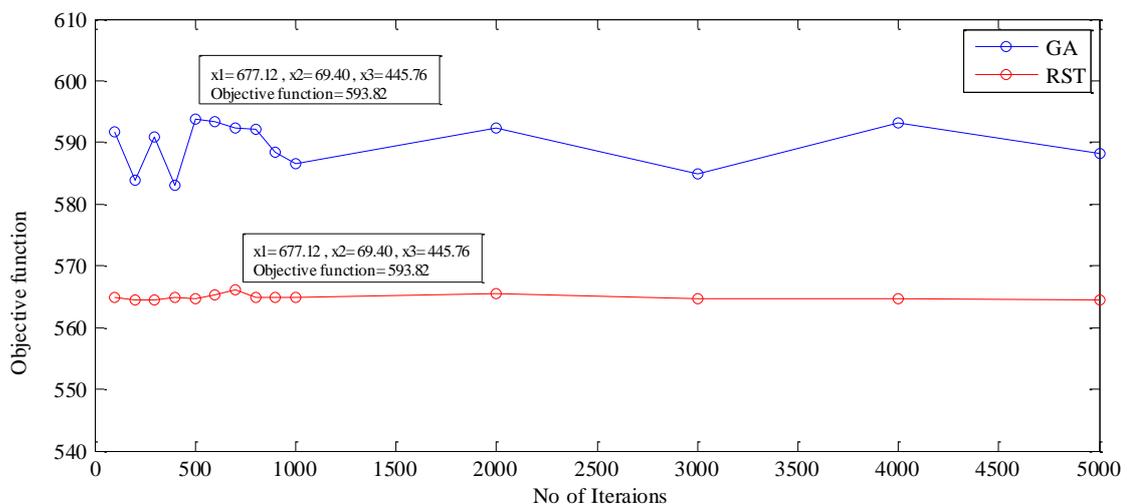


Figure 6. comparison of RST2 and GA (reduced bounds)

However critical analysis shows that the performances of both the techniques are comparable with a small deviation of 4.6%. The probable range of decision variables and objective function is given in Table 5.

V. CONCLUSIONS

We have explored the possibility of solving non-linear mathematical model of animal diet problem using Controlled Random Search Technique and Genetic Algorithm by slightly modifying them to suit our requirement. The objective of the study was to demonstrate the merits of using heuristic approaches in solving a non linear model of Livestock Ration Formulation.

In view of the results obtained & discussed in section 4, we conclude that heuristic approaches to non linear animal diet problem, can be more useful than conventional approach. Hence it is suggested that these approaches can be extended to solve any non linear optimization problem as they replace the traditional concept of a static requirement with a dynamic one. We also observe that both the algorithms effectively give flexibility to choose any option from the wide range of solutions that act as additional bonus to the planner.

ACKNOWLEDGEMENT

The authors acknowledge the constant support from Mrs. Kokila Ramesh, faculty in School of Engineering and Technology, Jain University, Bangalore.

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