Linear Programming Optimization Model of Broilers Poultry feeds for Local entrepreneurs in Tanzania. A case study of Morogoro Municipality.

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Abstract
The aim of this research was to formulate linear programming model that enables poultry entrepreneurs maximize their profits as well as minimize costs on their farm, the resources optimized were feeds only. This research proposed linear programming (LP) technique to minimize the feed cost for small scale poultry entrepreneurs. It employs locally available feed ingredients to formulate broiler starter, grower and finisher feed mix.
The dietary nutrient requirement for broiler starter, grower and finisher stage were determined from the prescribed standard specification by the department of poultry science of the University of Georgia. Costs of nine feed ingredients were obtained in the market at Morogoro municipal. The nine feed ingredients were selected to formulate the optimal feed mix to minimize the total cost of feed mix subject to the essential nutrient constraints.
The Simplex method were used to formulate and solve the Linear Programming model and optimal feed mix for broiler starter, grower and finisher were obtained. The obtained Model and its optimal solution compared with existing practice of the case study farm. The proposed optimal formulation of the linear programming model gives about 38.2%, 43.7% and 37.3% reduction in feed formulation costs compared to the existing formulation in case of broiler starter, grower and finisher respectively on the farm.

Keywords: *Linear Programming, Optimization Model, Broilers Poultry and Entrepreneurs*

Introduction

In Africa, poultry farming is one the biggest business opportunities on the continent. South Africa is the largest poultry meat producer which produced 1.5million metric tons of chicken meat, followed by Egypt, Morocco, Nigeria and Algeria (Ringo, 2018).
In Tanzania the poultry sector still at infant stage, both in the commercial and traditional subsector. Some areas such as Singida, Tabora and Dodoma contribute much in the business of poultry however, there is no clear evidence to which extent they contribute. About 70% of Tanzanian indigenous has employed themselves in farming activities which has a contribution of about 40% of the gross domestic product(GDP) and poultry is one of farming activity which contribute not only to the GDP but also to indigenous income (Ringo, 2018). More over Ringo (2018) pointed out that, apart from having about 72 million chickens in 2018, one of the major problems is lack of reliable supply of poultry feeds.

In farming, poultry is one of the activity with boundless important to human being apart from improving household finance, it is also one of the major areas that provide not only food but also nutrients. Poultry meat is one of the crucial sources of high-quality proteins, minerals and vitamins to balance the human diet(Ravindran, 2009). For entrepreneurs to get efficient profits, the farmer needs a lot of important facts about poultry farming. These facts include cost minimization and profit maximization.
There many studies done to optimize the feed mix and increase the households income outside Tanzania, like those of Mallick et al., (2020); Mathias & Therence, (2018); Olugbenga O & Abayomi O, (2015); and Dekker, (1996) but to the best of our knowledge, currently there is no any study which has been done in Tanzania specifically in creating a linear programming model to optimize the poultry feed mix and come up with a software application. Those which has been done within Tanzania, most of them are rural or urban community projects. Studies by Msami, (2007) and Ringo, (2018) focused on poultry sector in general and one study done by Mgeni and Ahmed, (2019) focused on Evaluation of Production Performance of The Broiler Chicken Industry, all researchers did not show the specific model which could be useful for the optimization of feed mix. Therefore this was the drive to do the study specifically in Tanzania.

Marketing of Poultry Products

According Queenan *et al*, (2016) Marketing of poultry products was defined as a movement of products that is eggs or broilers from one place to another for the purpose of medium exchange (selling).Tanzania is a very big country with poor especially infrastructure in rural areas. Movement of products from one place to another is therefore a major problem. Similarly, marketing of poultry and poultry products in urban, peri-urban and rural areas was a problem. Commercial poultry farmers for layers or broilers were disorganized and there was no proper marketing. Producers sell their products (eggs or live broilers) to consumers directly or through middlemen (Lekule, 2018).

Rationale

The mathematical model formulated will be used by local farmers to mix their feeds using the locally available feeds which will have a minimum cost. Moreover, the model formulated can be used in different scenario when the nutritional requirement and the costs are known then it will be easily used by the locally available feedstuffs to supply those nutrients.

Material and Methods

The study, first find the nutritious requirements for poultry at different stages, which was obtained from different literatures of Poultry farming and specifically here in Tanzania can obtain from the Sokoine University of Agriculture (SUA) or from drug and food authorities. Second, after knowing the nutritional requirement for each stage then we surveyed the costs of locally available feeds ingredients by using a uniform scale of cost per kilogram of each feed and lastly know the nutritional contribution of each feed, which is the energy, minerals, proteins, vitamins, fiber and so on

Using the nutritional requirements, the feeds cost and nutritional contribution was used to formulate a linear programming model which was later be solved by using Simplex method which is one of the powerfully method and LINGO software for validity (Vanderbei, 2007).

The Simplex Method

Simplex method is a standard technique in linear programming for solving an optimization problem, typically one involving a function and several constraints expressed as inequalities. The simplex method algorithms based on the fundamental theorem of linear programming the states that: the optimal solution to linear programming problem if it exists always occurs at one of the corner (Bazaraa *et al*, 2010).

Standard form of Linear Programming

The simplex method is easiest to explain for linear programs that are in a fixed format called standard form. A linear program in standard forms looks likes:

Maximize:

$$f(x_1, x_2, \dots x_n) = c_1x_1 + c_2x_2 + \cdots c_nx_n$$

Subject to;

$$\begin{gathered} a_{11}x_1 + a_{12}x_2 + \cdots + a_{1n}x_n \leq b_1 \\ a_{21}x_1 + a_{22}x_2 + \cdots + a_{2n}x_n \leq b_2 \\ . \\ . \\ . \\ a_{m1}x_1 + a_{m2}x_2 + \cdots + a_{mn}x_n \leq b_m \\ x_1, x_2, \dots x_n \geq 0 \end{gathered}$$

The following are characteristics of standard form linear programming according to (Bazaraa *et al*, 2010).

i. They were about maximizing, not minimizing.
ii. They had positivity constraint for each variable.
iii. The other constraints were all of the form "linear combination of variables ≤ constant".

Simplex Tableau

The simplex method was carried out by performing elementary row operation on a matrix that we call the simplex tableau. The tableau consisted of the augmented matrix corresponding to the constraints equations together with the coefficients of the objective function written in the form (Taha, 2017).

Table 1.1: Structure of a Simplex Tableau

	C_j	**C_1**	**C_2**	**...**	**C_n**	**0**	**0**	**…**	**0**	
$\boldsymbol{C_{Bi}}$	Basic variables B	X_1	X_2	…	X_n	S_1	S_2	…	S_m	Basic solution b($=X_B$)
0	S_1	a_{11}	a_{12}	…	a_{1n}	1	0	…	0	b_1
0	S_2	a_{21}	a_{22}	…	a_{2n}	0	1	…	0	b_2
…	…	…	…	…	…	…	…	…	…	…
0	S_m	a_{m1}	a_{m2}	…	a_{mn}	0	0	…	1	b_m
	$Z_j - C_j$	$-c_1$	$-c_2$	…	$-c_m$	0	0	…	0	Z=0

Where

C_j= Coefficients of the variables (m + n) in the objective function.

C_{Bi} = Coefficients of the current basic variables in the objective function.

Z_j=$\sum a_{ij} c_{Bi}$where i=1, 2… m; for each j=1, 2… n+m

B = Bas is variables in the basis.

X_B=Solution values of the basic variables.

$Z_j - C_j$= Index row. Or relative cost factor

The rules used for the construction of the initial simplex table are same in both the maximization and the minimization problems.

According to Panik (1996) steps of the simplex method include the following;

1. Formulate the problem

   Formulate the mathematical model of the given linear programming problem. If the objective function was given in minimization form then convert it into maximization form in the following way:

   Min Z = −Max (−Z)

2. Find out the initial solution

Calculate the initial basic feasible solution by assigning zero value to the decision variables. This solution was shown in the initial simplex table.

3. Test for optimality

   Calculate the values of$Z_j - C_j$. If the values of $Z_j - C_j$ are positive, the current basic feasible solution is the optimal solution. If there are one or more negative values, choose the variable corresponding to which the value of $Z_j - C_j$ is least (most negative) as this is likely to increase the profit most.

4. Test for feasibility

   Divide the value under X_B column by the corresponding positive coefficient (a_{ij}) in the key column, and compare the ratios. The row that indicates the minimum ratio is called the key row. However, division by zero or negative coefficients in the key column is not allowed. In the case of a tie, break the tie arbitrarily.

5. Identify the pivot element(key element)

   The number that lies at the intersection of the key column and key row of a given element. It is always a non –zero positive number.

6. Determine the new solution

   The numbers in the replacing row may be obtained by dividing the key row elements by the pivot element. The numbers in the remaining rows may be calculated by using the following formula:

   New number $=$ old number − [(corresponding no. of key row) × (corresponding no. of key column)] ÷ pivot element.

Assumptions

According to Luenberger and Ye (2016), before a valid result can be obtained from linear programming technique, the following assumptions must be holding:

- ❖ The contribution of each activity to the value of the objective function **z** is proportional to the level of the activity $x_{j,\ as}$ represented by the $C_{j,}X_j$ term in the objective function.
- ❖ The Every function in linear programming model is the sum of the individual contributions of the respective activities.
- ❖ Decision variables in a linear programming model are allowed to have any values including non-integer values that satisfy the functional and non-negativity constraints.
- ❖ The value assigned to each parameters of linear programming model is assumed to be a known constant.

Model formulation.

Data collected for this study were based on raw materials (feed stuffs) specification, constrained imposed on the selected raw material and the dietary nutrient requirements in each stage of life of broiler flocks. The main source of these data was from the farmers, Costs of feed stuffs used in the diet formulation were obtained from the prevailing market prices of feed stuffs in Morogoro municipality through survey on March 28, 2021. The analysis of feed stuffs ingredients and minimum and maximum levels of various feed stuffs used in diet obtained from standard tables and sources. Feed stuffs used in ration formulation for local poultry farms include maize (X_1), soya bean meal (X_2), cotton seed meal (X_3), sunflower seed meal (X_4), fish meal (X_5), bone meal (X_6), limestone (X_7), Di –calcium phosphate (X_8) and lysine(X_9).

Model Formulation

The nutrient diet model formulation is a combination of different feed ingredients needed for a balance diet of the broiler. The model has to satisfy a set of constraints on nutritional levels, availability restrictions, special ingredients to be included, demand constraint, energy and budget constraints. The generic mathematical model which is applicable to each type of ration using the available ingredients is constructed as follows:

Let

i = feed nutrient components with i = 1, 2 … 9

j = feed ingredients with j =1, 2…n

$\mathbf{X_j}$ = quantity of feed ingredient j in the feed mix (decision variable)

N = total quantity (Kg) of feed to be produced

Z = Total cost of feed ingredients used in the feed formulation

$\mathbf{C_j}$ = unit cost of feed ingredient j

$\mathbf{a_{ij}}$ = amount (in fraction of X_j) of nutrient i available in feed ingredient j

$\mathbf{b_i}$ = dietary requirement (fraction of N) of nutrient i for a bird category

Objective Function:

The objective of this linear programming model is to minimize total feed costs.

Min $Z = \sum_{j=1}^{n} C_j X_j$

Subject to;

Demand requirements:

The demand requirement is an indication of the total amount of feed mix required based on the requirement of broilers at different stages according to their ages, in our study it is 1kg.

$\sum_{j=1}^{n} X_j \geq \text{N}$

Minimum requirement:

$a_{ij} \sum_{j=1}^{n} X_J \geq b_i(\text{Min})$

Non negativity constraints:

$X_j \geq 0$

The Broiler feeds Formulation Problems

The generic feed formulation model can be adapted to suit any ration and its application demonstrated by broilers feed ration, with nutrient requirement as indicated in the *table 1.2*. The model has been parameterized by the nutrients yields and costs of locally available feed ingredients summarized in *table 1.2*

Table 1.2: Nutrient Requirements with regard to Production Aims

	Crude Protein (%)	Energy ME (kca/kg)	Crude Fibre (%)	Lysine (%)	Methonine (%)	Calcium (%)	AvP	Sodium
Broiler starter	21-24	2900-3100	5	1.10	0.37	0.85-1.05	0.3-0.6	0.01-0.3
Broiler grower	18-23	3000-3300	8	0.85	0.33	0.80-1.00	0.3-0.55	0.01-0.3
Broiler finisher	17-22	3100-3300	8	0.9	0.3	0.3-0.5	0.35	0.01-0.3

Source: The Department of Poultry Science of the University of Georgia

Cost Implications and Nutrients Levels of Feed Ingredients

Ingredients	Price (Tshs/Kg)	Crude Protein (%)	Me Energy (Kca/Kg)	Crude Fibre (%)	Lysine (%)	Methonine (%)	Calcium (%)	Avp	Sodium
Maize	800	7.5	3373	1.9	0.24	0.18	0.01	0.12	0.02
Soya bean meal	1700	42.0	2420	6.5	2.7	0.6	0.2	0.15	0.0
Cotton seed meal	850	41.0	2100	12.6	1.52	0.55	0.32	0.17	0.04
Sunflower seed meal	750	27.9	1834	18.84	0.99	0.63	0.32	0.14	0.0
Fish meal	3300	61.0	2600	1.0	4.3	1.65	7.0	3.5	0.97
Bone meal	350	0.0	0.0	0.0	0.0	0.0	24.0	12.0	0.46
Limestone	100						38.0		
Di-calcium phosphate	7500	59.0	3680			98.0			
Lysine	4000	94.4	4600		78.8				

Model Construction

Linear Programming model for Broilers Starter ratio is:

$$\mathbf{MinZ = 800X_1 + 1700X_2 + 850X_3 + 750X_4 + 3300X_5 + 350X_6 + 100X_7 + 7500X_8 + 4000X_9}$$

Subject to;

$X_1 + X_2 + X_3 + X_4 + X_5 + X_6 + X_7 + X_8 + X_9 \geq 1$ (Minimum demand requirement)

$7.5X_1 + 42X_2 + 41X_3 + 27.9X_4 + 61X_5 + 59.0X_8 + 94.4X_9 \geq 21$ (protein)

$3373X_1 + 2420X_2 + 2100X_3 + 1834X_4 + 2600X_5 + 3680X_8 + 4600X_9 \geq 3000$ (energy) $1.9X_1 + 6.5X_2 + 12.6X_3 + 18.84X_4 + 1.0X_5 \geq 5$(fibre)

$0.24X_1 + 2.7X_2 + 1.52X_3 + 0.99X_4 + 4.3X_5 + 78.8\, X_9 \geq 1.1$(lysine)

$0.18X_1 + 0.6X_2 + 0.55X_3 + 0.63X_4 + 1.65X_5 + 98X_8 \geq 0.37$(methonine)

$0.01X_1 + 0.2X_2 + 0.32X_3 + 0.32X_4 + 7X_5 + 24X_6 + 38X_7 \geq 0.85$(calcium)

$0.12X_1 + 0.15X_2 + 0.17X_3 + 0.14X_4 + 3.5X_5 + 12X_6 \geq 0.3$ (AvP)

$0.02X_1 + 0.04X_3 + 0.97X_5 + 0.46X_6 \geq 0.01$ (Sodium)

$X_i \geq 0$ for $i = 1,2,\ldots,9$

Linear Programming model for Broiler Grower Ratio is;

$Min\ Z = 800X_1 + 1700X_2 + 850X_3 + 750X_4 + 3300X_5 + 350X_6 + 100X_7 + 7500X_8 + 4000X_9$

Subject to;

$X_1 + X_2 + X_3 + X_4 + X_5 + X_6 + X_7 + X_8 + X_9 \geq 1\ (Minimumdemandrequirement)$

$7.5X_1 + 42X_2 + 41X_3 + 27.9X_4 + 61X_5 + 59.0X_8 + 94.4X_9 \geq 18\ (protein)$

$3373X_1 + 2420X_2 + 2100X_3 + 1834X_4 + 2600X_5 + 3680X_8 + 4600X_9 \geq 3000\ (energy)$

$1.9X_1 + 6.5X_2 + 12.6X_3 + 18.84X_4 + 1.0X_5 \geq 8 (fibre)$

$0.24X_1 + 2.7X_2 + 1.52X_3 + 0.99X_4 + 4.3X_5 + 78.8\ X_9 \geq 0.85 (lysine)$

$0.18X_1 + 0.6X_2 + 0.55X_3 + 0.63X_4 + 1.65X_5 + 98X_8 \geq 0.33 (methonine)$

$0.01X_1 + 0.2X_2 + 0.32X_3 + 0.32X_4 + 7X_5 + 24X_6 + 38X_7 \geq 0.80 (calcium)$

$0.12X_1 + 0.15X_2 + 0.17X_3 + 0.14X_4 + 3.5X_5 + 12X_6 \geq 0.3\ (AvP)$

$0.02X_1 + 0.04X_3 + 0.97X_5 + 0.46X_6 \geq 0.01\ (Sodium)$

$X_i \geq 0\ for\ i = 1,2,\ldots,9$

Linear Programming Model for Broiler Finisher Ratio is;

$\text{Min Z} = 800X_1 + 1700X_2 + 850X_3 + 750X_4 + 3300X_5 + 350X_6 + 100X_7 + 7500X_8 + 4000X_9$

Subject to;

$X_1 + X_2 + X_3 + X_4 + X_5 + X_6 + X_7 + X_8 + X_9 \geq 1$ (Minimumdemandrequirement)

$7.5X_1 + 42X_2 + 41X_3 + 27.9X_4 + 61X_5 + 59.0X_8 + 94.4X_9 \geq 17$ (protein)

$3373X_1 + 2420X_2 + 2100X_3 + 1834X_4 + 2600X_5 + 3680X_8 + 4600X_9 \geq 3100$ (energy)

$1.9X_1 + 6.5X_2 + 12.6X_3 + 18.84X_4 + 1.0X_5 \geq 8$ (fibre)

$0.24X_1 + 2.7X_2 + 1.52X_3 + 0.99X_4 + 4.3X_5 + 78.8\ X_9 \geq 0.9$ (lysine)

$0.18X_1 + 0.6X_2 + 0.55X_3 + 0.63X_4 + 1.65X_5 + 98X_8 \geq 0.3$ (methonine)

$0.01X_1 + 0.2X_2 + 0.32X_3 + 0.32X_4 + 7X_5 + 24X_6 + 38X_7 \geq 0.3$(calcium)

$0.12X_1 + 0.15X_2 + 0.17X_3 + 0.14X_4 + 3.5X_5 + 12X_6 \geq 0.35$ (AvP)

$0.02X_1 + 0.04X_3 + 0.97X_5 + 0.46X_6 \geq 0.01$ (Sodium)

$X_i \geq 0$ for $i = 1,2,\ldots,9$

Results and Discussion

The data presented in this study are the results and analysis of the formulated linear programming model for the optimization of feed cost for broiler poultry. The models for broiler starter diet, broiler grower diet and broiler finisher diet were solved using linear programming method in simplex method.

Result of Broiler Starter Diet

The proposed diet formulation result produced by linear programming model has shown that for approximately 1kg of starter feed mix the diet consist of 0.6441kg of maize, 0.3831kg of cotton seed meal, 0.0131kg of bone meal, 0.0107kg of limestone, 0.0004 kg of Di-calcium and 0.0046kg of lysine. This feed mix costs approximately 868.3619Tsh per 1Kg.

Result of Broiler Grower Diet

The proposed diet formulation result produced by linear programming model has shown that for approximately 1kg of grower feed mix the diet consist of *0.6583*kg of maize, *0.125*kg of cotton seed meal *0.2747*kg of sunflower seed meal, *0.0134*kg of bone meal, *0.0009*kg of limestone and *0.0029*kg of lysine. This feed mix costs approximately 856.1411Tsh per 1Kg.

Result of Broiler Finisher Diet

The proposed diet formulation result produced by linear programming model has shown that for approximately 1kg of finisher feed mix the diet consist of *0.7042*kg of maize, *0.0655*kg of cotton seed meal, *0.3098*kg of sunflower seed meal, *0.0176*kg of bone meal and *0.0041*kg of lysine. This feed mix costs approximately 874.0383Tsh per 1Kg.

Comparison between Existing Diet Formulation and Proposed Diet Formulation

For Broiler Starter

Comparison of proposed broiler starter local feed formulation with the existing feed produced in the industry show that the cost of proposed feed mix for broiler starter is 43,420 Tshs for 50 Kgs of feed mix and 868.3619 Tshs (approximately 868.4 Tshs) for 1kg of feed mix**.** The cost of the ration is around 43,420TShs for 50kgs against the existing feed which produced in industry cost of 60,000TShs for one bag of 50kgs.This cost save about 16,580TShs which is about 38.2%.

Based on the information receive from a broiler farmer, it was recorded that on the average monthly feed consumption of 300 broilers is 200Kg.starter feed is fed to the broilers for 4 weeks. So the total cost of feed for 4 weeks (a month) will be 868.4TShs $\times$ 200kgs = 173,680TShs

Whereas the existing feed mix which costs 60,000Tsh for one bag of 50kgs the total cost for 4weeks consumption is60,000TShs $\times$ $4bags = 240{,}000\,Tsh$.

For Broiler Grower

Comparison of proposed broiler starter local feed formulation with the existing feed produced in the industry show that the cost of proposed feed mix for broiler starter is 42,800 Tshs for 50 Kgs of feed mix and 856.1411 Tshs (approximately 856 Tshs) for 1kg of feed mix**.** The cost of the ration is around 42,800TShs for 50kgs against the existing feed which produced in industry cost of 61,500TShs for one bag of 50kgs.This cost save about 18,700TShs which is about 43.7%.

Based on the information receive from a broiler farmer, it was recorded that on the average monthly feed consumption of 300 broilers is 250Kg.starter feed is fed to the broilers for 4 weeks. So the total cost of feed for 4 weeks (a month) will be 856.1TShs $\times$ 250kgs = 214,025TShs

Whereas the existing feed mix which costs 61,500Tsh for one bag of 50kgs the total cost for 4weeks consumption is 61,500TShs $\times$ $5bags = 307{,}500\,Tsh$.

For Broiler Finisher

Comparison of proposed broiler starter local feed formulation with the existing feed produced in the industry show that the cost of proposed feed mix for broiler starter is 43,700 Tshs for 50 Kgs of feed mix and 874.0383 Tshs (approximately 874.0 Tshs) for 1kg of feed mix. The cost of the ration is around 43,700TShs for 50kgs against the existing feed which produced in industry cost of 60,000TShs for one bag of 50kgs.This cost save about 16,300TShs which is about37.3%.

Based on the information receive from a broiler farmer, it was recorded that on the average monthly feed consumption of 300 broilers is 200Kg.starter feed is fed to the broilers for 4 weeks. So the total cost of feed for 4 weeks (a month) will be $874.0\text{TShs} \times 200\text{kgs} = 174{,}800\text{TShs}$
Whereas the existing feed mix which costs 60,000Tsh for one bag of 50kgs the total cost for 4weeks consumption is $60{,}000\text{TShs} \times 4bags = 240{,}000\ Tsh$.

Conclusions

This study employed a linear programming technique for reasons of accuracy and easy of doing calculation in comparison to other manual techniques of feed formulation employed by local farms. The mathematical model results presented in this work show clearly that the Simplex method is the best tool which gives best outcome subject to the necessary constraints. This study has collected and provided information on various nutrients required for proper growth of broilers at different stages and the sources of these nutrients. The LP methodology used could be helpful for the academicians and entrepreneurs in developing a proper feed mix with lowest cost. The proposed broiler starter, grower and finisher diets are not having enough of some essential nutrients this could be due to sourcing of nutrient composition of feed ingredients data from various animal nutrition text books and publication that in some cases they have wide variations on feed composition information. So, these proposed diets cannot be practiced by farmers without the improvement in the nutrients requirement. From the conclusion we realized that using scientific methods to produce feed helps the poultry farmers to increase their profits. Hence we recommend the poultry entrepreneurs to adapt this model in their feed production.

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Conflict of interest

The authors declare they have no conflict of interest.

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