Stochastic Programming and C-Somga: Animal Ration Formulation

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Abstract- ***A self-organizing migrating genetic algorithm(C-SOMGA) is developed for animal diet formulation. This paper presents animal diet formulation using stochastic and genetic algorithm. Bi-objective models for cost minimization and shelf life maximization are developed. These objectives are achieved by combination of stochastic programming and C-SOMGA. Stochastic programming is used to introduce nutrient variability for animal diet. Self-organizing migrating genetic algorithm provides exact and quick solution and presents an innovative approach towards successful application of soft computing technique in the area of animal diet formulation.***

Keywords- Animal feed ration, feed formulation, linear programming, stochastic programming, self-migrating genetic algorithm, C-SOMGA technique, shelf life maximization, cost minimization, nutrient maximization.

I. INTRODUCTION

Animal ration is mixture of feed ingredients that provides energy and fulfills nutrient requirements of animal. It refers to allotment of nutrient ingredients for better output from animal in terms of milk yield and weight gain. Necessary nutrition to the animal at different stages of growth and production can be provided effectively by mean of feed formulation. A chronological review was presented for animal diet formulation models including data for more than 100 years [1].

Tozer presented a linear program and variability of a certain nutrient named crude protein is included in the feed by using three methods and results were compared [2]. An extensive review was presented on the basis of programming techniques used for optimized diet of animals [3]. A model has been developed for African catfish to minimize the adverse effects of the nutrient variability and stochastic programming is used for this purpose. The results showed the superiority of stochastic programming over linear programming when nutrient variability is considered [4]. A paper has been presented to compare Linear programming with a margin of safety (LPMS) and stochastic programming (SP). These models are used to formulate poultry rations at minimum cost meeting nutrient requirements as set by NRC. [5]. Nonlinear programming is used to maximize the weight gain for sheep [6].

Models for ration formulation with stochastic programming (STCH) and linear programming with a margin of safety(LPMS) for laying hens were presented [7]. A goal programming model was presented for optimization of livestock feed blend [8]. A program based on nonlinear approach is presented for animal diet formulation [9]. Linear and nonlinear approaches of animal diet formulation are compared and results were verified by real world data [10].

Objective of this paper is to obtain optimized animal ration at minimum cost. This objective is designed with the help of bi-criterion models. A combination of feed ingredients is to be obtained which has maximum nutritional value, better shelf life at minimum cost. First objective is set for cost minimization and second objective is set for better shelf life of animal ration (achieved by minimization of water content). Programming models are introduced for each objective by linear programming and solved [11]. This paper is extension of the work including nutrient variability. Nutrient variability is introduced in the pig ration by using stochastic programming and all models are solved by C-SOMGA technique.

Input data for pig feed cost minimization and shelf life maximization are discussed in section 2. 18 models for bi-objective models are formulated and solved. Result analysis is presented in section 4 and conclusion is given in section 5.

II. INPUT DATA FOR DETERMINATION OF PIG RATION

9 feed ingredients and 8 nutrient ingredients are used to formulate the models. Table 1 represents feed ingredients with cost, water content and nutritional composition. It also represents requirement for price, nutrient content and water content. Notations used are:

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z objective function, c_j per unit cost of feed ingredient j , x_j quantity of jth feed ingredient in the feed mix , a_{ij} amount of nutrient i available in the feed ingredient j , k probability level, b_i minimum requirement of ith nutrient , i index identifying feed nutrient components with i = 1,2,….m , j index identifying feed components with j =1,2,………n

III. MATERIAL AND METHODS

In this paper, models are formulated using stochastic programming and are solved by using the proposed technique C-SOMGA. These bi-criteria models are developed for better shelf life of the ration with minimum cost. Maximization of shelf life and minimum cost feed is formulated by linear programming models [11]. This paper is extension of the linear model by inclusion of stochastic models.

Stochastic Programming Model

The nutrient composition of feed ingredients may have variation and this variation may have a negative impact on the growth of the animals as well as on the cost. Therefore to reduce the risk of not meeting the nutrient requirements by under or over formulation, it is essential to consider this variation while developing the models for animal feed mix formulation. Stochastic programming model is an appropriate tool to deal with the nutrient variability. Here models have been developed to incorporate nutrient variability and stochastic programming is used for this purpose. It is included by nonlinear variance of each nutrient ingredient and a desired probability level. σ_{ij}^{2} represents variance of nutrient i in ingredient j and it is included with a certain probability level. This model is formulated

$$\begin{aligned}
&Min\ \ z = \sum c_{j3} x_j \\
&\sum_{j=1}^{n}\left(a_{ij} - z\left(\sqrt{\sum_{j=1}^{n}\sigma_{ij}^{2}}\right)\right)x_j \geq b \\
&\sum_{i=1}^{13} x_i = 0.90 \\
&0 \leq x_i \leq 0.10, 0.15, 0.20 (i = 1,2,...9) \\
&x_j \geq 0, b_i \geq 0
\end{aligned}$$

$$\begin{aligned}
&Min\ \ z = \sum c_{j2} x_j \\
&\sum_{j=1}^{n}\left(a_{ij} - z\left(\sqrt{\sum_{j=1}^{n}\sigma_{ij}^{2}}\right)\right)x_j \geq b \\
&\sum_{i=1}^{13} x_i = 0.95 \\
&0 \leq x_i \leq 0.10, 0.15, 0.20 (i = 1,2,...9) \\
&x_j \geq 0, b_i \geq 0
\end{aligned}$$

Probability is assumed as 80% to consider the variability of nutritional values of feed component. This assumption implies that there is 80% probability that a ration contains the desired level of nutrients. For this level of probability, k

$$\begin{aligned}
&Min\ \ z = \sum c_{j2} x_j \\
&\sum_{j=1}^{n}\left(a_{ij} - z\left(\sqrt{\sum_{j=1}^{n}\sigma_{ij}^{2}}\right)\right)x_j \geq b \\
&\sum_{i=1}^{13} x_i = 0.98 \\
&0 \leq x_i \leq 0.10, 0.15, 0.20 (i = 1,2,...9) \\
&x_j \geq 0, b_i \geq 0
\end{aligned}$$

is 2. In this model, it is important to define a certain value of nutrient.

The requested probability determines the nutrient concentration for ration formulation. Ration formulation includes the variation in the percentage of various vitamin additives disregarding the ingredients included in the feed mixture. In these models, summation of all feed ingredients is limited to the values 0.90, 0.95, and 0.98 respectively. Another constraint is added to make the meal plan as heterogeneous as possible by introduction of limit the share of any feed ingredient to 10, 15, and 20 %. By inducing these two variations in meal plan, 18 models are solved for optimized ration formulation. This ration is optimized for better nutrient inclusion in ration, maximum shelf life with minimum cost. The models are formulated by stochastic programming and then solved by the use of C-SOMGA.

C-SOMGA Programming Model

In this paper an extended stochastic model of pig ration model has been developed. To solve this model the technique C-SOMGA has been used as discussed in [12]. C-SOMGA is a hybridized population based stochastic search technique which can be used to solve constrained optimization problem. This technique combines the features of both binary coded GA and real coded SOMA. The methodology and computational steps of this technique in brief are as follows: first the population of individuals has been generated randomly, then a leader and active individual has been selected among the population based on the best and worst fitness value respectively. Active individual starts its journey in the direction of the leader in n steps of the defined path length as follows:

$$x_{i,j}^{MLnew} = x_{i,j,start}^{ML} + \left(x_{L,j}^{ML} - x_{i,j,start}^{ML}\right) t\,PRTVector_j$$

$$where\quad t \in <0,\ by\ Step\ to,\ PathLength>,$$

ML is actual migration loop.

$x_{i,j}^{MLnew}$ is the new positions of an individual.

$x_{i,j,start}^{ML}$ is the positions of active individual.

$x_{L,j}^{ML}$ is the positions of leader.

PRTVector is a perturbation vector and is generated using PRT parameter which is defined in the range of (0,1). t= step size.

Now the position of active individual at each step is sorted from best to worst and their feasibility has been checked using a well known constraint tournament selection and best feasible position takes place of previous position of active individual. The methodology of this tournament selection method can be seen in [12][13]. After selection, a two pint binary crossover is used to create the new individuals and then a bitwise mutation operator is used to maintain the diversity among the population. The cycle of selecting leader, active, selection of feasible new position of active individual, crossover and mutation is repeated till the termination criterion is satisfied. Each cycle is known as migration loop also. In this paper population size is taken as 20, crossover probability as .85, probability of mutation as 0.001, step size 0.81 and path length is taken as 3.

IV. RESULTS AND DISCUSSION

Objective of cost minimization and water content minimization for better quality of ration are achieved respectively. These models are firstly solved by linear programming [11], and then stochastic programming is used to include nutrient variability in the animal diet. Nonlinear variance of each nutrient ingredient is introduced at a desired probability level.

These three tables represent optimum value of nutrient ingredients for better quality of animal ration in terms of maximum nutrient, minimum water content and minimum cost. Graphical view of results is shown by fig. 1, fig. 2 and fig. 3.

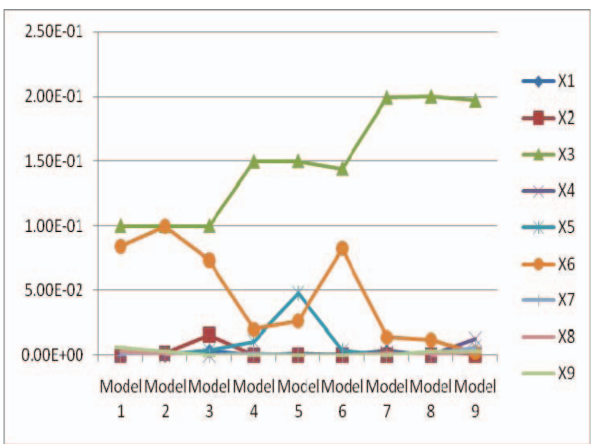

Fig. 1. Optimum value of nutrient ingredients for cost minimization

Figure 2 and 3 represent optimum values of nutrient ingredients for maximum nutrient inclusion and minimum water content.

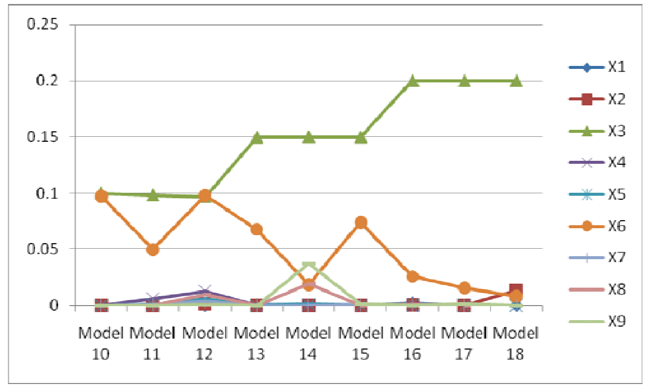

Fig. 2. Optimum value of nutrient ingredients for nutrient maximization

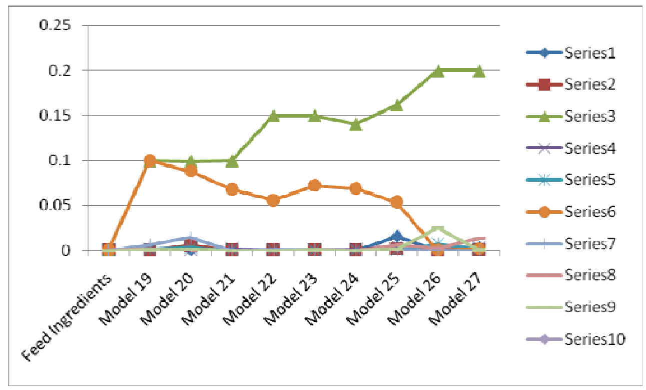

Figure 3. Optimum value of nutrient ingredients for water content minimization

By comparing these results from linear models, it is clear that nutrient variability is included by the use of stochastic programming. It can also be concluded that C-SOMGA provides values for more variables as compared to solve by TORA and LINGO. 18 models are solved and results were obtained by C-SOMGA. Comparison of results shows that by combining scholastic programming with C-SOMGA, more nutrient variability and greater inclusion of nutrients can be obtained at lower cost. It is clear from the table 1, that cost is minimum for model 4 (upper bound of each nutrient .15 and summation equals to 90). In the same way, water content is minimum for model 21 (upper bound of each nutrient .20 and summation equals to 90). and nutrients can be maximized by choosing model 12 (upper bound of each nutrient .15 and summation equals to 90), i.e. . It provides optimal combination of feed ingredients for bi-criteria models.

V. CONCLUSION

Combination of stochastic programming with C-SOMGA is presented to optimize animal ration. This method introduces intervention of genetic algorithms in the field of animal feed formulation. Combination of C-SOMGA with stochastic programming introduces inclusion of nutrient variability and nonlinear term for better results. Bi-criteria objectives are achieved by this combination of mathematical programming soft computing technique (C-SOMGA). Future research can be focused on the transformation of objectives by multi-objective and goal programming.

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Table 1. Composition of feed ingredients with cost, water content and nutritional requirements

Feed	Price(min)	Nutrient (Max)	Water Content(min)	Calcium-Ca	Phosphorus-P	Ash	Metionin	Lignin	Isoleucine	Histidine
Barley grain	1.75	70	11	0.08	0.42	2.5	0.18	0.53	0.17	0.42
Maize grain white	1.75	80	12	0.01	0.25	1.5	0.17	0.22	0.09	0.37
fish meal high protein	9	69	9	7	3.5	24	1.65	4.3	0.7	3.1
Soya meal	2.7	92	10	0.25	0.59	4.6	0.54	2.4	0.52	2.18
Soya hull	3.5	79	11	0.2	0.6	6	0.6	2.7	0.65	2.8
Dried Whey	9	78	6	0.87	0.79	9.7	0.2	1.1	0.2	0.9
Rape Pellets	1.8	66	8	0.6	0.93	7.2	0.67	2.12	0.46	1.41
Wheat	1.8	79	12	0.05	0.41	2	0.25	0.4	0.18	0.6
Sunflower Pellets	1.8	68	1.8	7	1	7.7	1.5	1.7	0.5	2.1

Table 2 Results for Cost Minimization

Feed Ingredients	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9
X_1	6.52314e-05	1.37329e-05	0.00336018	9.91345e-05	0.00118375	0.000296688	0.00316944	2.5177e-05	0.0020998
X_2	2.09809e-06	0.00166092	0.0160166	4.62056e-05	1.00136e-05	0.00025034	2.47956e-05	0	0.000158692
X_3	0.0999999	0.0998973	0.099915	0.149696	0.149997	0.144127	0.199191	0.199992	0.196802
X_4	2.05994e-05	8.58308e-07	8.38281e-05	2.57492e-06	1.43051e-06	0.000604678	0.00158692	0	0.012554
X_5	0.000296974	0.000988961	0.00354691	0.01028	0.0477748	0.00354224	0.000159264	0.000332642	0.0062912
X_6	0.0837879	0.0997058	0.0731819	0.0200157	0.0261927	0.0824161	0.0138853	0.0120129	0.00214958
X_7	2.67029e-06	0.000441361	0.000221062	0.00134626	0.00031271	0.000156927	0.000158882	0.000642777	0.00625725
X_8	0.00312662	0.000610638	5.31197e-05	0.000187826	6.29426e-06	7.49589e-05	0.00176182	0	0.00313378
X_9	0.00627595	0.0032959	0.000269985	2.30313e-05	3.76225e-05	3.57628e-06	0.000293732	0.00317421	0.00325013
Z	1.67223	1.81065	1.6054	1.56645	1.75565	2.0543	1.93211	=-1.91612	1.87319

Table 3 Results for nutrient maximization

Feed Ingredients	Model 10	Model 11	Model 12	Model 13	Model 14	Model 15	Model 16	Model 17	Model 18
X_1	0	1.71662e-05	0.000127316	0.000585938	2.73228e-05	3.29018e-06	0.00198059	6.29426e-06	3.8147e-07
X_2	1.23978e-05	5.72205e-07	0.00158749	2.08855e-05	7.35284e-05	7.36714e-05	0.00104027	3.2425e-06	0.0134766
X_3	0.0999751	0.0984298	0.0968184	0.14967	0.149937	0.149924	0.199899	0.199999	0.19995
X_4	5.81742e-05	0.00625306	0.012524	3.00408e-06	7.58172e-06	3.73364e-05	9.97544e-05	9.15528e-06	2.67029e-05
X_5	4.76838e-07	0.000782395	0.0062521	3.14713e-06	0.00117502	7.32423e-05	0.00072403	1.90735e-06	6.67573e-06
X_6	0.0976465	0.0499917	0.0984059	0.0677747	0.0186945	0.074177	0.0260388	0.0156157	0.00815335
X_7	4.76838e-07	0.000793839	0.00352831	7.41006e-05	7.58172e-05	0.000589085	0.00017128	0	5.72205e-07
X_8	1.75476e-05	1.90735e-07	0.00951253	0	0.0193361	7.35284e-05	0.000798989	5.03541e-05	1.46866e-05
X_9	3.05176e-06	9.98498e-05	0.000430966	1.85967e-06	0.0375268	0.00177684	0.000196457	0.00157166	0.000203705
Z	14.5227	11.3885	17.1518	15.6619	15.9896	16.3114	16.2001	15.1305	15.5287

Table 4 Results for Water content minimization

Feed Ingredients	Model 19	Model 20	Model 21	Model 22	Model 23	Model 24	Model 25	Model 26	Model 27
X_1	0.00175877	0.000507451	3.12805e-05	5.579e-06	0.000880481	8.26836e-05	0.0157677	1.83106e-05	0.00323029
X_2	0.000392723	0.00587226	0.000405407	3.80516e-05	0.000497818	5.43595e-06	0.00166779	2.44141e-05	0.000476838
X_3	0.0998524	0.0993993	0.0998029	0.149983	0.149999	0.140585	0.162102	0.199987	0.2
X_4	3.32833e-05	0.000213337	0.0015625	0.000226307	7.38145e-05	0.000878907	0.00500889	0.000204086	0.00330544
X_5	0.00156498	0.0031868	0.000113487	3.83377e-05	3.93391e-05	7.86782e-06	0.000108719	0.00704385	0.0016716
X_6	0.0997939	0.0878137	0.0678275	0.0556514	0.0720631	0.0688828	0.0536049	6.77109e-05	0.00161514
X_7	0.00625191	0.0141694	0.000197602	0.0012188	0.000923968	1.20163e-05	0.00101223	0.000198174	0.000103951
X_8	0.00156851	0.000433636	3.05176e-06	1.60217e-05	0.000151348	0.000120163	0.00648575	0.00284539	0.0140659
X_9	0.000848103	0.00164433	8.96455e-06	0.000368929	0.00121307	0.000377941	0.00163746	0.0250065	0.000519753
Z	1.61382	1.66478	1.32895	1.69949	1.8169	1.69259	2.12268	2.09109	2.07565