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Optimization of Poultry Feeds Production Using Linear Programming Technique

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A B S T R A C T

In Production Industries where the objectives of firms are centred on the increment in profit and reduction in the cost of production, while maintaining standard quality product, it becomes necessary to evaluate the equivalent units of production that promote the company's goal. This paper presents a Linear Programming (LP) approach that optimizes production units to achieving the overall maximum profit generated from different types of feeds produced by poultry feed industry, while considering several constraints during the blend of constituents in the production of rations. Data from a feed mill in Lagos State in South-West Nigera that produces poultry feeds, such as starter mash, grower mash, chick mash, and broiler mash were collected for validation of the Linear Programming (LP) model. Results showed that by utilizing 1000kg of maize, 1331.42kg of wheat ofals, 819.43kg of soya beans, 407.34kg of metaioline, 5.34kg of lysine, and 67.49kg of fish meal from the available quantities in stock, the overall profit to be generated from poultry feeds production increases from N7,602 to N9,424.60. It was also deduced from results obtained that the feed mill can achieve maximum profit by concentrating on production of layer mash and broiler finisher mash or increasing the production of these types of feeds among others usually produced in the feed mill.

1. Introduction

The optimization of poultry feeds production in different ration formulation has received considerable attention because of its technical, socio-economic and agricultural importance. Previous studies have shown that the high cost of compound feeds for poultry is derived largely from the exorbitant prices of feed ingredients, increasing competitive demand for them and the scarcity of the conventional ingredients (Ojewola *et al.*, 2004). Criteria such as capability, flexibility, ease of use, and cost are considered by a firm when choosing a project selection model (Souda, 1973). Feed production is one of the basic needs of poultry birds, and performance with development is directly dependent on the diet intake of these birds. It has been established that feeding constitutes over 70% of the total cost of egg and broiler production (Afolayan and Afolayan, 2008; Fetuga, 1989). Formulation of ration is a difficult task as it should select a combination of feed ingredients that adequately meet stated nutrients and other requirements of the animal. Linear programming (LP) is a tool for solving optimization problems. It is a widely used mathematical modeling technique designed to help managers in making plan relative to resource allocation (Chvatal, 1983). LP finds its application in determining optimal value of a given function called the objective function, subject to a set of stated restrictions, or constraints, placed on the variable concerned (Simmons, 1973; Stroud, 1994).). Waugh (1951) became the first researcher to apply linear programming as a tool for optimizing livestock ration. Olorunfemi *et al.* (2006) applied LP technique to solve the problem of least-cost ration formulation in poultry, utilizing duckweed for broiler starter. It was discovered from the LP model applied that utilization of broiler starter diet containing 26.09% of duckweed reduces the cost of feed by 10.64%, which improves profitability in broiler production. Linear programming approach has been used by researchers to develop nutrition programs for high producing dairy herds to attain efficient and profitable levels of milk production (Sklan *et al.,* 1991), as a tool to optimize human nutrition and annealing optimization work (Kirpatrick *et al.*, 1983).

Linear Programming techniques have been used in solving ration optimization in order to minimize production cost. Linear programming has been used to balance the nutrient ingredients included in the diet and minimize the cost of ration. Oliveira et al. (2010) developed an economically optimal plan based on a multiperiodic linear programming model to minimize overall feeding costs of category of grazing horses. The result shows significant reduction in feeding costs in the horse production system by decreasing supplementation and substitution of commercial concentrate. Al-Desert (2009) employed Linear programming (LP) technique to determine the most efficient way of combining locally available ingredients in boiler ration formulation. Least cost for

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starter boiler and finisher rations were achieved.

The LP model can be solved for a complicated set of nutrient requirements to give a relatively well-balanced ration (VandeHaar and Black, 1991). The principal objective in the application of LP to feed formulation is the production of maximized profit at a minimum cost of ration production. A feed formulation model that requires cueing-in of ingredients and their required quantities for birds was developed by Onwurah (2011). The developed model gave an estimate of feed requirements of birds at various ages, and the cost of feed required. One of the common uses of programming techniques is to optimize profit by reducing the overall cost of production of a particular product. Nath and Talukdar (2014) applied LP technique to fish feed formulation. The optimal solution obtained gave reduction in feed formulation costs compared to the existing farm method. A cost analysis spreadsheet and validation of that spreadsheet on milking and custom heifer operations was developed by Guevara (2004). Lead factors are used in computerized ration formulation programs developed at Virginia Tech to increase milk production above a herd or group average for which total mixed rations are formulated for group feeding.

The cost optimization of poultry feeds production is a key element in determining the least-cost feed mixture according to poultry nutrient requirements and the effective use of the feed components. This paper analyses the optimization of poultry feeds production for commercial purpose, considering several constraints during the blend of the raw constituents. Feed Production is one of the basic needs of Poultry birds and other farm animals. Performance and development of animal is directly dependent on diet intake of animal. Different stages of poultry birds are considered in the course of this work, which have different requirements of energy and ration formulated in such a way that energy requirement of animal must be fulfilled. The main objective of optimization of the feed production is to achieve a maximized profitable production of different rations which also satisfies the nutrient level of the poultry species at minimized cost. In this paper, the cost optimization of feeds is performed by Linear programming, considering the growing style and type, age, nutritional requirements and feedstuff costs for poultry.

2. Methodology

2.1 Model Formulation

To determine the optimum product quantity of feed types that maximizes the total profit per period, the LP model has three basic components. These components are;

I. Decision variables which are the basic values that make up the model

ii. Objective function (goal) that is, profit that is needed to be optimized, and

iii. Constraints, that is, the available ingredient in the inventory

Poultry feed mills basically produce the following types of feed viz. starter marsh, grower marsh, layer marsh, chick marsh, and broiler finisher marsh from certain number of constituents, such as, corn, wheat, soybeans, fish meal, bone meal, lysine etc. Assuming there is unlimited demand for all different types of feeds produced:

Let,

x_1 = production of starter feed (in bags) per period

x_2 = production of grower feed (in bags) per period

x_3 = production of layer feed (in bags) per period

x_4 = production of chick feed (in bags) per period

x_5 = production of broiler feed (in bags) per period

p_1 = profit per bag of starter mash feed

p_2 = profit per bag of grower mash feed

p_3 = profit per bag of layer mash feed

p_4 = profit per bag of chick mash feed

p_5 = profit per bag of broiler mash feed

p_j = profit per bag of feed type

q_{ij} = quantity of feed constituent (kg) per bag of feed per period, where i = 1,2,3…m

Q_i = maximum available quantity of ingredients for feeds production

The objective function is to maximize the total profit 'P' of the product per period, i.e.

Maximize;

$$P = \sum_{j=1}^{n} p_j x_j$$

For j = 1, 2, 3… n , where P is the overall profit to be maximized. If the maximum usage of the constituents $C_1, C_2, C_3 \ldots C_m$ is $Q_1, Q_2, Q_3, \ldots, Q_n$, then the constraints that restrict (limit) constituents usage, i.e ,the constituent restrictions are expressed as

$$\begin{bmatrix} \textit{consumption of a constituent} \\ \textit{in the production of} \\ \textit{feeds per period} \end{bmatrix} \leq \begin{bmatrix} \textit{maximum quantity} \\ \textit{of ingredients available} \\ \textit{for production per period} \end{bmatrix}$$

,

The consumption of constituent C_1 by starter feed = $q_{11}x_1$ kg per bag

The consumption of constituent C_1 by grower feed = $q_{12}x_2$ kg per bag

The consumption of constituent C_1 by layer feed = $q_{13}x_3$ kg per bag

The consumption of constituent C_1 by chick feed = $q_{14}x_4$ kg per bag

The consumption of constituent C_1 by broiler feed = $q_{15}x_5$ kg per bag

Hence consumption of constituent C_n by the types of feeds is;

$$q_{n1}x_1 + q_{n2}x_2 + q_{n3}x_3 + q_{n4}x_4 + q_{n5}x_5 \quad (1)$$

If the maximum usage of constituent C_n is Q_n, then the constraint that limits the constituent usage is expressed as;

$$q_{n1}x_1 + q_{n2}x_2 + q_{n3}x_3 + q_{n4}x_4 + q_{n5}x_5 \leq Q_n \quad (2)$$

These constraints are expressed as;

$$\textstyle\sum_{j=1}^{n} q_{ij}x_j \leq Q_i$$

For i= 1,2,3, …, m and j = 1 ,2, 3, …, n

The complete LP model for the optimization of the feed production is therefore presented as

Maximize; $$P = \sum_{j=1}^{n} p_j x_j$$

Subject to;

$$\sum_{j=1}^{n} q_{ij}x_j \leq Q_i$$

$x_j > 0$ (Non-negative condition)

The above sets of summarized equations are used to formulate the practical and workable mathematical model for the surveyed. Each of the alphabetical parameters is represented by the real variables gathered from the company.

2.2 Model Simplification

Two basic methods by which LP models can be simplified are graphical and simplex methods. The graphical method can handle LP models with two (2) decision variables, however when the decision variables are more than two (2), simplex method is to be employed to simplify such LP models. Thus, in this study, a multi-decision variable model has been developed and a simplex method was employed to simplify the model. A solver add-in in Microsoft excel which works based on simplex method algorithm was used to solve the formulated LP model to yield the values of the decision variables that would maximize the objective function

2.3 Case Study

In the course of this study, data were gathered from a feed mill in Lagos State, Nigeria for model validation. The feed mill, located at the outskirts of Orile-Agege in Lagos State, is one of the leading producers of feeds for livestock and poultry in Nigeria. It produces feeds with different feed ingredients combined by experts who have done extensive research into animal feeds and development. Having considered possible constituents to blend for making the starter, grower, finisher, boiler and layers feeds, the feed constituents and their contribution per kg in the feed mill are given in Table 1.

2.4 Computation Procedure of the Feed mill A

Maximize

$P = 20x_1 + 34x_2 + 35x_3 + 40x_4 + 34x_5$

Subject to:

$$10.56x_1 + 4x_2 + 3x_3 + 7.9x_4 + 4x_5 \leq 1000$$

$$9.8x_2 + 4x_3 + 4.78x_4 + 2.43x_5 \leq 1700$$

$$6.825x_1 + 5x_2 + 5x_3 + 5.308x_4 + 4.7725x_5 \leq 2340$$

$$2.41x_1 + 2x_2 + 0.7x_3 + x_4 + 1.9164x_5 \leq 2300$$

$$0.41x_1 + 5x_2 + 2.06x_3 + 1.3x_4 + 1.5x_5 \leq 466$$

$$0.0518x_1 + 0.0625x_2 + 0.0625x_3 + 0.051x_4 + 0.04791x_5 \leq 564$$

$$0.04x_1 + 0.02x_2 + 0.89x_3 + 0.0204x_4 + 0.01916x_5 \leq 234$$

$$0.0301x_1 + 0.003x_2 + 0.02x_3 + 0.0196x_4 \leq 244$$

$$0.4015x_1 + 0.005x_2 + 0.6025x_3 + 0.4083x_4 + 0.05x_5 \leq 245$$

3. Results and Discussion

3.1 Result Testing

The feed mills have varying values of constituent depending on the formulation of the feed to be produced. The various values were input in the excel spreadsheet and the simplex method. The results are given in a tabular form by the excel spreadsheet. The initial values of the projection of the feed mill are as follow:

Bags of Starter mash to be produced in a day = 14 bags
Bags of Grower mash to be produced in a day = 18 bags
Bags of Layer mash to be produced in a day = 90 bags
Bags of Chick mash to be produced in a day = 4bags
Bags of Broiler finisher mash to be produced in a day = 100bags
The projected profit for this production combination is = N 7602

The daily combination of this objective function i.e. the total profit is optimized with the use of the spreadsheet and results are given in Tables 2-4. Table 2 shows the initial number of bags to be produced as outlined, the optimized number of bags, and quantity of constituents which is combined for the production of each type of feed. The combination of these ration states how effective the production would be and the various constituents have their basic contribution to the optimal result. Table 3 presents the report of the optimized values of poultry feeds production. The optimized value from the combination of projected production of the various types of bags increased from the original value of N 7,602 to final value of N9, 424.59. Adjustable cell also shows the variation in the initial number of bags being produced and the final (optimized) number of bags. The constraint part of Table 3 indicates that corn and limestone have zero slack values, i.e., they are binding. This means these ingredients are critical in the feeds production. Result also indicates that only the contribution of the Layer mash and Broiler finisher production gave the optimal profit, with all other types of feeds having negligible contribution to the overall optimized profit. The implication of the findings is that the feed mill needs to encourage the consumption of Layer mash and Broiler finisher.

Table 1: Constituents' Contribution in the Feed Mill

CONSTITUENTS	Quantity required per unit of feed (KG) STARTER MASH	GROWER MASH	LAYER MASH	CHICK MASH	BROILER MASH	Maximum available quantity
CORN	10.5600	4.0000	3.0000	7.9000	4.0000	1000
SOYAMEAL	0.0000	9.8000	4.0000	4.7800	2.4300	1700
WHEAT OFALS	6.8250	5.0000	5.0000	5.308	4.7727	2340
BONE MEAL	2.4100	2.0000	0.7000	1.0000	1.9164	2300
LIMESTONE	0.4100	5.0000	2.0600	1.300	1.5000	466
SALT	0.0518	0.0625	0.0625	0.0510	0.0479	564
METAOLINE	0.0400	0.0200	0.8900	0.0204	0.0192	234
LYSINE	0.0310	0.0030	0.0200	0.0204	0.0192	244
FISH MEAL	0.4015	0.0050	0.6025	0.4083	0.0500	245
PROFIT/BAG OF FEEDS N	20	34	35	40	34	

Table 2: The Optimized Values of Contribution of the Constituents

	STARTER MASH	GROWER MASH	LAYER MASH	CHICK MASH	BROILER FINSHER				
Bags qnty to produce (Kg)	0	0	97.32620321	0	177.0053476				
								OBJ FUNCTION	
Profit (#)	20	34	35	40	34			9424.59893	
			Product Blend						
	STARTER	GROWER	LAYER MASH	CHICK MASH	BROILER MASH		QUANTITY USED	AVAILABLE IN STOCK	
INGREDIENT (Kg)									
Corn	10.56	4	3	7.9	4		1000	1000	
Wheat Ofals	6.825	5	5	5.308	4.7727		1331.424439	2340	
Soya Bean	0	9.8	4	4.78	2.43		819.4278075	1700	
Bone Meal	2.41	2	0.7	1	1.9164		407.3413904	2300	
Limestone	0.41	5	2.06	1.3	1.5		466	466	
Salt	0.0518	0.0625	0.0625	0.051	0.04791		14.5632139	564	
Metaioline	0.04	0.02	0.89	0.0204	0.01916		90.01174332	234	
Lysine	0.0301	0.003	0.02	0.0204	0.01916		5.337946524	244	
Fish meal	0.4015	0.005	0.6025	0.4083	0.05		67.48930481	245	

Table 3: Answer Report of the Optimized Values of Production

Microsoft Excel 12.0 Answer Report
Worksheet: [Book1]Sheet1
Report Created: 2/14/2012 7:19:40 AM

Target Cell (Max)

Cell	Name	Original Value	Final Value
$I$4	Profit (#)	7602	9424.59893

Adjustable Cells

Cell	Name	Original Value	Final Value
$B$2	Bags qnty to produce (Kg) STARTER	14	0
$C$2	Bags qnty to produce (Kg) GROWER MASH	18	0
$D$2	Bags qnty to produce (Kg) LAYER MASH	90	97.32620321
$E$2	Bags qnty to produce (Kg) CHICK MASH	4	0
$F$2	Bags qnty to produce (Kg) BROILER FINSHER	100	177.0053476

Constraints

Cell	Name	Cell Value	Formula	Status	Slack
$H$9	Corn	1000	$H$9<=$I$9	Binding	0
$H$10	Wheat Ofals	1331.424439	$H$10<=$I$10	Not Binding	1008.575561
$H$11	Soya Bean	819.4278075	$H$11<=$I$11	Not Binding	880.5721925
$H$12	Bone Meal	407.3413904	$H$12<=$I$12	Not Binding	1892.65861
$H$13	Limestone	466	$H$13<=$I$13	Binding	0
$H$14	Salt	14.5632139	$H$14<=$I$14	Not Binding	549.4367861
$H$15	Metaioline	90.01174332	$H$15<=$I$15	Not Binding	143.9882567
$H$16	Lysine	5.337946524	$H$16<=$I$16	Not Binding	238.6620535
$H$17	Fish meal	67.48930481	$H$17<=$I$17	Not Binding	177.5106952
$B$2	Bags qnty to produce (Kg) STARTER	0	$B$2>=0	Binding	0
$C$2	Bags qnty to produce (Kg) GROWER MASH	0	$C$2>=0	Binding	0
$D$2	Bags qnty to produce (Kg) LAYER MASH	97.32620321	$D$2>=0	Not Binding	97.32620321
$E$2	Bags qnty to produce (Kg) CHICK MASH	0	$E$2>=0	Binding	0
$F$2	Bags qnty to produce (Kg) BROILER FINSHER	177.0053476	$F$2>=0	Not Binding	177.0053476

Table 4 presents the report of the sensitivity analysis which provides basic information about optimized quantity of bags required to yield maximum profit. Information provided re-affirmed that increase in the production of grower mash and broiler finisher mashes are highly significant for profit to be maximized. The Lagrange multiplier signifies the criticality of corn and limestone in the production of feeds as their usage have hit the maximum quantity available in stock.

4. Conclusion

This study used the LP approach to optimize the production of poultry feed types while considering blends of feed ingredients, with an optimal diet from a menu of possible sources. The blends met the minimum requirement on ingredients such as corn, wheat ofals, soya bean, bone meal, limestone, salt, metaioline, lysine, and fish meal, without exceeding maximum levels of its requirement and the content in each type of feeds .

Table 4: Sensitivity Report

Microsoft Excel 12.0 Sensitivity Report
Worksheet: [Book1]Sheet1
Report Created: 2/14/2012 7:19:41 AM

Adjustable Cells

Cell	Name	Final Value	Reduced Gradient
$B$2	Bags qnty to produce (Kg) STARTER	0	-33.69047103
$C$2	Bags qnty to produce (Kg) GROWER MASH	0	-35.56150501
$D$2	Bags qnty to produce (Kg) LAYER MASH	97.32620321	0
$E$2	Bags qnty to produce (Kg) CHICK MASH	0	-10.25827468
$F$2	Bags qnty to produce (Kg) BROILER FINSHER	177.0053476	0

Constraints

Cell	Name	Final Value	Lagrange Multiplier
$H$9	Corn	1000	4.689839339
$H$10	Wheat Ofals	1331.424439	0
$H$11	Soya Bean	819.4278075	0
$H$12	Bone Meal	407.3413904	0
$H$13	Limestone	466	10.16042843
$H$14	Salt	14.5632139	0
$H$15	Metaioline	90.01174332	0
$H$16	Lysine	5.337946524	0
$H$17	Fish meal	67.48930481	0

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