Applied Mathematics. 2011; 1(2): 106-108
DOI: 10.5923/j.am.20110102.17

Comparison of Linear and Nonlinear Programming Techniques for Animal Diet

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Abstract Linear programming techniques have been extensively used for animal diet formulation for more than last fifty years. To overcome the drawback of linear approximation of objective function for diet formulation, a mathematical model based on nonlinear programming technique is proposed to measure animal performance in terms of milk yield and weight gain. At the second step, it compares the result of proposed program with that of linear programming model. Result of proposed model gives better results using nonlinear programming. Thus the study is an attempt to develop a nonlinear programming model for optimal planning and best use of nutrient ingredients.

Keywords Diet Formulation, Linear Programming, Nonlinear Programming, Nutrient Ingredients, Feeding Standards

1. Introduction

Research on nutrition is under process for more than hundred years. Diet formulation is a process by which different ingredients are combined to provide necessary nutrition to animals at different stages of production. A diet should supply all essential nutrients and energy to maintain vital physiological functions of growth, reproduction and health of animals. Diet should be highly digestible and should have very less adverse environmental effect.

A number of methods have been defined for the formulation of animal diet; square method, two by two matrix methods, simultaneous equation method, trial and error method and linear programming method to formulate least cost diet. Linear programming is widely used for this purpose. Diet formulated by linear programming is based on assumption of linearity between animal yield and nutrient ingredients included in the diet. To overcome the assumption of linearity and to include complexity of different nutrient ingredients, a nonlinear model is proposed in this paper to maximize milk yield. This concept of non-linear programming may be used to maximize the weight gain of the animal or animal yields approximately.

A combination spreadsheet is represented for ration formulation using linear programming [VandeHaar M. J., Black J. R., 1991]. Chance-constrained programming is used to formulate commercial feeds for animals [William B. Roush, Robert H. Stock, Terri L. Cravener and Thomas H. D'Alfonso, 1994]. Genetic algorithms are applied for the cost optimization of the feed mixtures and a software is developed by using Delphi environment, which provides flexible, extensible and user-friendly framework for tuning the heuristic relevant parameters and improving the solution quality[M. Akif Şahman, Mehmet Çunkaş, Şeref İnal et al, 2009]. A stochastic-linear program Excel workbook was developed that consisted of two worksheets illustrating linear and stochastic program approaches. Both approaches used the Excel Solver add-in[W. B. Roush, J. Purswell and S. L. Branton, 2007]. Iterative linear programming is used to solve two nonlinear optimization problem of animal diet formulation [Alan G. Munford, 1996]. A model is developed to achieve a final calving weight of 600Kg. for large breed replacement dairy heifers [P. R. Tozer, 2000].

Present study is carried out to compare the diet formulation model by linear and nonlinear programming method. At the first step, linear model is considered by taking essential nutrients into account and objective function is formulated approximating linear relationship. As the second step, a mathematical model is proposed by using Nonlinear Programming. At third step, this result is compared to the result of linear programming model.

2. Material and Methods

Present study is carried out on the animal experiment data of the research project at National Dairy Research Institute, Karnal [Virendra Kumar]. Briefly, the study consists of lactating sahiwal cows of second to fifth lactation number, were selected from the National Dairy Research Institute herd, and divided into four group, which were switched over four times (as the number of treatments) in a Latin-square change over design. Care was taken to minimize the variation within the animals of various groups. Each period

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Published online at http://journal.sapub.org/am

was of 40 days duration. The 4 groups A, B, C and D were fed with isonitrogeneous and isocaloric concentrate mixtures, containing ground nut cake, cotton cake, cotton seedcake (undecorticated) and cotton seed cake (decorticated), respectively. In addition to the maintenance requirements, 50 gm DCP requirement, 50 percent 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.

Table 1 gives composition of concentrate mixtures in respect of DCP and TDN. 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.

Table 1. Computation of concentrate mixtures in respect of DCP and TDN

Ingredients	Control (G.N.Cake)	Cotton seed (whole)	Cooton seed cake (unde)	Cooton seed cake (deco)
Groundnut cake	22	10	0	0
Cotton seed	0	57	0	0
(undecorticated)	0	0	44	0
(decorticated)	0	0	0	27
Wheat bran	75	30	53	70
Common salt	2	2	2	2
Mineral mixture	1	1	1	1

Present study is carried out to maximize the milk yield. The milk yield and the efficiency with which the nutrients are utilized mainly depend on 3 factors, which may be used to maximize it. Accounting all these facts, milk yield of an animal depends upon:

1. Digestible crude protein,
2. Total digestible nutrient and,
3. Digestible dry matter.

Metabolic weight is used as a base for whole of the calculations [Morrison, Frank B]. Studying the intake in growing animals, $Kg^{0.75}$ is considered as metabolic weight [Moir et. al].

3. Result and Discussion

Data is used to formulate linear and non-linear programming problem. This innovative approach of diet formulation (non-linear programming) is being compared to linear programming problem with the same set of data. This work represents a comparative study of linear and nonlinear programming method of animal diet formulation. Firstly, there is consideration of linear programming.

3.1. Linear Programming Formulation

Assuming a linear relationship between milk yield of cows and dry matter, crude protein and total digestible nutrient, weightage of these variables is decided. Using least square method, this relationship is established between all the nutrient ingredients and milk yield.

$$y = -8.370301\times10^{-1}x_1 + 6.362904x_2 + 2.346158x_3 - 2.592929\times10^{2} \quad (1)$$

This equation describe the weightage of the variables x_1, x_2, and x_3.

Mathematical model is formulated as,

$$Y = 0.00403908701533x_1 + 0.25469485541324x_2 + 0.02110699233x_3 - 8.67895696598672 \quad (2)$$

$$608.6718 \le x_1 \le 782.978$$
$$60.641 \le x_2 \le 75.943 \quad (3)$$
$$366.0412 \le x_3 \le 508.9343$$

Constraints are applied according to feeding standards on the above-mentioned variables according to feeding standards of NRC.

After formulating objective function and constraints, solution is found at corner points of feasible region.

$$x_1 = 782.978 gm/kg.$$
$$x_2 = 75.943 gm/kg.$$
$$x_3 = 508.9343 gm/kg.$$

3.2. Formulation of Nonlinear Programming Model

By using least square relation between y and x_1, y and x_2, y and x_3 of different degrees are established and then F-test is used to evaluate best fit relation. Applying the F-test, following are the most appropriate relationship between the variables;

$$y = -4.391942\times10^{2} + 1.297282x_1$$
$$y = 2.117103\times10^{4} - 6.145162\times10^{2}x_2 + 4.585451x_2^{2}$$
$$y = -1.550797\times10^{4} + 6.375803\times10^{1}x_3 - 6.277966\times10^{-2}x_3^{2}$$

Now objective function is formulated by using the appropriate relations of the variables x_1, x_2, x_3 according to their weightage on milk yield of the cows and constrains are applied according to feeding standards of NRC recommendations [NRC, 1981]

$$Y = 4.179244219x_2^{2} - 4.082239204\times10^{-6}x_3^{2} + 0.114836671x_1 - 560.0786654x_2 + 4.145857585\times10^{-3}x_3 + 19255.68675 \quad (4)$$

$$608.6718 \le x_1 \le 782.978$$
$$60.641 \le x_2 \le 75.943$$
$$366.0412 \le x_3 \le 508.9343$$

3.3. Solution of the Problem

Introducing Kuhn-Tucker conditions, we can maximize the milk yield of the cows as

$$L = 4.179244219x_2^{2} - 4.082239204\times10^{-6}x_3^{2} + 0.114836671x_1 - 560.0786654x_2 + 4.145857585\times10^{-3}x_3 + 19255.68675 - \lambda_1[x_1 - 782.978] - \lambda_2[x_2 - 75.943] - \lambda_3[x_3 - 508.9343]$$

Using Kuhn-Tucker method of solution following optimum values of three nutrient ingredients are obtained to maximize the milk yield.

We have, $x_1 = 782.97800$ $x_2 = 67.00717$, $x_3 = 507.79209$ gm/ Kg. metabolic body weight, subject to the condition: $\lambda_1 \neq 0$, λ_2, $\lambda_3 = 0$ satisfying all the conditions.

4. Conclusions

This study compares the method of linear and non-linear programming of animal diet formulation and shows that linear programming method gives result at corner points of feasible area. This result is at higher side of results as compared to results obtained from Nonlinear programming problem. This comparison shows that linear programming gives higher value of variables to maximize the animal yields than that of nonlinear programming variable values. This comparison shows that non linear programming gives better result for maximization of animal yield and weight gain and represents simultaneous effect of all variables altogether.

This approach of formulating model using nonlinear programming overcomes the drawback of linearity assumption and represents future prospective of extension of this technique for more variables.

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