Modeling of Polyculture Fish Feed Using Mathematical Programming

ABSTRACT

This study incorporates the application of a linear programming technique for composition of fish feed mixture to minimize the cost without sacrificing the nutrients levels. Designing the best fish diet for fry, fingerling, and growth stages is the main goal of this study. Regarding nutrient composition and manufacturing costs, the study's results show that a variety of elements can be combined much more effectively than in commercially available feed. The combinations lead to significantly reduced costs while raising nutrient intake, which might be quite advantageous to neighboring fish farmers. . The suggested model was solved with Microsoft Excel to make it more user-friendly.

***Keywords**: Fish farming, Optimum model, Linear programming, Simplex method, Sensitivity analysis*

1. INTRODUCTION

Fisheries is one of the prime sectors which have major contribution in economic and social development of India. Fresh water fish farming plays an important role in outdoor swap in numerous countries including India. It's known for its versatility of providing food, nutritional, ecological safety & securities and employment. Increasing production and relatively lower initial investment motivates entrepreneurs and small scale farmers to adopt fisheries as a profession. The production of two or more fish species in a specific aquaculture habitat is known as Polyculture. In India, Haryana comes 2nd in the average annual fish production. The average annual fish production in the state is 7000 kg per hectare beside a national average of 2900kgperhectare.Thestatehasalsogainedself-relianceinseedproduction of Indian Major Crop and Common Crop (https:\\harfish.gov.in). The major assertion of the Fisheries department of Haryana is to bring all available water bodies under fish culture by creating a class of fish farmers through hands on training and providing essential financial and technical assistance(https:\\harfish.gov.in).

It is well known that the financial resources available with any farmer are scarce and the same is the case of fish farmers.Porchelvietal.(2018) has reported that in the fish farming, farmer has the maximum expenditure on cost of production.

Feed formulation is the process of combining various substances to give animals the nutrients they require at various stages of production. A diet should provide all the nutrients and energy needed to support an animal's key physiological processes for growth, reproduction, and health. Animal diet formulation can be done using a variety of techniques, including the square approach, the two-by-two matrix method, the simultaneous equation method, the trial-and-error method, and the linear programming(LP) method.

The feed formulation model looks for the best possible mix of feed ingredients that will meet the animal's nutritional needs at the lowest cost. The model must adhere to nutrient levels, availability and market prices of feed materials and financial restraints for each type of feed. A linear programming mathematical model of the feed formulation problem is created after defining the choice variables, objective function, and problem constraints.

Waughand Frederick [1] (1951) established least-costrained by linear programming and minimising the cost of dairy feeds. His efforts resulted in rations incorporating oil seeds, whole grains, and a 24 percent protein mix using four equations and 14 feeds (variables).Christensen and Mighell [2](1951) reduced the cost of hog rations by15 % using soybean oil meal instead of cornto balance protein. The linear programming technique was used to illustrate that soybean oil meal is a lower cost source of protein than corn. Fisheretal. [3](1953) applied linear programming techniques to adjust layer and hog rations as the price of cottonseed meal fluctuated. Analyzing four different price situations, they indicated that alfalfa meal (15 percent crude protein) would replace cottonseed meal (41percentcrudeprotein) as the price of cotton seed meal reaches its point of critical difference. Bath *et al.* [4](1968) concluded that feed cost may be reduced by least-cost concentrated mixes for dairy cows while maintaining optimum milk production. Law *et al.* [7] (1993) applied linear programming for least–cost feed formulation using locally available feed ingredients Rahman*etal*.[8](2010) investigated feed mix approaches used by nutritionists, researchers and an enhanced algorithm was developed in order to deal with the development of aquaculture industry .Saxena [9](2011) compared different mathematical programming techniques used for animal diets. A mathematical method based on optimization technique was developed for optimal use of nutrient ingredient to measure animal performance in terms of milk yield and weight gain. According to Jayasankar [10] (2014) small and marginal farmers with customary mind-set and confined resources are reluctant to adopt supplemental feeding techniques. However, supplemental feeding of cultured fish is adopted by West Bengal. Feed cost can be significantly confined by restoring to feeds made from locally available ingredients. Production-demand ratio of feed concentrate is 44:143, prompt deficiency of 69%. Nath and Talukdar [11] employed the LP technique in fish feed formulation to improve Assam's fish sector and alleviate poverty, as fish is the primary or secondary source of income for the communities. The goal of the paper is to create a low-cost optimised fish feed composition that meets the nutrient requirements of juvenile and adult Mystus nemurus sp. catfish utilising LP.Olugbenga et al.[12] (2015) applied linear programming with nine decision variables andten parameters and subject to a set of twelve obtained constraints from a local farm for dietformulation of Broiler Poultry.The excel solver package was used to solve model. The suggested optimal formulation of the linear programming model gives about 7.48% and 9.96% reduction in feed formulation costs compared to the existing formulation in case of broiler starter and finisher respectively on the farm. Poonia et al. (2016)[13] developed a linear programming model to determine the optimal crop combination for rural farmers in Hisar district,Haryana.Palani *et al.* [14](2019) studied linear encoding problem on price minimization on fishfeeds to reduce the cost of production of fish feeds. LP problem was formulated to evaluate the data and the optimum solution was obtained at 2^{nd} iteration with fingerling feeds to be 1.2 of tons and grower's feeds to be 0.8 tons and the least cost of producing the tones of fingerlings and growers was ₹93,358. Tonk *et al.*(2019)[15] used a mathematical programming approach to optimize net returnsfor medium farmers in village Bherian, Hisar.Zailani *et al.* [16] (2019) reviewed distinctive methods used in operation research to know different diet issues. In the study an optimal and practical solution was suggested to solve diet problem.

In this paper the linear programming is used to formulate fish feed models based on farmers information. Also the LP model has been developed using information of dietary requirement based on literature and locally available ingredients. The two approaches were compared as the study was planned to make a bridge between scientific investigation and fish farmers for understanding and optimizing sources so that the feed cost can be reduced. Alternate plans of fish feed for fry, fingerling and grower fulfilling minimal nutrition requirement and made with locally available ingredients will generate more options of feed mixtures for polyculture fish farming.

2. Material and Methods

The data about the nutrient requirements of fry, fingerling and grower stage of fish (rohu, catla, migil) and nutrient composition of feed ingredients were obtained from the literature and schedule-structured interviews of farmers from seven different location of Hisar district, viz Dabra, Panihar Chak, Rajli, Shamsukh, Sundawas, Shahpur villages and Blue Bird Lake, Hisar.The prices of ingredients were obtained from local market.

2.0 Mathematical formulation of the model:

Today, the term "programming" is nearly synonymous with "computer programming," which is solely a tool for computation, such as solving a set of equations or evaluating an expression. A computer programme does not contribute directly to the development of the formulations that lead to the set of equations or the derivation of the expressions. Linear programming, on the other hand, is essentially a mathematical formulation for determining optimal solutions that do not violate certain imposed constraints. When multiple variables and specifications are involved, the computations required to obtain optimal solutions become very heavy, and an electronic computer assists the speedy and efficient execution of the computing method.LP is a strategy for optimising a linear objective function that is constrained by linear equality and linear inequality [5]. Some numerical value will be maximised or minimised by the objective function [6]. The goal of this study is to reduce the cost of fish feed formulation while fulfilling a set of fish nutrient needs limitations. The conventional form of the LP model is shown below:

Objective function: Minimize Z = $\sum_{j=1}^{n} c_j\, x_j$

Subject to the Constraints:

$\sum_{j=1}^{n} x_j$ = N (Total quantity of feed composition)

$\sum_{j=1}^{n} a_{ij} x_j \geq b_i$(Minimum requirement)

$\sum_{j=1}^{n} a_{ij} x_j \leq b_i$(Maximum requirement)

$\sum_{j=1}^{n} a_{ij} x_j = b_i$ (Restricted constraints)

where, Z = Total cost of feed ingredients used to formulate fish feed

b_i = Feed nutrients componenets with i = 1,2,….,m

x_j = Feed ingredient with j = 1,2,…,n

c_j = Unit cost of feed ingredient j

x_j = Quantity of feed ingredients j in the feed mixture

a_{ij}= Amount of nutrients i avaliable in feed ingredient j.

b_j= Requirement of nutrient i for a fish stage

There is no single feed ingredient that can provide all the nutrients required for optimal growth of polyculture fish.Feed formulation for polyculture fish's life stages fry, fingerling and grower were attempted in this study. Fourteen ingredients were considered for feed formulation through linear programming. Let x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8, x_9, x_{10}, x_{11}, x_{12}, x_{13} and x_{14} be the respective quantities in kg of mustard oilseed cake, rice bran, fish meal, wheat, soybean, pearl millet, maize, Meringa, jiggery, fish oil, vitamin, mineral premix, salt and di-calcium phosphate was considered for the mixture used in model formulation.Nutritional requirement of these stages of fish in terms of five nutrients mainly crude protein, crude fat, ash, carbohydrates and crude fiber were collected from[13](www.fao.org)andused for the analysis.The information regarding the nutrient requirements of life stages (fry, fingerling and grower), the prices of ingredients, and nutrient composition of fish feed ingredients to be used in the mathematical model construction is listed in the tables below.

Table 1.Farmer's Fish feed ingredients and nutrition level (%)

Nutrients	Mustard oilseed Cake	Rice bran	Jaggery	Fish feed
Crude protein	30.12	12.20	0.40	32
Crude fat	8.90	11.80	0.10	4
Ash	6.70	13.10	5	0
Carbohydrates	29	40.60	28.80	0
Crude fiber	5.90	12.30	10	4

Table 2.Nutritional Composition of different feed ingredients (column 1 to 14 values in %)

Sr. No.	Ingredients	Crude Protein	Crude Fat	Ash	Carbohydrates	Crude Fiber
1.	**Mustard oilseed cake(x_1)**	30.12	8.90	6.700	29	5.90
2.	**Rice bran(x_2)**	12.20	11.80	13.100	40.60	12.30
3.	**Fish meal(x_3)**	52	7.60	25.20	0	3.10
4.	**Wheat (x_4)**	11	1	2	9	12.15
5.	**Soybean (x_5)**	48	3.10	6.30	40	3
6.	**Pearl millet(x_6)**	11.20	4.30	10.40	80	2.80
7.	**Maize (x_7)**	10.40	15	10.00	21	24
8.	**Maringa(x_8)**	30.20	2.220	8.05	63.20	7.20
9.	**Jaggery(x_9)**	0.40	0.10	0.50	28.80	10
10.	**Fish oil(x_{10})**	0	100	0	40	0
11.	**Vitamin(x_{11})**	13.50	3.90	5.30	60	3
12.	**Mineral premix(x_{12})**	5	0.50	38	30	4
13.	**Salt(NaCl) (x_{13})**	0	50	90	0	0
14.	**Di-calcium phosphate(x_{14})**	0	0	95	5	0

Table 3. Market prices of Ingredients [₹/kg]

Sr. No.	Ingredients	Cost/kg
1.	**Mustard oilseed cake(x_1)**	23
2.	**Rice bran(x_2)**	12
3.	**Fish meal(x_3)**	27
4.	**Wheat(x_4)**	19
5.	**Soybean (x_5)**	40
6.	**Pearl millet(x_6)**	16
7.	**Maize(x_7)**	13
8.	**Maringa(x_8)**	35
9.	**Jaggery(x_9)**	35
10.	**Fish oil(x_{10})**	120
11.	**Vitamin(x_{11})**	350
12.	**Mineral premix(x_{12})**	300
13.	**Salt(NaCl) (x_{13})**	24
14.	**Di-calcium phosphate(x_{14})**	32

2.1 Sensitivity Analysis

In LP models objective coefficients and the constraints are the input or parameters of the model. The optimal solution is obtained by the values of the coefficients and coefficients are selected from the sample data. The sensitivity analysis help us to know about how “sensitive” optimal solution is change in data values. It also measures how optimal solution affected by the changes in the input coefficients.There are two types of sensitivity analysis: first due to changes in the objective function coefficients and secondly changes in the available resources or R.H.S. value of constraints.

2.1.1The linear programming model construction for farmer's plan can be written as:

Model A

Objective Function:

Minimize $Z = 23 x_1 + 12x_2 + 35x_3 + 82 x_4$

Subject to constraints:

(Minimum Nutrition Requirements)

$0.3012x_1+0.122x_2+0.004x_3+0.32 x_4 \geq 25$;

(Crude Protein)

$0.089 x_1+0.118x_2+0.001x_3+0.04 x_4 \geq 3.5$;

(Crude fat)

$0.29x_1+ 0.406x_2 + 0.288x_3 \geq 24$;(Carbohydrates)

(Maximum Nutrition Requirements)

$0.067 x_1 + 0.131x_2 + 0.05x_3 \leq 7$;(Ash)

$0.059 x_1 + 0.123x_2 + 0.1x_3+0.04 x_4 \leq 12$;

(Crude fiber)

(Ingredients Quantity Constraints)

$20 \leq x_1 \leq 25$, $x_2 \geq 25$, $x_3 \leq 6$, $x_4 \geq 30$

$x_1+ x_2 + x_3+ x_4 \geq 100$

$x_1, x_2, x_3, x_4 \geq 0$ (Non-Negativity Constraints)

2.1.2The linear programming model construction for fry stage can be written as:

Model B

Objective Function:

Minimize $Z = 23x_1+ 12x_2 + 27x_3+19 x_4+ 40x_5+16 x_6+13x_7+ 35x_8+35x_9+ 120x_{10}+350 x_{11}+300x_{12}+24 x_{13}+32x_{14}$

Subject to constraints:

(Minimum Nutrition Requirements)

$0.089x_1+0.118x_2+0.076x_3+0.01x_4+ 0.031x_5+0.043x_6+0.15x_7+0.222x_8+0.001x_9+x_{10}+0.039x_{11}+0.005x_{12} +0.5x_{13} \geq 4$;(Crude fat)

$0.29x_1 + 0.406x_2 +0.09 x_4+ 0.4x_5+0.8 x_6+0.21x_7+ 0.632x_8+0.288x_9+ 0.4x_{10}+0.6x_{11}+0.3x_{12} +0.05x_{14} \geq 27$;(Carbohydrates)

(Maximum Nutrition Requirements)

$0.3012x_1+0.122x_2+0.52x_3+0.11x_4+ 0.48x_5+0.112 x_6+0.104x_7+ 0.302x_8+0.004x_9+0.135x_{11}+0.05x_{12} \leq 40$;(Crude Protein)

$0.089x_1+0.118x_2+0.076x_3+0.01x_4+0.031x_5+0.043x_6+0.15x_7+0.222x_8+0.001x_9+x_{10}+0.039x_{11}+0.005x_{12} +0.5x_{13} \leq 8$;(Crude fat)

$0.067x_1+0.131x_2+0.252x_3+0.02x_4+0.063x_5+0.104x_6+0.1x_7+0.805x_8+0.05x_9+0.053x_{11}+0.38x_{12}+0.9x_{13}+0.95x_{14} \leq 7$;(Ash)

$0.059x_1+0.123x_2+0.031x_3+0.1215x_4+0.03x_5+0.028x_6+0.24x_7+0.72x_8+0.1x_9+0.03x_{11}+0.04x_{12} \leq 12$;

(Crude fiber)

(Ingredients Quantity Constraints)

$x_1 \leq 20$, $x_2 \geq 5$, $x_4 \leq 5$, $x_8=0.02$, $x_9=3$;

$x_1+x_2+x_3+x_4+x_5+x_6+x_7+x_8+x_9+x_{10}+x_{11}+x_{12}+x_{13}+x_{14} =100$

$x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8, x_9, x_{10}, x_{11}, x_{12}, x_{13}, x_{14} \geq 0$(Non-Negative Constraints)

2.1.3The linear programming model construction for fingerling stage can be written as:

Model C

Objective Function:

Minimize $Z = 23x_1 + 12x_2 + 27x_3+19 x_4+ 40x_5+16 x_6+13x_7+ 35x_8+35x_9+ 120x_{10}+350 x_{11}+300x_{12}+24 x_{13}+32x_{14}$

Subject to Constraints:

(Minimum Nutrition Requirements)

$0.3012x_1+0.122x_2+0.52x_3+0.11x_4+0.48x_5+0.112 x_6+0.104x_7+0.302x_8+0.004x_9+0.135x_{11}+0.05x_{12} \geq 33$;(Crude Protein)

$0.089x_1+0.118x_2+0.076x_3+0.01x_4+0.031x_5+0.043x_6+0.15x_7+0.222x_8+0.001x_9+x_{10}+0.039x_{11}+0.005x_{12} +0.5x_{13} \geq 5$;(Crude fat)

$0.29x_1 + 0.406x_2 +0.09 x_4+ 0.4x_5+0.8 x_6+0.21x_7+ 0.632x_8+0.288x_9+0.4x_{10}+0.6x_{11}+0.3x_{12}+0.05x_{14} \geq 32$;(Carbohydrates)

(Maximum Nutrition Requirements)

$0.089x_1+0.118x_2+0.076x_3+0.01x_4+0.031x_5+0.043x_6+0.15x_7+0.222x_8+0.001x_9+x_{10}+0.039x_{11}+0.005x_{12} +0.5x_{13} \leq 15$;(Crude fat)

$0.067x_1+0.131x_2+0.252x_3+0.02x_4+0.063x_5+0.104x_6+0.1x_7+0.805x_8+0.05x_9+0.053x_{11}+0.38x_{12}$ $0.9x_{13}+0.95x_{14} \leq 12$;(Ash)

$0.059x_1+0.123x_2+0.031x_3+0.1215x_4+0.03x_5+0.028x_6+0.24x_7+0.72x_8+0.1x_9+0.03x_{11}+0.04x_{12} \leq 12$;

(Crude fiber)

(Ingredients Quantity Constraints)

$x_1 \leq 20$, $x_7 \geq 5$, $x_8=0.02$, $x_9=3$;

$x_1+x_2+x_3+x_4+x_5+x_6+x_7+x_8+x_9+x_{10}+x_{11}+x_{12}+x_{13}+x_{14} \leq 100$

$x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8, x_9, x_{10}, x_{11}, x_{12}, x_{13}, x_{14} \geq 0$; (Non-Negative Constraints)

2.1.4The linear programming model construction for grower stage can be written as:

Model D

Objective Function:

Minimize $Z = 23x_1 + 12x_2 + 27x_3+19 x_4+ 40x_5+16 x_6+13x_7+ 35x_8+35x_9+ 125x_{10}+350 x_{11}+300x_{12}+24 x_{13}+32x_{14}$

Subject to Constraints:

(Minimum Nutrition Requirements)

$0.3012x_1+0.122x_2+0.52x_3+0.11x_4+0.48x_5+0.112x_6+0.104x_7+0.302x_8+0.004x_9+0.135x_{11}+0.05x_{12} \geq 25$;(Crude Protein)

$0.089x_1+0.118x_2+0.076x_3+0.01x_4+0.031x_5+0.043x_6+0.15x_7+0.222x_8+0.001x_9+x_{10}+0.039x_{11}+0.005x_{12}+0.5x_{13} \geq 3.5$;(Crude fat)

$0.067x_1+0.131x_2+0.252x_3+0.02x_4+0.063x_5+0.104x_6+0.1x_7+0.805x_8+0.05x_9+0.053x_{11}+0.38x_{12}+0.9x_{13}+0.95x_{14} \geq 8$;(Ash)

$0.29x_1+0.406x_2+0.09x_4+0.4x_5+0.8x_6+0.21x_7+0.632x_8+0.288x_9+0.4x_{10}+0.6x_{11}+0.3x_{12}+0.05x_{14} \geq 27$;(Carbohydrates)

$0.059x_1+0.123x_2+0.031x_3+0.1215x_4+0.03x_5+0.028x_6+0.24x_7+0.72x_8+0.1x_9+0.03x_{11}+0.4x_{12} \geq 6$;(Crude fiber)

(Maximum Nutrition Requirements)

$0.089x_1+0.118x_2+0.076x_3+0.01x_4+0.031x_5+0.043x_6+0.15x_7+0.222x_8+0.001x_9+x_{10}+0.039x_{11}+0.05x_{12}+0.5x_{13} \leq 16$;(Crude fat)

$0.067x_1+0.131x_2+0.252x_3+0.02x_4+0.063x_5+0.104x_6+0.1x_7+0.805x_8+0.05x_9+0.053x_{11}+0.38x_{12}+0.9x_{13}+0.95x_{14} \leq 19$;(Ash)

$0.059x_1+0.123x_2+0.031x_3+0.1215x_4+0.03x_5+0.028x_6+0.24x_7+0.72x_8+0.1x_9+0.03x_{11}+0.4x_{12} \leq 13$;(Crude fiber)

(Ingredients Quantity Constraints)

$x_1 \geq 30$, $x_2 \geq 10$, $x_3 \leq 5$, $x_4 \geq 5$, $x_5 \geq 10$, $x_6 \geq 5$, $x_7 \geq 5$, $x_8=0.02$, $x_9=3$;

$x_1+x_2+x_3+x_4+x_5+x_6+x_7+x_8+x_9+x_{10}+x_{11}+x_{12}+x_{13}+x_{14} \leq 100$

$x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8, x_9, x_{10}, x_{11}, x_{12}, x_{13}, x_{14} \geq 0$;(Non-Negative Constraints)

As can be seen, the mathematical models are given in a similar manner, except for the different parameters used for each stage.The decision variable x_j represents the different types of ingredients, where the coefficient c_j is the unit price of the ingredients.

3.RESULTS AND DISCUSSION

This section presents the results of the fish feed formulation using the LP model. Optimal results were obtained using Microsoft excel solver for farmer's pattern, fry, fingerling and grower stages.The tables below present details on the nutrient composition of the ingredients for farmer's plan,fry,fingerling and grower.

Table4. LP model suggested quantity of ingredients in feed mix for farmer's plan

Ingredients	**Cost(₹)**	**Quantity of ingredients (kg)**	**Percentage of ingredients in feed composition**
Mustard oilseed cake(x_1)	23	25	23.55
Rice bran(x_2)	12	39.94	37.63
Jaggery(x_3)	35	1.85	1.74
Fish feed(x_4)	82	39.34	37.06
	Minimum Cost (106.13kg)	4345.19	

Table 5. LP model suggested quantity of ingredients in feed mix for fry

Ingredients	**Cost(₹)**	**Quantity of ingredients(kg)**
Mustard oilseed cake(x_1)	23	17
Rice bran(x_2)	12	5
Fish Meal(x_3)	27	3
Wheat (x_4)	19	5
Soybean (x_5)	40	67.16
Pearl Millet(x_6)	16	0
Maize (x_7)	13	0
Maringa(x_8)	35	0.02

Jaggery(x_9)	35	3
Fish oil(x_{10})	120	0
Vitamin(x_{11})	350	0
Mineral premix(x_{12})	300	0
Salt(NaCl) (x_{13})	24	0
Di-calcium phosphate(x_{14})	32	0

Table 6.Sensitivity analysis on objective function coefficients in LP model for fry

Name	Final Value	Obj. function	Max. Range	Min. Range
Mustard oilseed cake(x_1)	17	23	27.55	-
Rice bran(x_2)	5	12	-	0.65
Fish Meal(x_3)	2.81	27	43.80	-6.85
Wheat (x_4)	5	19	-	9.85
Soybean (x_5)	67.16	40	-	31.83
Pearl Millet(x_6)	0	16	-	2.11
Maize (x_7)	0	13	-	1.72
Maringa(x_8)	0.02	35	-	-
Jaggery(x_9)	3	35	-	-
Fish oil(x_{10})	0	120	-	0.88
Vitamin(x_{11})	0	350	-	8.76
Mineral premix(x_{12})	0	300	-	-28.08
Salt(NaCl) (x_{13})	0	24	-	-78.75
Di-calcium phosphate(x_{14})	0	32	-	-83.17

Table7.Sensitivity Analysis of available resources in LP model for fry

Name	Final Value	Constraint R.H.S.	Max. R.H.S.	Min. R.H.S.	Shadow Price
Mustard oilseed cake	17	20	-	17	0
Jaggery	3	3	5.57	1.86	38.16
Maringa	0.02	0.02	0.74	0	77.22
Wheat	5	5	8.64	3.51	9.14
Rice bran	5	5	13.20	3.55	11.34
Crude fiber	4.64	12	-	4.64	0
Crude protein	40	40	41.43	39.46	93.09
Total quantity	100	100	101.15	97.21	0.88
Crude fat	4.45	4	4.45	-	0
Carbohydrates	35.15	27	35.15	-	0
Crude fat	4.45	8	-	4.45	0
Ash	7	7	9.54	6.46	-88.48

Table 8. LP model suggested quantity of ingredients in feed mix for fingerling

Ingredients	**Cost(₹)**	**Quantity of ingredients(kg)**
Mustard oilseed cake(x_1)	23	20
Rice bran(x_2)	12	14.91
Fish Meal(x_3)	27	21.37
Wheat (x_4)	19	0
Soyabean (x_5)	40	25.82
Pearl Millet(x_6)	16	9.85
Maize (x_7)	13	5
Moringa(x_8)	35	0.02
Jaggery(x_9)	35	3
Fish oil(x_{10})	120	0
Vitamin(x_{11})	350	0
Mineral premix(x_{12})	300	0
Salt(NaCl) (x_{13})	24	0
Di-calcium phosphate(x_{14})	32	0

Table 9. Sensitivity Analysis on objective function coefficients in LP model for fingerling

Name	**Final Value**	**Obj. function**	**Max. Range**	**Min. Range**
Mustard oilseed cake(x_1)	20	23	27.22	-
Rice bran(x_2)	14.91	12	12.81	7.80
Fish Meal(x_3)	21.37	27	38.27	23.84
Wheat (x_4)	0	19	-	16.42
Soyabean (x_5)	25.82	40	43.11	34.29
Pearl Millet(x_6)	9.85	16	24.14	14.42
Maize (x_7)	5	13	-	11.50
Moringa(x_8)	0.02	35	-	-
Jaggery(x_9)	3	35	-	-
Fish oil(x_{10})	0	120	-	12.79
Vitamin(x_{11})	0	350	-	19.50
Mineral premix(x_{12})	0	300	-	-10.26
Salt (NaCl) (x_{13})	0	24	-	-50.76

Table 10. Sensitivity Analysis of available resources in LP model for fingerling

Name	**Final Value**	**Constraint R.H.S.**	**Max. R.H.S.**	**Min. R.H.S.**	**Shadow Price**
Jaggery	3	3	9.57	0	26.11
Moringa	0.02	0.02	2.00	0	55.02
Maize	5	5	13.13	0	1.49
Mustard oilseed cake	20	20	34.80	0.99	-4.22

Total quantity	100	100	104.58	95.65	9.91
Crude protein	33	33	36.82	24.79	65.52
Crude fat	7.14	5	7.14	-	0
Crude fiber	6.24	12	-	6.24	0
Carbohydrates	32	32	36.941	28.69	7.19
Crude fat	7.14	15	-	7.14	0
Ash	12	12	14.68	10.34	-67.42

Table 11. LP model suggested the quantity of feed ingredients for grower

Ingredients	**Cost(₹)**	**Quantity of ingredients(kg)**
Mustard oilseed cake(x_1)	23	43.41
Rice bran(x_2)	12	23.56
Fish Meal(x_3)	27	5
Wheat (x_4)	19	5
Soyabean (x_5)	40	10
Pearl Millet(x_6)	16	5
Maize (x_7)	13	5
Moringa(x_8)	35	0.02
Jaggery(x_9)	35	3
Fish oil(x_{10})	120	0
Vitamin(x_{11})	350	0
Mineral premix(x_{12})	300	0
Salt(NaCl) (x_{13})	24	0
Di-calcium phosphate(x_{14})	32	0

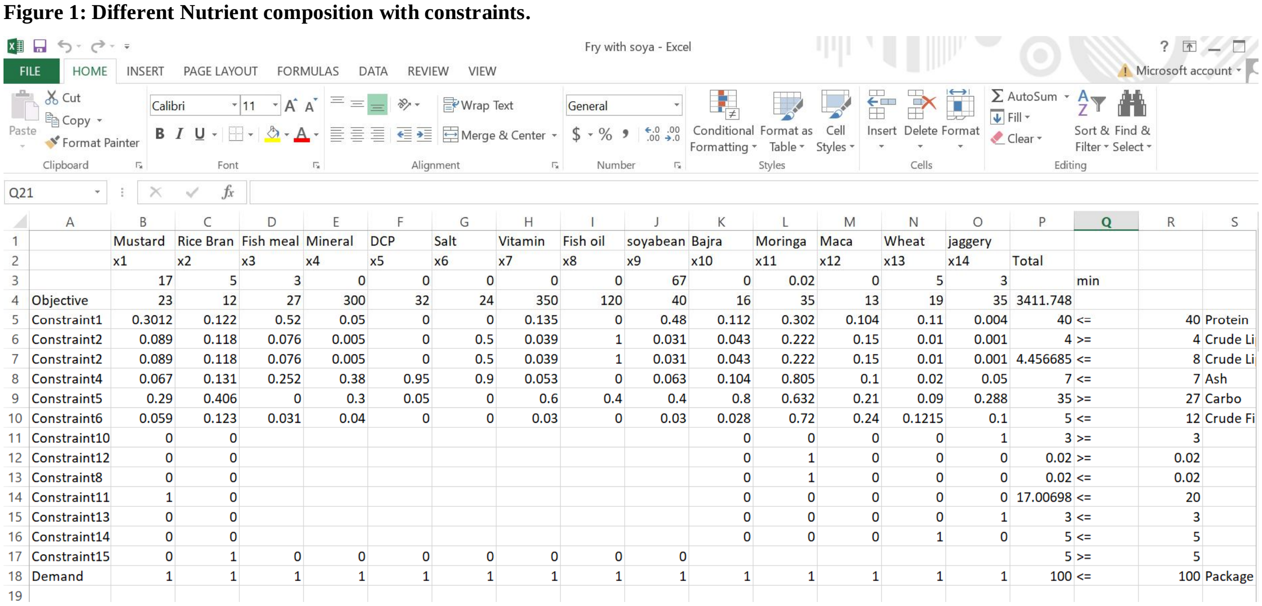
Table 12. Sensitivity Analysis on objective function coefficients in LP model for grower

Name	**Final Value**	**Obj. function**	**Max. Range**	**Min. Range**
Mustard oilseed cake(x_1)	43.41	23	26.01	18.75
Rice bran(x_2)	23.56	12	13.91	5.96
Fish Meal(x_3)	5	27	36.43	-
Wheat (x_4)	5	19	-	11.26
Soyabean (x_5)	10	40	-	33.97
Pearl Millet(x_6)	5	16	-	11.38
Maize (x_7)	5	13	-	10.89
Moringa(x_8)	0.02	35	-	-
Jaggery(x_9)	3	35	-	-
Fish oil(x_{10})	0	120	-	4.51
Vitamin(x_{11})	0	350	-	12.79
Mineral premix(x_{12})	0	300	-	7.58
Salt(NaCl) (x_{13})	0	24	-	4.51
Di-calcium phosphate(x_{14})	0	32	-	4.51

Table 13. Sensitivity Analysis of available resources in LP model for grower

Name	Final Value	Constraint R.H.S.	Max. R.H.S.	Min. R.H.S.	Shadow Price
Crude fibre	8.17	13	-	8.17	0
Maize	5	5	17.32	0	2.10
Jaggery	3	3	11.17	0	30.24
Moringa	0.02	0.02	7.31	0	11.95
Mustard oilseed cake	43.41	30	43.41	-	0
Wheat	5	5	15.16	0	7.73
Rice bran	23.56	10	23.56	-	0
Fish meal	5	5	11.04	0.54	-9.43
Soybean	10	10	16.71	0	6.02
Pearl millet	5	5	17.84	0	4.61
Total quantity	100	100	119.70	93.28	4.51
Crude protein	25	25	27.43	22.59	61.38
Crude fat	8.356	16	-	8.357	0
Ash	9.171	8	9.171	-	0
Carbohydrates	32.534	27	32.534	-	0
Crude fiber	8.176	6	8.176	-	0

Figure 1: Different Nutrient composition with constraints.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
1		Mustard	Rice Bran	Fish meal	Mineral	DCP	Salt	Vitamin	Fish oil	soyabean	Bajra	Moringa	Maca	Wheat	jaggery				
2		x1	x2	x3	x4	x5	x6	x7	x8	x9	x10	x11	x12	x13	x14	Total			
3		17	5	3	0	0	0	0	0	67	0	0.02	0	5	3		min		
4	Objective	23	12	27	300	32	24	350	120	40	16	35	13	19	35	3411.748			
5	Constraint1	0.3012	0.122	0.52	0.05	0	0	0.135	0	0.48	0.112	0.302	0.104	0.11	0.004	40	<=	40	Protein
6	Constraint2	0.089	0.118	0.076	0.005	0	0.5	0.039	1	0.031	0.043	0.222	0.15	0.01	0.001	4	>=	4	Crude Li
7	Constraint2	0.089	0.118	0.076	0.005	0	0.5	0.039	1	0.031	0.043	0.222	0.15	0.01	0.001	4.456685	<=	8	Crude Li
8	Constraint4	0.067	0.131	0.252	0.38	0.95	0.9	0.053	0	0.063	0.104	0.805	0.1	0.02	0.05	7	<=	7	Ash
9	Constraint5	0.29	0.406	0	0.3	0.05	0	0.6	0.4	0.4	0.8	0.632	0.21	0.09	0.288	35	>=	27	Carbo
10	Constraint6	0.059	0.123	0.031	0.04	0	0	0.03	0	0.03	0.028	0.72	0.24	0.1215	0.1	5	<=	12	Crude Fi
11	Constraint10	0	0								0	0	0	0	1	3	>=	3	
12	Constraint12	0	0								0	1	0	0	0	0.02	>=	0.02	
13	Constraint8	0	0								0	1	0	0	0	0.02	<=	0.02	
14	Constraint11	1	0								0	0	0	0	0	17.00698	<=	20	
15	Constraint13	0	0								0	0	0	0	1	3	<=	3	
16	Constraint14	0	0								0	0	0	1	0	5	<=	5	
17	Constraint15	0	1	0	0	0	0	0	0	0						5	>=	5	
18	Demand	1	1	1	1	1	1	1	1	1	1	1	1	1	1	100	<=	100	Package
19																			

The result achieved through the developed models shows that the cost of the farmers feed plan was ₹4350.86 for 106.13 kg mixture with

39.94kg rice bran, 39.34kg commercially available feed/fish feed, 25kg mustard oilseed cake and 1.85kg jaggery The cost of 100 kg pack was calculated and it would be ₹ 4099.26. Also it was found that 67.16 kg soyabean, 17kg mustard oilseed cake, 5kg wheat, 5kg rice bran, 3kg fish meal, 3kg jaggery and 0.02kg moringaare required to formulate 100 kg of fish feed that satisfies the minimum nutrient contents requirements of fry at a total cost for raw material of ₹3411.74. For fingerling,25.82kg soybean, 20kg mustard oilseed cake, 21.37kg fish meal,14.91kg rice bran, 9.85kg pearl millet, 3kg jaggery and 0.02kg moringaare required to formulate 100 kgof fish feed that satisfies the minimum nutrient contents requirements of fingerling of ₹2577.73.For grower, 43.41kg mustard oilseed cake ,23.56kg rice bran, 10.82kg soyabean, 5kg fish meal, 5kg wheat, 5kg pearl millet, 5kg maize, 3kg jaggery and 0.02kg moringaare required to formulate 100kg of fish feed that satisfies the minimum nutrient contents requirements of grower at a total cost for raw material of ₹2162.05. Sensitivity analysis of fry model shows that nutrients such as crude protein, ash,rice bran, wheat, moringa & jaggery were the binding constraints and mustard oilseed cake was non –binding. For fingerling model nutrients such as crude protein, ash, carbohydrates were binding and non–binding nutrients were crude fat, crude fiber. Moreover, in the optimal solution, ingredients such as wheat, pearl millet, maize, moringa & jaggery were binding constraints and mustard oilseed cake,

rice bran was non–binding. For grower the binding nutrient crude protein and non-binding nutrients were crude fat, ash, carbohydrates, crude fiber. Moreover, in the optimal solution, ingredients such as mustard oilseed cake, maize, moringa & jaggery were binding constraints.

The findings of the fish feed formulation using the LP model are shown in this section. Model suggested quantity of ingredients in feed mix for fry, fingerling and grower stages using the Microsoft Excel 15.0 and the solver engine is Simplex LP with the help of following tables (Tables 5, 8 and 11) provide information on the nutrient composition of the components for each stage.So, this section shows that the cost of the farmers feed plan was ₹ 4099.26 for 100kg pack, but our proposed model for 100 kg of fish feed that satisfies the nutrient contents requirements of fry stage at a total cost for raw material of ₹3411.74 and for fingerling it is ₹2577.73, for fish feed that satisfies the minimum nutrient contents requirements of grower stage at a total cost for raw material of ₹2162.05 Sensitivity analysis of the model presented in table 6,9,12, presented minimum and maximum range of ingredients for feed mix, where the optimal LP solution will remain unchanged within these range of values of the ingredients. The value of mustard oilseed cake in the optimal plan was 43.41kg when the cost of mustard oilseed cake was ₹23 and the mode lremains stable until the cost reaches ₹ 26.01. However, in the case of binding ingredients, the optimal LP model will be same until the cost reduces to certain limit. For example, in the case the binding ingredients pearl millet and maize, the optimal model will be same until the cost reducesto ₹11.38 and ₹10.89 respectively.

In the future, the LP approach will be utilised to optimise nutrient requirements for ornamental fish feed formulation at the lowest possible cost in order to promote growth and color. Because commercial feeds for preserving fish colour are costly, we are eager to develop a low-cost ornamental fish feed based on alternative sources such as waste from natural sources that can aid in nutrient requirements. The project's success will boost the ornamental fish industry and lower the cost of fish feed.It will be help for small scale fish farming ,cottage industry and beneficial for factory of fish feed.

4. CONCLUSION

Farmers always looks for alternatives of nutriotional adequate fish feed mixture. The model developed in this study showed a reduction in the cost of fish feed mixture as compared to commercial fish feed mixture. This contribute to reduction of the production cost of fish feed not only for farmers but also will increase the profit of fish feed manufacturers. This research shows that if farmer used the result of fry model the minimum feed cost of mixture can be reduced up to16.77% and if farmers will use the proposed plan for the fingerling stage, the reduction in expenditure would be 24.44%. Also if farmers will use the proposed plan for the grower stage the reduction in expenditure would be 16.12%. If the farmers use the recommendation of feed composition for fry which is maximum of all the three they can save at least ₹687.52/100kg feed composition. Three alternate feed plans were suggested for the polyculture fish (fry, fingerling & grower stage). The cost for farmer's plan was found the highest in comparison to the other three stage wise feed mix plan Sensitivity analysis of the developed models showed minimum and maximum range of ingredients for feed mix, where the optimal LP solution will remain unchanged within these range of values of the ingredients. It is critical for fish farmers to investigate alternate feedstuffs in order to minimise the cost of producing fish without sacrificing feed quality or fish productivity. The results of our mathematical model showed that the cost of fish feed formulation was lower when compared to commercial fish feed.

This research benefits not only fish farmers but also fish feed manufacturers by allowing them to increase their profits. Through this research, fish feed producers can produce different varieties of fish feed at a reduced cost, and fish farmers would undoubtedly prefer these types of feed to help their fish develop faster in less time while cutting rearing costs.

COMPETINGINTERESTS

Authors have declared that no competing interests exist.

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