IOSR Journal Of Humanities And Social Science (IOSR-JHSS)
Volume 23, Issue 10, Ver. 2 (October. 2018) 28-33
e-ISSN: 2279-0837, p-ISSN: 2279-0845.
www.iosrjournals.org

Linear Programming method for solving Optimized Nutrients Feed formulation in GIFT Tilapia

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Abstract: This study is carried out in applying the linear programming technique, which is an optimization method which helps in finding nutrient diet formulation in fish feed. In aquaculture, farming is critical because feed represents maximum of the production costs. The problems in choosing the nutrients play a very vital role in determining the minimum cost that will satisfy daily nutritional requirement. Data on feed ingredients, nutrients composition and prices were obtained from local market survey. The mathematical model which has been applied in this paper has nine decision variables, which is subject to a set of seven constraints. The proposed model was solved using (LiPS) software for easy accessibility.

Keywords: Fish feed formulation, linear programming, GIFT Tilapia, minimum cost, LiPS Software.

Date of Submission: 24-09-2018 Date of acceptance: 11-10-2018

I. INTRODUCTION

Linear programming is a branch of Mathematics that deals with modeling a decision problem and subsequently solving it by Mathematical techniques. It has also made a considerable impact on agricultural, livestock and animal husbandry research in recent years and it is also helpful for fish farmers in determining the fish feed compounds to improve the productivity of fishes. Fish feed formulation is a process where several ingredients are combined to provide necessary nutrition to fishes at different stages. The weight of marketable fish depends on how we feed the fish during culture and this problem turns out to be an optimization problem, which depends on factors like minimum time and least costs. Adequate nutrition's in animal production system is very much essential in economically producing high quality and healthy products. Feeds must be nutritious for maintenance, reproduction and growth. The growth of fish depends on the proper propositions of nutrients in its diets.

Proper nutritious diet to fishes determines the optimal growth, health and its life span. Though natural fish food is available, supplementary feeds are required to get more yields. Moreover, some of these by-products provide a source of protein that can be accessible, inexpensive and available from the local food industry. The energy level of diet which is less expensive than protein supplements is adjusted to the desired level by addition of high energy supplements. Every feedstuff for animal feed formulation will be determined for a specific reason and a purpose; i.e., it is rich in a limiting amino acid, it is a good energy source, and so on. Additionally, each feedstuff in a specific diet formulation should be the least costly ingredient available for its particular function. Fish feed formulation is both a science and an art, requires good knowledge of fish feed, some patience and innovation. Typical formulation indicates the amount of each ingredient that should be included in the fish feed, and then provide the concentration of composition in the feed. Adewumi and Olaleye (2011) studied about catfish farming associated problems of production, feed production and fingerling supply.

With this knowledge, mathematical model is constructed and formulated. They are used to derive the amounts of each ingredient to be included in the fish feed formulation. Prabu et al. (2017) studied the feed diets are made primarily from a mixture of several feedstuffs such as soybean meal, rice bran, vitamin, minerals, fish oil, di-calcium phosphate, cassava leaf meal and salt. Waugh (1951) studied the method of least expensive combination of feeds which meets its requirements. Nath and Talukdar (2014) studied about a mathematical model, which has to satisfy a set of constraints on nutritional levels, special ingredients to be included, availability restrictions and budget constraint ingredients is prevalent in the industry, and availability of feed ingredients and its prevalent market prices. Linear programming technique is a powerful approach for identifying a low-cost healthy diet which is an optimization technique. This paper also illustrates how this technique can be used to minimize the cost for preparing fish feed and maximize the life span of fishes. Csaba

Hancz (2011) suggested that supplemental feeds are rich in protein but nutritionally incomplete which may be used to increase production in which foods are major source of nutrition in aquacultural ecosystems. Supplemental feed may include rice bran, ground nut or multi-ingredient processed feed. Nutritionally complete supplementary feeds are required in foods which are the minor source of nutrients.

Producing sufficient ingredients in feeds to fishes, there is a problem in determining digestible nutrient values. The primary importance for fish farmers is to find affordable and high quality fish feeds through the use of locally available ingredients. The most easily available sources of energy are the carbohydrates contained in common grains products and plant generally. Necessary quantities of fat may be added to increase dietary energy concentrations and palatability. Fish when reared in high densities require proper nutrients. Jacob and Paulraj(1987) studied application of the linear programming technique to find the minimum-cost feed mixture meeting for several specifications in fish feed formulation. The main job is to quantify the nutritional and other specifications, and to ascertain the availability and price of feed ingredients.

II. NECESSITY OF NUTRITION IN FISH FEED

Protein	It acts as a body building nutrient and the most expensive portion. This is usually the first nutrient that is computed in diet formulation in most animal diets. It is important to determine the protein requirements accurately for each species and size of cultured fish.
Lipids	This is the high energy nutrients that can be used in aquaculture feeds. It acts for normal functioning of the body and for energy. High lipid content was found in fish meal and fishery by-products.
Energy	These dietary nutrients are essential for the construction of living tissues. The nutritional value of a dietary ingredient is to supply energy and it is a source of stored energy for fish digestion, reproduction, absorption, growth, and the other life processes. A diet with inadequate energy content will result in weight loss since the fish cannot eat enough feed to satisfy their energy requirements for growth.
Fiber and Ash	In most feedstuffs minerals are found in a group of materials. In experimental diets, fiber is used as a filler whereas ash is used a source of calcium and phosphorous.
Carbohydrates	It is the most economical and inexpensive sources of energy for fish diets. Although not essential, carbohydrates are included in tilapia feeds to provide a cheap source of energy and for improving pellet binding properties.

Model Formulation for nutrition diet is a combination of different ingredients needed for a proper and balanced diet to the fish. The model has to satisfy a set on nutritional levels, availability restrictions, special ingredients to be included, demand constraint and energy constraints. Jacob and Paulraj(1987) and Winston(1995) studied a linear programming problem with "*n*" decision variables and "*m*" constraints that can be mathematically modeled as follows:

2.1 *Notations*

Let i =Feed nutrient components with $i = 1,2, \dots, m$
j= Feed ingredients with $j = 1,2, \dots, n$
x_j =Quantity of feed ingredient j in the feed mixture
c_j = Unit cost of feed ingredient$j$
N =Totalquantity (kg) of feed to be produced
Z =Total cost of feed ingredients used to formulate fish feed.
a_{ij} = Amount of nutrient i available in feed ingredient j.
b_j =Dietary requirement of nutrient i for a fish category.

2.2 Formulation of LP model

The formulation can be done mathematically as a linear programming problem. The objective of the specified model is, $minimize\ Z = \sum_{j=1}^{n} c_j x_j$
Subject to:
$\sum_{j=1}^{n} x_j = N$ (Demand Requirement)
$\sum_{j=1}^{n} a_{ij} x_j \geq b_j$ (Minimum Requirement)
$\sum_{j=1}^{n} a_{ij} x_j \leq b_j$ (Maximum Requirement)
$\sum_{j=1}^{n} a_{ij} x_j = b_j$ (Restricted constraints)

2.3 Model Construction

The objective of this model is to minimize cost of producing a particular feed after satisfying a set of constraints. After this formulation, the diets for cost minimization with local foods were obtained. This diet should not be regarded as an ideal diet, but to attain optimization cost, nutritionally adequate diet for the animal (GIFT Tilapia) which has limited dietary quality. Throughout this survey, Costs of feedstuff used in the diet formulation were obtained from prevailing market prices of feedstuffs and fish processing unit, Nagapattinam, TamilNadu. The analysis of feed ingredients for maximum and minimum levels of various feedstuffs used in diet feed formulation datum were taken from "feedipedia" and Department of Fish Nutrition and Feed Technology, Thoothukudi.

Ingredients	**Protein %**	**Lipid %**	**GE %**	**Carb. %**	**Ash %**	**Fiber %**
Fish Meal	52	7.6	18.6	0	25.2	3.1
Cassava leaf Starch	28	7.8	18	38	5.2	9.8
Soybean Meal	48	3.1	17.6	40	6.3	3
Rice bran	17	12	16.6	52	10	18.8
Fish oil	0	100	39	40	0	0
Vitamin	13.5	3.9	15.8	60	5.3	3
Mineral premix	5	0.5	8	30	38	4
Salt(Nacl)	0	50	0	0	90	0
Dicalcium Phosphate	0	0	5	5	95	0

Table 1.Nutrient levels of feed ingredients

Ingredients	Fish Meal	Cassava leaf Starch	Soybean Meal	Rice bran	Fish oil	Vitamin	Mineral premix	Salt(Nacl)	Dicalcium Phosphate
Cost Rs./Kg	120	16	29	12	125	350	315	24	256

Table 2. Cost implications of raw materials

Consider the quantity of the mixture to be prepared is 100kg. In order to construct a linear programming model to formulate fish feed, Table 1 represents the basic information needed, and fig 1, gives the minimum nutrient requirement.

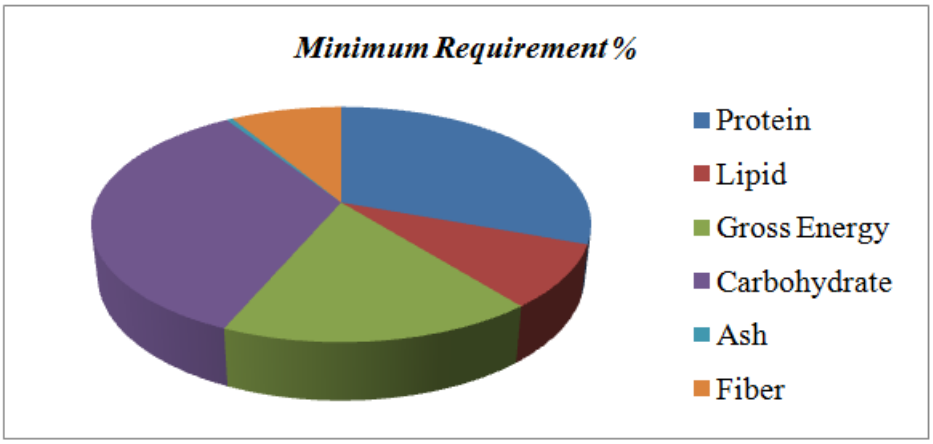


Fig 1: Minimum Nutrient Contents Requirement of GIFT Tilapia

Let $x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8$ and x_9 be the respective quantities in kg of fish meal, cassava leaf starch, soybean meal, rice bran, fish oil, vitamin, mineral premix, salt and di-calcium phosphate are required for the mixture.

The minimum cost linear programming model can be written as.

$$\boldsymbol{minimize}\ Z = 120X_1 + 16X_2 + 29X_3 + 12X_4 + 125X_5 + 350X_6 + 315X_7 + 24X_8 + 256X_9$$

Subject to:

$0.52x_1 + 0.28x_2 + 0.48x_3 + 0.17x_4 + 0.135x_6 + 0.05x_7 \geq 32$; (Protein Requirement)

$0.076x_1 + 0.078x_2 + 0.031x_3 + 0.12x_4 + x_5 + 0.039x_6 + 0.005x_7 + 0.5x_8 \geq 9$; (Lipid Requirement)

$0.186x_1 + 0.18x_2 + 0.176x_3 + 0.166x_4 + 0.39x_5 + 0.158x_6 + 0.08x_7 \geq 18$; (Gross energy Requirement)

$0.38x_2 + 0.4x_3 + 0.52x_4 + 0.4x_5 + 0.6x_6 + 0.3x_7 + 0.05x_9 \geq 36$; (Carbohydrate Requirement)

$0.252x_1 + 0.052x_2 + 0.063x_3 + 0.1x_4 + 0.053x_6 + 0.38x_7 + 0.9x_8 + 0.95x_9 \geq 0.5$; (Ash Requirement)

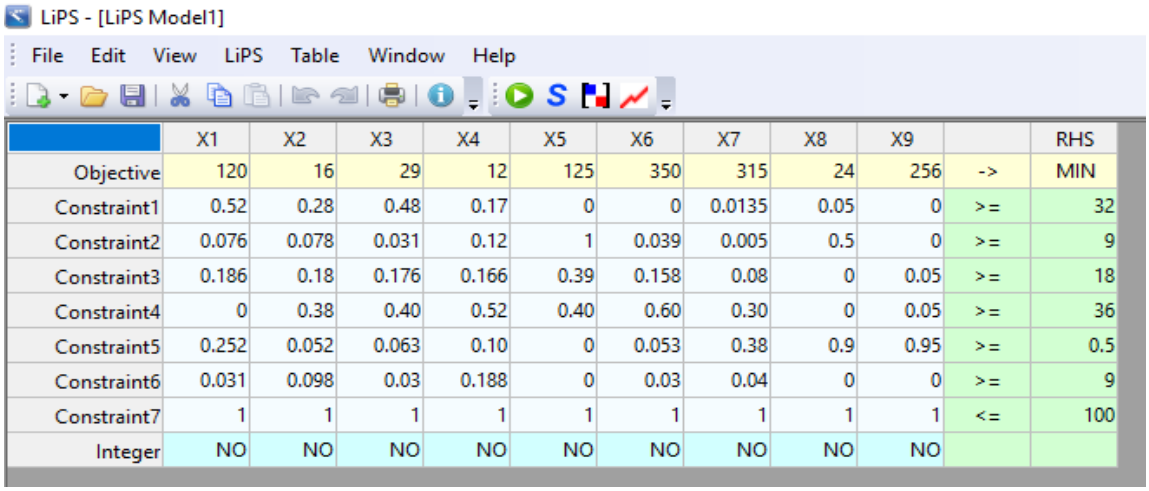
$0.031x_1 + 0.098x_2 + 0.03x_3 + 0.188x_4 + 0.03x_6 + 0.04x_7 \geq 9$; (Fiber Requirement)

$x_1 + x_2 + x_3 + x_4 + x_5 + x_6 + x_7 + x_8 + x_9 = 100$; (Demand)

$x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8, x_9 \geq 0$; (Non-Negativity Constraints)

III. DATA ANALYSIS

The method of data analysis employed in this study was Linear Programming model. All the data were computed using Linear Program Solver (LiPS) software for feed formulation. This software is extremely useful for practical applications. The optimum feed formulated by this software is presented in Table 3.



	X1	X2	X3	X4	X5	X6	X7	X8	X9		RHS
Objective	120	16	29	12	125	350	315	24	256	->	MIN
Constraint1	0.52	0.28	0.48	0.17	0	0	0.0135	0.05	0	>=	32
Constraint2	0.076	0.078	0.031	0.12	1	0.039	0.005	0.5	0	>=	9
Constraint3	0.186	0.18	0.176	0.166	0.39	0.158	0.08	0	0.05	>=	18
Constraint4	0	0.38	0.40	0.52	0.40	0.60	0.30	0	0.05	>=	36
Constraint5	0.252	0.052	0.063	0.10	0	0.053	0.38	0.9	0.95	>=	0.5
Constraint6	0.031	0.098	0.03	0.188	0	0.03	0.04	0	0	>=	9
Constraint7	1	1	1	1	1	1	1	1	1	<=	100
Integer	NO	NO	NO	NO	NO	NO	NO	NO	NO		

Figure 2. Problem Formulation

Variable	*Objective cost*	*Value*
x_1	120	0
x_2	16	45.4033
x_3	29	33.481
x_4	13.2	18.8619
x_5	125	2.06067
x_6	350	0
x_7	315	0
x_8	24	0.193054
x_9	256	0

Table 3: Computational results using LIPS software

Sensitivity analysis result is given in figure 3.

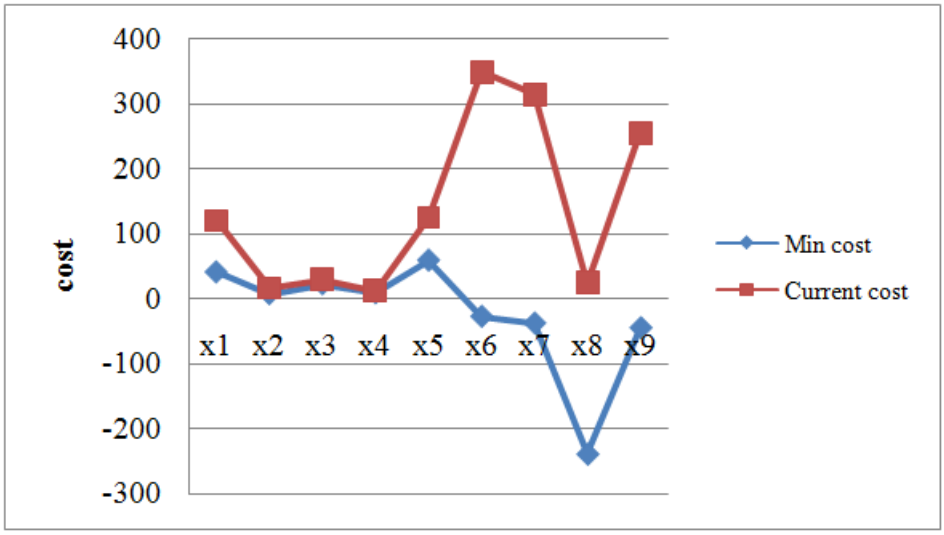


Figure 3. Sensitivity Analysis

IV. RESULTS AND DISCUSSIONS

By this study, it is proposed that 45.4033kg of Cassava leaf meal, 33.481kg of Soybean meal, 18.8619 kg of Rice bran, 2.06067 kg of Fish oil and 0.193054 kg of Salt are the required quantities for the mixture of 100kg which satisfies the Minimum Nutrient Contents Requirement of GIFT Tilapia and the optimal cost for 100kg mixture is calculated to be $Rs.2185.96$.With this effect, fish farmers are advised to include the locally available ingredients with high protein and energy levels in fish feeds.

V. CONCLUSION

The result obtained from this study concludes that without any negative effects on growth and feed utilization for small-scale fishes were obtained. This solution states, requirements for achieving the objective are providing proper quality and quantity feed with minimum cost. The current study suggests that inclusion of plant feedstuffs and fish oil in GIFT Tilapia diets would improve the quality and affordability of fish diets for small scale fish farmers at minimum cost.

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IOSR Journal Of Humanities And Social Science (IOSR-JHSS) is UGC approved Journal with Sl. No. 5070, Journal no. 49323.

J. Irine'' Linear Programming method for solving Optimized Nutrients Feed formulation in GIFT Tilapia." IOSR Journal Of Humanities And Social Science (IOSR-JHSS). vol. 23 no. 10, 2018, pp. 28-33