Teaching Learning Based Optimization Approach for Product-Mix in a Dairy Industry

Prof. K.Venkata Subbaiah
e-mail: drkvsau@yahoo.co.in

Rayeneni Mounica
e-mail: rayenenimounica@gmail.com

Challa Suresh
e-mail: challasuri213@gmail.com

Department of Mechanical Engineering, Andhra University College of Engineering (A), Visakhapatnam, India.

Abstract— India is the largest milk producer. Milk production in India takes place in Millions of rural households scattered across the length and breadth of the country. The performance of the Indian Dairy sector over the last three decades has been extremely impressive. The present paper deals with optimization of profit in a dairy industry that produces eight major end products. The optimum product levels are used to calculate the recourses utilization such as raw milk utilization, consumption of steam, refrigeration capacity, etc., and are compared with available quantity of resources. Teaching-Learning Based Optimization (TLBO) and Fuzzy Goal Programming (FGP) techniques are used for present thesis. These TLBO techniques perform based on the dependency of the learners in a class on the quality of teacher in the class. The teacher raises the average performance of the class and shares the knowledge with the rest of the class. The individuals are free to perform on their own and excel after the knowledge is shared. Teaching-Learning Based Optimization optimizes the considered objectives and final solution is optimum product levels produces and maximum profit. Obtained results are compared with that of the results from fuzzy goal programming optimization. This comparison showed that using TLBO is best technique to the problem.

Keywords- *Product-mix; Fuzzy Goal Programming; Teaching Learning Based Optimization*

NOTATION

AL_j : limit setting of j^{th} resource
AQ_j : available quantity of j^{th} resource
a_{lj} : tolerance for j^{th} resource utilization limit setting
a_{pi} : tolerance for i^{th} product requirement
a_{rj} : tolerance for j^{th} resource utilization
L_i : required quantity for i^{th} product
X_i : production of i^{th} product

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I. Introduction

In today's world the ever increasing demand on the organization is to lower the production costs by optimal usage of raw materials to withstand consumption, has prompted to look for rigorous methods to design and produce products both economically and effectively. Optimization techniques reached a high degree of maturity over the past several years. Hence there is fast advancement in the fields of technology up gradation and modernization. The dairy unit is also aiming for upgradation of technology, application of dynamic distribution and optimization of product mix. Venkata Subbaiah et al [1] discussed a brief analysis on Product mix in a diary industry using goal programming and fuzzy goal programming. Khatra, et al [2] dealt with optimum product mix by linear programming (LP) approach to the milk products. Sarma et al [3] discussed on the application of lexicographic goal programming to solve a product-mix problem in a large steel manufacturing unit. Ign Suharto et al, [4] demonstrated a fuzzy multi-objective linear programming model having probabilistic constraints in order to make product-mix decision. R. Venkata Rao and Vivek Patel [5] developed an improved teaching-learning-based optimization algorithm for solving unconstrained optimization problems. M. R. Nayak et al, [6] applied Multi-Objective Teaching Learning Based Optimization Algorithm to Optimal Power Flow Problem. V. Durga Prasada Rao et al, [7] discussed on Optimization of product mix in a paper mill using branch and bound paradigm, one of the heuristic approach of solving optimization problems. Kai-Lin Wang et al, [8] discussed Toward Teaching-Learning-Based Optimization Algorithm for Dealing with Real-Parameter Optimization Problems. Seyed Amin Badri et al, [9] explained in their thesis a multi-criteria decision-making approach to solve the product mix problem with interval parameters based on the theory of constraints.

II. MODEL FORMULATIONS

A. *Fuzzy Goal Programming*

The objectives and constraints are converted into goals. In addition to the above goals product requirement goal, their limit setting goals, resource utilization and their limit setting goals are considered. The various goals considered in can be viewed as multiple objectives and equivalent fuzzy goal programming is formulated by aggregating the goals using Zandeh's intersection operation discussed by Bellmen, et al[10].

- *Problem Formulation In Fgp*

Fuzzy goal equations

Product requirement goals

$X_i - a_{pi}\lambda \geq L_i$ for i= 1,2,3….8

Resource utilization goal

$F_i(X) + a_{rj} \leq AQ_i + a_{ri}$ for j=1,2,..7

Resource utilization limit setting goal

$F_i(X)-a_{lj}\lambda \geq AL_j$ for j= 1,2,..5

Objective function in fuzzy goal programming

Maximize λ

Where λ = minimum ($\mu_{Gm(x)}, \ldots\ldots G_{m(x)}$)

$\mu_{Gm(x)}$ = membership function of m^{th} goal

$G_{m(x)}$ = m^{th} goal

B. Teaching Learning Based Optimization

TLBO is also a population-based method and uses a population of solutions to proceed to the global solution. The population is considered as a group or class of learners.

In this optimization algorithm a group of learners is considered as population and different subjects offered to the learners are considered as different design variables of the optimization problem and a learner's result is analogous to the 'fitness' value of the optimization problem.

The best solution in the entire population is considered as the teacher. The design variables are actually the parameters involved in the objective function of the given optimization problem and the best solution is the best value of the objective function.

1) Initialization

The *jth* parameter of the *ith* vector (learner) in the initial generation is assigned values randomly using the equation.

$$X^1_{(i,j)} = X^{min}_j + rand_{(i,j)} \times (X^{max}_j - X^{min}_j)$$

Where $rand_{(i,j)}$ represents a uniformly distributed random variable within the range (0,1). The parameters of the *ith* vector (or learner) for the generation g are given by

$$X^g_{(i)} = \left[X^g_{(i,1)}, X^g_{(i,2)}, \ldots\ldots X^g_{(i,j)} \ldots\ldots X^g_{(i,D)}\right]$$

The objective values at a given generation form a column vector

$$[Y^g_i] = \left[f\left(X^g_{(i)}\right)\right]$$

For all the equations used in the algorithm i=1,2,….N, j=1,2……D and g=1,2,….G. The random distribution followed by all the *rand* values is the uniform distribution.

Teacher Phase The mean vector containing the mean of the learners in the class for each subject is computed. The mean vector M is given as

$$M^g = \begin{bmatrix} mean[x^g_{(1,1)}, \ldots\ldots\ldots x^g_{(i,1)}, \ldots\ldots x^g_{(N,1)}] \\ \cdots \\ mean[x^g_{(1,j)}, \ldots\ldots\ldots x^g_{(i,j)}, \ldots\ldots x^g_{(N,j)}] \\ \cdots \\ mean[x^g_{(1,D)}, \ldots\ldots\ldots x^g_{(i,D)}, \ldots\ldots x^g_{(N,D)}] \end{bmatrix}^T$$

which effectively gives us

$$M^g = [m^g_1, m^g_2, \ldots..m^g_j \ldots\ldots m^g_D]$$

The best vector with the minimum objective function value is taken as the teacher ($X^g_{teacher}$) for that iteration. The algorithm proceeds by shifting the mean of the learners towards its teacher. A randomly weighted differential vector is formed from the current mean and the desired mean vectors and added to the existing population of learners to get a new set of improved learners.

$$X^g_{new\ (i)} = X^g_{(i)} + rand^g \times (X^g_{teacher} - T_F M^g)$$

Where T_F is a teaching factor which is randomly taken at each iteration to be either 1 or 2. The superior learners in the matrix X_{new} replace the inferior learners in the matrix X using the non-dominated sorting algorithm.

2) Learner Phase

This phase consists of the interaction of learners with one another. The process of mutual interaction tends to increase the knowledge of the learner. Each learner interacts randomly with other learners and hence facilitates knowledge sharing. For a given learner, $X^g_{(i)}$ another learner $X^g_{(r)}$ is randomly selected ($i \neq r$). The i^{th} vector of the matrix X_{new} in the learner phase is given as

$$X^g_{new\ (i)} = \begin{cases} X^g_{(i)} + rand^g_{(i)} \times \left(X^g_{(i)} - X^g_{(r)}\right) if \left(Y^g_{(i)} > Y^g_{(r)}\right) \\ X^g_{(i)} + rand^g_{(i)} \times \left(X^g_{(r)} - X^g_{(i)}\right) \ otherwise \end{cases}$$

3) Constraint Handling

For constraint handling Deb's heuristic method is used. Deb's method uses a tournament selection operator in which two solutions are selected and compared with each other. The following three heuristic rules are implemented on them for the selection:

- If one solution is feasible and the other infeasible, then the feasible solution is preferred.
- If both the solutions are feasible, then the solution having the better objective function value is preferred.
- If both the solutions are infeasible, then the solution having the least constraint violation is preferred.

4) Algorithm Termination

The algorithm is terminated after G iterations are completed.

III. CASE STUDY

Organisation profile

The dairy located in the Visakhapatnam district of Andhra Pradesh, is considered for the present study. The dairy was established in 1977 with the handling of 50,000 l/day. At present handling capacity of dairy is three lakh l/day. Although it was record of manufacturing products like ice cream mix, whole milk powder etc, the factory has confined to the production and marketing of few popular products. The production figures are those in the marketing line and for which the costing and optimization were carried out are presented in Table 1. Eight products listed in table 1, are chosen for the study. Each product resulted in a separate identity and commanded regularity of production and marketing.

Table 1. Availability of Resources

Product specification	Product, kgs (L_i a_{pi})	Limit setting values (LS_i)
Whole Milk	(64250, 7000)	8300
Toned Milk	(184348, 20000)	184348
Standardized Milk	(46319, 5000)	56000
Skimmed Milk	(18052, 5000)	21572
Cream	(10500 1300)	16000
Butter	(38672, 4000)	42539
Ghee	(36944, 4000)	40638
Skimmed Milk Powder	(10350, 1000)	25000

The by-products like sterilized flavored milk, lassi, pannier etc., were kept out of purview for the reason that production is not market oriented. The Table 2 shows the utilization of resources with fuzzy goal programming and teaching learning based optimization marketing. The by-products like sterilized flavored milk, lassi, pannier etc., were kept out of purview for the reason that production is not market oriented. The Table 2 shows the utilization of resources along with fuzzy violations and proposed limit setting of resource utilization along with fuzzy violations.

Table 2. Utilization and limit setting of resources

Description of resources	Quantity available	Utilization limit setting (AQ_j, a_{rj})
Raw Milk Utilization, kgs	(31296, 4700)	(16500, 16500)
Consumption of Steam, kgs	(120000, 20000)	(85000, 10000)
Electricity Utilization, kwh	(27600, 2760)	(20000, 2000)
Refrigeration Capacity, ton-hr	(25200, 2520)	(14000, 1200)
Man Power Requirement	(800, 100)	(300,100)
Oil Expenditure, Rs	(700000, 100000)	(600000, 100000)
Profit, Rs	(500000, 52999)	

IV. RESULTS AND DISCUSSION

The product mix problem is formulated in Teaching Learning Based Optimization and Fuzzy Goal Programming. Table 3 shows the optimum levels of the products obtained. MATLAB programs for each of the methods are used to solve the problem and obtained values are compared with each other. The production quantities of various products are increased in TLBO and FGP. The below results it is observed that there is large increase in whole milk compared to other end products. Table 4 shows the resource utilization of production. There is low utilization in case of raw milk, steam, and man power requirement. There is moderate utilization in refrigeration capacity and oil expenditure in TLBO approach. There is great percentage utilization in oil expenditure and electricity utilization. There is low percentage utilization in raw milk. Percentage consumption of steam and electricity utilization is greater in TLBO approach than of FGP. The product levels obtained after using TLBO algorithm are subsequently increasing levels. This shows that using this had an effective way of increasing in profit to 49891.750 per day. The quantities are kgs per day. All resources utilization had an effective way in decreasing the amount required to spend for available resources.

Table 3. Optimal levels of products obtained

Description of End Products (Kgs)	Actual Production	TLBO	FGP
Whole Milk	64250	71260	68144
Toned Milk	184348	204448	194309
Standardized Milk	46319	51298	48067
Skimmed Milk	18052	20073	17708
Cream	10500	11843	11002
Butter	38672	42726	37003
Ghee	36944	40834	38870
Skimmed Milk Powder	10350	11426	11008

Table 4. Utilization of resources

Resources	Quantity Available	Quantity Utilized TLBO	Quantity Utilized FGP
Profit (Rs)	-	498917.750	437802.00
Raw Milk Utilization (Kgs)	312969	143776.480	133919.40
Consumption of Steam (Kg)	120000	79867.287	72384.16
Electricity Utilization (kWh)	27600	18143.028	15117.00
Refrigeration Capacity (t/h)	25200	22001.186	15113.99
Man Power Requirement	800	271	260
Oil Expenditure (Rs)	700000	661254.103	608797.63

CONCLUSION

Generally conflict arises between marketing department and production department about product mix. Marketing department is always interested in easily sealable products. Production department is interacted in easily sealable products. Organization survival depends only on optimizing the contribution within the available constraints which satisfies requirement of all departments. Teaching Learning Based Optimization is used in such studies which is more useful.

In this approach the main objective is profit maximization which is achieved. Also the results show that there is effective increase in profit in using TLBO than that of Fuzzy Goal Programming approach.

By using TLBO programming approach, errors associated with computational and complexities with conventional approaches are eliminated. In this paper, TLBO algorithm approach is applied to product mix problem of linear nature, it can be extended to other problems of imprecise non linear nature.

This approach to optimum product mix for dairy industry, eight major products are considered. This study can be extended to all the problems with different grades and product levels. And also additional constraints to all the problems like power available and wastage generated etc., can be taken up. This can be applied to the industry having more number of end products.

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