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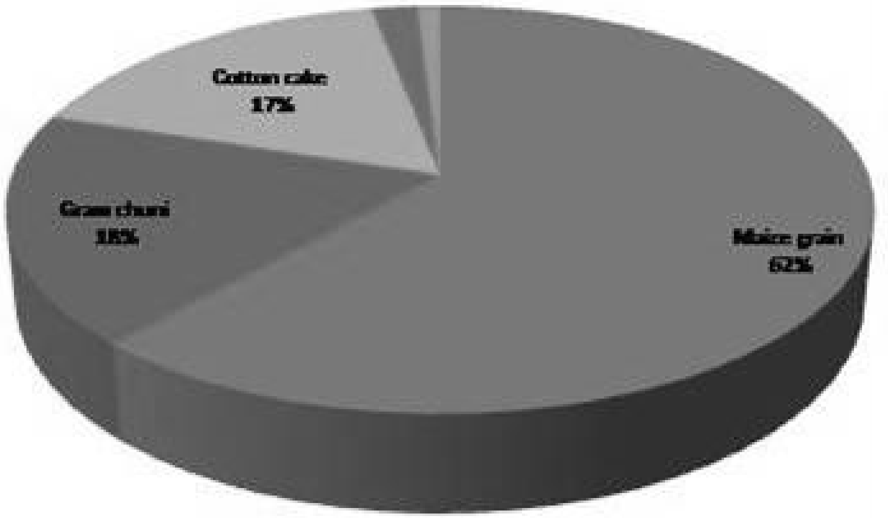

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RESEARCH ARTICLE

OPTIMIZED CONCENTRATE FEED MIX FOR PANDHARPURI BUFFALO

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ABSTRACT

The cost optimization is the element to determine least cost feed mixture to animal by taking into account nutrient requirement of animal and also the effective use of available feed resources. In this study, the best100 kg concentrate feed mix is prepared by using linear programming problem (LPP) technique for Pandharpuri buffalo.

INTRODUCTION

In India, the growth of dairy sector during the last three decades has been remarkable. In dairy farming, the situation is restricted to limited resources in feeding of their livestock, price for input etc. The cost minimization can be achieved by the dairy farmer through reallocation of resources given their restricted resources (Anbukkani *et al,* 2014). Rarely only forages can completely satisfy all mineral requirements (Bhanderi *et al,* 2013 and Garg *et al,* 2011). The most constraining factor to farmers is to supply quantity of concentrate mixture to the animals. The farmer is worried in developing a least cost concentrate mixture for their milch stock. The selection of a good mixed feed is the foremost problem for any farmer. This is due to fact that the cost of concentrate feeds is the main expense of the livestock farming. The farmer is trying to minimize the input cost. In India farmers do not adopt improved dairy management practices at the desired level (Patil *et al,* 2009).In such cases, it is necessary to improve optimization techniques in concentrate feed mix.

The different types of buffalo breeds are found in World. Pandharpuri is the breed found in Western Maharashtra. This buffalo is chosen by farmer in its breeding tract viz. Solapur, Kolhapur, Sangli and their adjoining districts (Fernandes *et al,* 2009). The top quality Pandharpuri buffaloes are found in Kolhapur district, 70 to 80 percent total milk production comes from these buffaloes and also population of Pandharpuri buffaloes is increasing day by day in Kolhapur district (Fernandes *et al,* 2009). It is the historical tradition of Kolhapur city to sale the raw fresh milk on *dudh kattas*. These *kattas* are mostly in old city particularly near to Talim (Wrestling schools), where most of the youths enjoy the raw fresh milk taste after the exercise (Patange *et al,* 2010).

In Kolhapur district, the famers are offering concentrate feeds to Pandharpuri buffalo viz. maize grain, jowar grain, wheat grain, wheat bhusa, rice bhusa, cotton cake, groundnut cake, sunflower cake, safflower cake, tur chuni, gram chuni etc. The famers have limited knowledge in various aspects viz. feeding, breeding, health care and management, calf rearing, milk handling and marketing etc. it is essential that this gap is reduced at the earliest by providing training to the farmers at the district/block/village level (Fernandes *et al,* 2009).

Cost of feeding is the single most important factor affecting the profitability of a dairy enterprise (Goswami *et al,* 2013).The economical feeding of buffaloes is a major component of a dairy farmer's decision making. Feed typically accounts for 60-80 per cent of variable cost of milk production (Patil *et al,* 2010) and over 60 per cent in poultry production (Rose *et al,* 1997) and in milk production feed costs are the largest expense (Bath *et al,* 1985).The present study is undertaken to optimize concentrate feed mix by applying simple optimization technique that is linear programming problem (LPP).

REVIEW OF LITERATURE

Linear and nonlinear techniques are mostly used for over two decades in many studies animal diet formulation (Alan *et al,*

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1996), optimization techniques for animal diet formulation (Saxena *et al,* 2011), use of controlled random search technique for global optimization in animal diet (Gupta *et al,* 2013), multi-objective programming approach to feed ration balancing and nutrient management (Tozer *et al,* 2001), linear programming technique for optimizing livestock ration (Waugh 1951), basic explanation of the programmers of the simplex method and linear programming in the solution of a ration formulation (Dent *et al,* 1967), linear programming in calculating diets based on referenced feedstuffs and nutrient compositions for a particular species of animal in a given location (Harris *et al,* 1968), iterative linear programming in practical applications of animal diet formulation (Alan *et al,* 1996), linear programming problem for feed formulation problem in Nigerian poultry farms (Oladokun *et al,* 2012), linear programming technique to formulate least cost ration plan for daily feeding for cross bred and local cows separately for small dairy farmers of Central India (Madhya Pradesh, Vidarbha region of Maharashtra and Chhattisgarh) (Goswami *et al,* 2013), linear programming technique to optimize feeding cost of cattle in dairy farms in Tamil Nadu (Anbukkani *et al,* 2014), linear programming technique for optimizing ration for milking Pandharpuri buffalo (Bhagat *et al,* 2015), linear programming technique for optimizing ration for dry Pandharpuri buffalo (Bhagat *et al,* 2015). Also any feed industry, a linear programming technique has been used to determine the inexpensive blend of available materials that meet certain level of nutritional requirements.

Review of literature shows that no study has been reported for 100 kg least cost concentrate mix ration for Pandharpuri buffalo. So, this study has significance.

MATERIALS AND METHODS

Presently, the buffalo husbandry is confronted with several problems such as poor growth, higher age at puberty, age at calving, longer intercalving, low fertility, reproductive problem etc. This may be attributed to the improper feeding and poor housing as well as neglected management (Bhagat *et al,* 2015). The scanty review of literature was available on Pandharpuri buffalo.

The Pandharpuri buffalo is medium sized animal (Fernandes *et al,* 2009). The performance of milk production of Pandharpuri buffaloes depicts that lactation milk yield, lactation length, per cent fat and per cent SNF viz. 1748.28 ± 32.10 kg, 321.60 ± 3.65 days, 7.00 ± 0.07 per cent and 7.47 and 9.81 percent respectively (Fernandes *et al,* 2010).

Ration balancing is an important component to optimize productivity through efficient use of available feed resources and confirm greater life time productivity in the livestock. Ration balancing means feeding of animals as per nutritional requirements fulfilling all macro and micro nutrients required to animals.
Several methods are present in formulating and balancing rations viz. Pearson square, simultaneous equations, trial and error, and linear programming. If we select to formulate and mix feed aiming at a nutritionally balanced and adequate diet while keeping the cost should be minimum then LP is the best technique. Linear programming is the common method of least cost feed formulation which compares the nutrients required by the animal to the nutrient supplied by the available feed ingredients, and combines them to obtain a balanced diet at the least possible cost.

In this paper, we have considered five formulations having different quantities of feedstuffs to be used in each formulation and out of five, our objective is to find out least cost concentrate mix ration for fulfilling minimum nutrient requirement viz. DCP, TDN, Ca and P in 100 kg ration. Costs of feedstuffs used in the formulation are obtained from the market price (Table 2). The analysis of feed ingredients and minimum nutrient requirement of DCP, TDN Ca and P are taken from recommended level of standards suggested by ICAR, New Delhi (ICAR 2013). The technique of LPP is highly beneficial to investigate the varied types of feedstuffs for deciding on the best feed formulation for implementation. The following linear programming model is used for present study.

Structure of optimization Model

Objective function

$$Minimize\ z = \sum_{j=1}^{n} C_j X_j$$

Subject to linear constraints

$\sum_{j=1}^{n} a_{ij} X_j\ (\le, =, \ge)\ B_i\ , i = 1,2,3,4.$
Non negativity $x_j \ge 0$,
Where,
Z= total cost of feed in Rs.
X_j = Qty. of j^{th} feed material in the feed in kg
C_j = Unit cost of feed material X_j in Rs./kg
a_{ij} = Amount of i^{th} nutrient available in one kg of X_j feed material
B_1,B_2,B_3 and B_4 are required level of nutrients such as:
B_1= Digestible Crude Protein (DCP)
B_2 = Total Digestible nutrients (TDN)
B_3 = Calcium
B_4 = Phosphorus

Assumptions of model

- The study area has limited resources of feeds.
- The relative price structure of study will remain stable.
- All input and output coefficients and variables are positive.
- The constraints and objective function are linear.
- The response of each resource expressed by the constraints is proportional to the level of each activity expressed in the variables.
- Basic assumptions viz. linearity, additivity, certainty and divisibility exist.

Advantages

- LPP gives more productive efficiency with least cost.

- It increases profitability of the dairy farm.
- Easily add non – conventional feedstuffs.

Limitation of model

- The input variables are depending on geography, climate and cropping pattern.

The average female weight of Pandharpuri buffalo is 400 kg. The nutrient requirement of buffalo can be calculated as per the thumb rule of feeding was given by (Banerjee 1978).As per the following thumb rule of feeding, per day nutrient requirement of DCP, TDN, Ca and P of animal should be supplied from green fodder, dry fodder and concentrate (Table 1). The animals producing different milk yield with varying fat percent in milk. The buffalo needed ration not only for maintenance but also for milk. As per thumb rule of feeding, total dry matter requirement of buffalo @ 2.5 kg per 100 kg body weight of animal.

Table 1 Per day requirement of fodder and concentrate in Pandharpuri buffalo (in kg)

Wt. of buffalo (kg)	Requirement of total dry matter	Proportion of 10 kg dry matter		Proportion of 6.66 kg roughages	
		1/3 (conc.)	2/3 (roug.)	2/3 (dry)	1/3 (green)
400	10 kg	3.7 kg	6.66 kg	5kg	11.10 kg

$$0.85\ MAG + 0.85\ JOG + 0.76\ RIB + 0.71\ SUC + 0.79\ GRC \geq 70$$

$$0.007\ MAG + 0.004\ JOG + 0.0016\ RIB + 0.0033\ SUC + 0.0058\ GRC + 0.0030\ MIM \geq 0.53$$

$$0.0040\ MAG + 0.0034\ JOG + 0.0271\ RIB + 0.0093\ SUC + 0.0065\ GRC + 0.0008\ MIM \geq 0.34$$

$$MAG \leq 40$$
$$JOG \leq 25$$
$$RIB \leq 15$$
$$SUC \geq 17$$
$$GRC \geq 20$$
$$MIM = 2$$
$$SAL = 1$$
$$MAG, JOG, RIB, SUC, GRC, MIM, SAL \geq 0$$

Model construction of formulation II

$$\text{Min } Z = 14\ MAG + 17\ JOG + 15\ WHB + 46\ SOC + 17\ GRC + 150\ MIM + 7\ SAL$$

Subject to the constraints

$$MAG + JOG + WHB + SOC + GRC + MIM + SAL = 100$$

$$0.07\ MAG + 0.08\ JOG + 0.08\ WHB + 0.25\ SOC + 0.46\ GRC \geq 16$$

Table 2 Notations used, chemical composition and cost per kg (in Rs.)

Sr. No.	Ingredients	Notations (X_j)	Nutritive value per cent / kg				Cost/kg (Rs.)
			DCP	TDN	Ca	P	
1	Maize grain	MAG	7.00	85.0	0.07	0.40	14.0
2	Jowar grain	JOG	8.00	85.0	0.04	0.34	17.0
3	Bajara grain	BAG	5.00	61.0	0.12	0.46	15.0
4	Wheat bhusa	WHB	8.00	70.0	0.14	1.24	15.0
5	Gram chuni	GRC	46.0	79.0	0.58	0.65	17.0
6	Tur chuni	TUC	8.00	64.0	0.10	1.00	18.0
7	Rice bhusa	RIB	9.00	76.0	0.16	2.71	12.0
8	Sunflower cake	SUC	23.0	71.0	0.33	0.93	46.0
9	Groundnut cake	GOC	46.0	79.0	0.20	0.56	27.0
10	Soyabean cake	SOC	25.0	85.0	0.36	0.63	46.0
11	Safflower cake	SAC	32.0	69.0	0.20	0.60	26.0
12	Cotton cake	COC	19.0	81.0	0.15	0.3	21.0
13	Mineral Mixture	MIM	--	--	0.30	0.08	150.0
14	Salt	SAL	--	--	--	--	7.0

Table 3 Feed mix formulations of the study

Sr. No.	Formulation I		Formulation II		Formulation III		Formulation IV		Formulation V	
	Ingredients	Qty. (kg)	Ingredients	Qty. (kg)	Ingredients	Qty. (kg)	Ingredients	Qty. (kg)	Ingredients	Qty. (kg)
1	Maize grain	40	Maize grain	45	Jowar grain	40	Jowar grain	40	Bajara grain	30
2	Jowar grain	25	Jowar grain	12	Wheat bhusa	35	Maize grain	25	Rice bhusa	25
3	Rice bhusa	15	Wheat bhusa	20	Groundnut cake	25	Gram chuni	15	Maize grain	10
4	Sunflower cake	17	Soyabean cake	17	Tur chuni	30	Cotton cake	17	Safflower cake	10
5	Gram chuni	20	Gram chuni	20	Mineral Mixture	02	Tur Chuni	20	Gram chuni	35
6	Mineral Mixture	02	Mineral Mixture	02	Salt	01	Mineral Mixture	02	Mineral Mixture	02
7	Salt	01	Salt	01	--	--	Salt	01	Salt	01

Model construction of formulation I

$$\text{Min } Z = 14\ MAG + 17\ JOG + 12\ RIB + 46\ SUC + 18\ GRC + 150\ MIM + 7\ SAL$$

Subject to the constraints

$$MAG + JOG + RIB + SUC + GRC + MIM + SAL = 100$$

$$0.07\ MAG + 0.08\ JOG + 0.09\ RIB + 0.23\ SUC + 0.46\ GRC \geq 16$$

$$0.85\ MAG + 0.85\ JOG + 0.76\ WHB + 0.85\ SOC + 0.79\ GRC \geq 70$$

$$0.007\ MAG + 0.004\ JOG + 0.0014\ WHB + 0.0036\ SOC + 0.0058\ GRC + 0.0030\ MIM \geq 0.53$$

$$0.0040\ MAG + 0.0034\ JOG + 0.0124\ WHB + 0.0063\ SOC + 0.0065\ GRC + 0.0008\ MIM \geq 0.34$$

$$MAG \leq 45$$
$$JOG \leq 12$$

$\text{WHB} \leq 20$
$\text{SOC} \geq 17$
$\text{GRC} \geq 20$
$\text{MIM} = 2$
$\text{SAL} = 1$
$\text{MAG, JOG, WHB, SOC, GRC, MIM, SAL} \geq 0$

Model construction of formulation III

$$\text{Min Z} = 17\ \text{JOG} + 12\ \text{WHB} + 27\ \text{GOC} + 18\ \text{TUC} + 150\ \text{MIM} + 7\ \text{SAL}$$

Subject to the constraints

$\text{JOG} + \text{WHB} + \text{BAG} + \text{GOC} + \text{TUC} + \text{MIM} + \text{SAL} = 100$
$0.08\ \text{JOG} + 0.08\ \text{WHB} + 0.46\ \text{GOC} + 0.08\ \text{TUC} \geq 16$
$0.85\ \text{JOG} + 0.70\ \text{WHB} + 0.79\ \text{GOC} + 0.64\ \text{TUC} \geq 70$
$0.004\ \text{JOG} + 0.0014\ \text{WHB} + 0.002\ \text{GOC} + 0.001\ \text{TUC} + 0.0030\ \text{MIM} \geq 0.53$
$0.0034\ \text{JOG} + 0.0124\ \text{WHB} + 0.0055\ \text{GOC} + 0.01\ \text{TUC} + 0.0008\ \text{MIM} \geq 0.34$
$\text{JOG} \leq 40$
$\text{WHB} \leq 35$
$\text{GOC} \geq 25$
$\text{TUC} \leq 30$
$\text{MIM} = 2$
$\text{SAL} = 1$
$\text{JOG, WHB, GOC, TUC, MIM, SAL} \geq 0$

Model construction of formulation IV

$$\text{Min Z} = 17\ \text{JOG} + 14\ \text{MAG} + 17\ \text{GRC} + 21\ \text{COC} + 18\ \text{TUC} + 150\ \text{MIM} + 7\ \text{SAL}$$

Subject to the constraints

$\text{JOG} + \text{MAG} + \text{GRC} + \text{COC} + \text{TUC} + \text{MIM} + \text{SAL} = 100$
$0.08\ \text{JOG} + 0.07\ \text{MAG} + 0.46\ \text{GRC} + 0.19\ \text{COC} + 0.08\ \text{TUC} \geq 16$
$0.85\ \text{JOG} + 0.85\ \text{MAG} + 0.79\ \text{GRC} + 0.81\ \text{COC} + 0.64\ \text{TUC} \geq 70$
$0.004\ \text{JOG} + 0.007\text{MAG} + 0.0058\ \text{GRC} + 0.0015\ \text{COC} + 0.001\ \text{TUC} + 0.0030\ \text{MIM} \geq 0.53$
$0.0034\ \text{JOG} + 0.0040\ \text{MAG} + 0.0065\ \text{GRC} + 0.003\ \text{COC} + 0.008\ \text{TUC} + 0.0008\ \text{MIM} \geq 0.34$
$\text{JOG} \leq 40$
$\text{MAG} \geq 25$
$\text{GRC} \geq 15$
$\text{COC} \geq 17$
$\text{TUC} \leq 20$
$\text{MIM} = 2$
$\text{SAL} = 1$
$\text{JOG, MAG, GRC, COC, TUC, MIM, SAL} \geq 0$

Model construction of formulation V

$$\text{Min Z} = 15\ \text{BAG} + 12\ \text{RIB} + 14\ \text{MAG} + 26\ \text{SAC} + 17\ \text{GRC} + 150\ \text{MIM} + 7\ \text{SAL}$$

Subject to the constraints

$\text{BAG} + \text{RIB} + \text{MAG} + \text{SAC} + \text{GRC} + \text{MIM} + \text{SAL} = 100$
$0.05\text{BAG} + 0.09\ \text{RIB} + 0.07\ \text{MAG} + 0.32\ \text{SAC} + 0.46\ \text{GRC} \geq 16$
$0.61\ \text{BAG} + 0.76\ \text{RIB} + 0.85\ \text{MAG} + 0.69\ \text{SAC} + 0.79\ \text{GRC} \geq 70$
$0.0012\ \text{BAG} + 0.0016\ \text{RIB} + 0.007\ \text{MAG} + 0.002\ \text{SAC} + 0.0058\ \text{GRC} + 0.0030\text{MIM} \geq 0.53$
$0.0046\ \text{BAG} + 0.0271\ \text{RIB} + 0.004\ \text{MAG} + 0.006\ \text{SAC} + 0.0065\ \text{GRC} + 0.0008\ \text{MIM} \geq 0.34$
$\text{BAG} \leq 30$
$\text{RIB} \leq 25$
$\text{MAG} \leq 10$
$\text{SAC} \geq 10$
$\text{GRC} \geq 35$
$\text{MIM} = 2$
$\text{SAL} = 1$
$\text{BAG, RIB, MAG, SAC, GRC, MIM, SAL} \geq 0$

RESULTS AND DISCUSSIONS

In this study, we have optimized cost of concentrate mix ration which satisfy the minimum nutritional requirements in 100 kg mix ration by using linear programming problem. The LINDO software is used for data analysis and final results are depicted in (Table 4). The results of 100 kg concentrate mix ration produced by linear programming model showed that concentrate mix ration varies according to their availability of ingredients. The final result of optimal costs for five formulations are presented in (fig. 1).

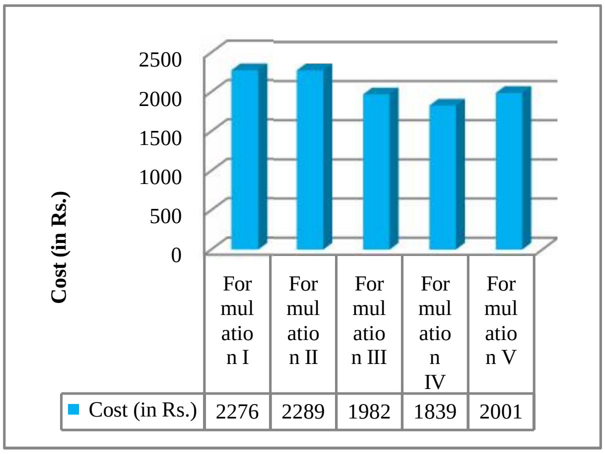

Fig 1. Optimal cost of different formulations of concentrate feed mix

The optimal cost of formulation IV is Rs. 1839/-. It is the least optimal cost as compared to the other four formulations. It means that formulation IV is the best formulation among the five formulations. The least cost ration formulation IV used 5 ingredients compared with 7 in the original feed plan.

The proportion of ingredients in least cost 100 kg concentrate mix ration optimal plan is presented in (fig. 2). It includes 62 kg maize grain, 18 kg gram chuni, 17 kg cotton cake, 2 kg mineral mixture and 1 kg salt etc.

Table 4 Results

Sr. No.	Formulation I		Formulation II		Formulation III		Formulation IV		Formulation V	
	Optimal plan	**Qty (kg.)**	**Optimal plan**	**Qty (kg.)**	**Optimal plan**	**Qty (kg.)**	**Optimal plan**	**Qty (kg.)**	**Optimal plan**	**Qty (kg.)**
1	Maize grain	40	Maize grain	45	Jowar grain	40	Jowar grain	--	Bajara grain	--
2	Jowar grain	--	Jowar grain	--	Wheat bhusa	32	Maize grain	62	Rice bhusa	3
3	Rice bhusa	10.5	Wheat bhusa	12.5	Groundnut cake	25	Gram chuni	18	Maize grain	10
4	Sunflower Cake	17	Soyabean cake	17	Tur chuni	--	Cotton Cake	17	Safflower cake	10
5	Gram chuni	29.5	Gram chuni	22.5	Mineral Mixture	2	Tur Chuni	--	Gram chuni	73
6	Mineral Mixture	2	Mineral Mixture	2	Salt	1	Mineral Mixture	2	Mineral Mixture	2
7	Salt	1	Salt	1	--		Salt	1	Salt	1
	Total	**100**	**Total**	**100**	**Total**	**100**	**Total**	**100**	**Total**	**100**

Fig 2. Proportion of ingredients in the best 100 kg concentrate feed mix

The final sensitivity results of best formulation IV is depicted in (Table 5). The positive dual price means that the objective value and the RHS move in the same direction and a negative dual price means that the objective value and RHS move in opposite directions (Nabasirye *et al* 2011).From economic point of view, there is need to reduce objective value. The dual prices of a constraint are the marginal change of the objective function when the RHS value of that constraint increases by one unit. For case, a unit increase in the total quantity produced will increase the objective value by Rs. 13.46 within the stated range [-5.47, 18.86]. In the case of DCP, COC and MIM, marginal costs estimated are Rs.7.69, Rs.6.08 and Rs.136.54 respectively. It means that every increase in one unit of these three constraints will cause an increase in cost of their respective dual prices. For SAL, if you increase the RHS of a constraint then decrease the objective value with positive dual price. The dual prices for TDN, Ca, P and MAG, GRC, TUC are equals zero are a consequence of the fact that the optimal mix already exceeds the requirement by a margin of 10.67%, 0.04%, 0.08% and 36.62 kg, 3.38 kg, 20 kg respectively in the optimal solution.

If the cost of MAG is revised by δ to 14+ δ, then δ should stay within the interval [-∞, 3.00] in order for the solution remain optimal. Similarly, for GRC, COC, TUC, MIM and SAL [-3.00, 19.74], [-6.07, ∞], [-3.92, ∞], [-∞,∞] and [-∞,∞] respectively.

Finally, the result of ranges for the original RHS constants revealed that for DCP, TDN, Ca, P, MAG, GRC, COC, MIM and SAL are revised to 16+ δ, 70+ δ, 0.53+ δ, 0.34+ δ, 25+ δ, 15+ δ, 17+ δ, 2+δ and 1+δ , then current basis will remain optimal for all δ inside the interval [-1.32 , 12.82], [-∞,10.67], [-∞,0.04],[-∞,0.08], [-∞, 36.62],[-∞,3.38], [-17,7.69], [-2.00, 9.35] and [-1,5.47] respectively.

Table 5 Results of sensitivity analysis for best formulation

Variable	Current Obj Coeff	Allowable increase	Allowable decrease	Reduced cost
JOG	17	Infinity	2.92	2.92
MAG	14	3.00	Infinity	0.00
GRC	17	19.74	3.00	0.00
COC	21	Infinity	6.07	0.00
TUC	18	Infinity	3.92	3.92
MIM	150	Infinity	Infinity	0.00
SAL	7	Infinity	infinity	0.00

Constraint	Current RHS	Allowable increase	Allowable decrease	Dual Prices
1 (=)	100	18.86	5.47	-13.46
2(≥)	16	12.81	1.32	-7.69
3(≥)	70	10.66	Infinity	0.00
4(≥)	0.53	0.04	Infinity	0.00
5(≥)	0.34	0.08	Infinity	0.00
6(≤)	40	Infinity	40.00	0.00
7(≥)	25	36.62	Infinity	0.00
8(≥)	15	3.38	Infinity	0.00
9(≥)	17	7.69	17.00	-6.08
10(≤)	20	Infinity	20.00	0.00
11(=)	2	9.36	2.00	-136.54
12(=)	1	5.47	1.00	6.46

CONCLUSION

On the basis of final results, it is suggested that farmers of Western Maharashtra, should include 62 kg maize grain, 18 kg gram chuni, 17 kg cotton cake, 2 kg mineral mixture and 1 kg salt etc. in preparation of 100 kg concentrate mix ration for Pandharpuri buffalo.

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