APPLICATION OF LINEAR PROGRAMMING AS AN INNOVATION IN FEED FORMULATION FOR GLOBAL COMPETITIVENESS IN POULTRY FARMING

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Abstract

Nutrition is of critical importance in the rearing of commercial layers. As such, this paper provides an insight to the formulation of layers feed at a least cost. The paper initially exploits Linear programming techniques and later extended to elastic programming. A combination of five different locally sourced feed ingredients were used as major decision variables with nine constraints. The Optimum solution of the proposed model was obtained at the ninth iteration and it reflects N76.64 reduction of the total cost per bag (25kg) compared with the existing feed formulation of the local Farm under study.

Keywords: *Linear programming, elastic programming, Optimum solution, formulation, layers.*

Introduction

Poultry farmers in most cases are faced with the decision relating to the type of feed formation under limited resources without jeopardizing the dietary nutrient requirement of their birds.

Linear programming has a fractional solution to the management of limited resources faced by these farmers. The development of linear programming (LP) and its application have made a considerable impact on agricultural research in recent years. LP was first introduced to the livestock compound feed formulation in the mid-fifties. Since then, its application in optimum formulation of feed for livestock has gained tremendous attention. Least cost feed formulation for poultry in Nigeria on the other hand is a recent innovation which has not been fully exploited. There are still many gaps in our knowledge of LP regarding poultry nutrition and digestibility. This work made an attempt to fill the gaps by employing LP techniques. In this paper, layers feed has been used as a case study to evaluate the effectiveness of this techniques in reducing feeding cost The cost of feed significantly contributes to the profitability of poultry industry and has been estimated to constitute 60-80% of the total cost (Webster, 1993; Rose, 1997). Therefore, any method of computing low cost feeds is really of great importance. Linear programing is one of such methods which has been widely used in the developed countries such as USA, UK, Canada and others. Application of this method is hoped to encourage both commercial and subsistence farmers to adopt LP in the development of low-cost feeds for their birds

Modern poultry feed formulations are formulated under nutrient specification, which changes as more advances are made in poultry. Nutrient specification may include minimum or maximum level of nutrients. The ingredients in the formulation of poultry feed differ in content and importance in poultry diet. These ingredients both locally and internationally sourced fall within the classification based on the nutrients of which they have imperative content. Some researchers have highlighted the nutrients which are very crucial in formulation of poultry feed such as metabolizable energy, crude protein, crude fibre, fats and oil, vitamins, amino-acids and minerals (Kekeocha, 1984; Parr, 1988; Pond et al, 2005; and Godfrey et al, 2016).

It is not the intent of this paper to discuss poultry feed formulation in the content of foreign feed ingredient. Rather an attempt is made in the context of optimizing the quantity of some locally selected feed ingredient such as maize, soya beans meal (SBM), wheat offal’s, bone meal (BM) and limestone in order to minimize the cost of feed formulation. The cost of these ingredients was obtained from the local feed millers in Yewa community of Ogun State.

To provide a more realistic model that will blend price and ingredient availability, a case study is used in the western part of Nigeria, where poultry business is developing at a rapid pace and where availability of a fairly wide selection of feed ingredients permits the realistic model of LP.

Literature Review

Vast literature of different approaches exists to minimize the cost of feed formulation. Researchers have engaged several mathematical techniques to provide solution to poultry feed formulation such as trial and error, Pearson's square method, goal programming, multi objectives goal programming, quadratic programming, nonlinear programming, pure integer programming, mixed integer programing and linear programming.

Wagner and Stanton (2014), used the Pearson's square method to balance animal rations. They found the nutritional requirement of an animal for a specific nutrient using Pearson's square. Short comings of this method is that it cannot handle a situation where ingredients are many. A weighted goal programing DASH diet model that minimizes the daily cost of the DASH eating plan as well as deviations of the diet nutrients content from the DASH diets tolerable to intake levels was presented by (Iwuji and Agwu, 2017).

In the thesis developed by Efeduma (2016). He determined the optimal feed mix of broiler starter and finisher at least cost using linear programing technique. He used 10 feed ingredients and solved using an excel solver application to obtain optimal feed mix.

Oladokun and Johnson (2012), developed an optimization feed formulation model, using locally available feed ingredients, for the Nigeria poultry industry. They also carried out the sensitivity analysis to take a position on their model and the existing method on the farm under study.

Olorunfemi (2007), in his classical use of linear programming approach to least cost ration formulation for poultry, used a computer-based technique to investigate, analyse and indicate how best the available local ingredient can be combined effectively to formulate least cost ration for poultry. He concluded that utilization of diet containing fillers at 7.94% is cost effective and reduce cost of feeding by as much as 24.95%.

Samuel et al (2015). These authors employed linear programing to propose optimal formulation of the LP model which gives about 7.48% and 9.96% reduction in feed formation costs compared to the existing formulation in case of broiler starter and finisher. The proposed model also reduced the amount of fat contained in the existing ration but adding more flesh by significantly increasing the metabolizable energy needed for physiological structure of the birds.

Piyaratne, et al (2012). In their study, they focused on the development of linear model based software with inclusion of digestible amino acid for least cost poultry ration formulation. Their model yielded ration with equalizing major nutrients requirement at the average inclusion level of commercial lysine 0.05% and methionine 0.02%. They realized that equal nutrient requirement gave up to 12 major nutrients with ideal amino acid profiles.

Godfrey, et al (2016), employed mixed integer programming to poultry feed ration optimization using the bat algorithm. In their research, they used findings of previous research to investigate the effects of moringa oleifera inclusion in poultry feed ration using the bat algorithm to obtain the optimum solution.

Nabasirye, et al (2011), demonstrated how to formulate a least cost diet using linear programming and discussed extensively the importance of proper interpretation of the sensitivity report on micro Excel solver output format.

Zhang and Roush (2002), applied a multiple objective programming (MOP) to the feed formulation process with the objectives of minimizing nutrient variance and minimizing ration cost. Where 21 ingredients with 17 nutrients were included in the formulation. They concluded that MOP model is more flexible in providing appreciable solution than a traditional feed formulation.

Aim

To obtain an optimum layer feed mix using local ingredients at minimum cost.

Objectives

1. To identify commonly used local ingredient at prevalence prices.
2. To determine percentage of various nutrients composition in each ingredient, Using Pearson's square method.
3. To develop a linear programming model that will satisfy necessary nutrient requirement of laying birds.
4. To extend the LP model to elastic programming to obtain a feasible solution.
5. Justify the proposed model with the existing formulation of the experimental farm.

Methodology

If the feasible region is a subset of the non-negative portion of Rn, define by linear equation and inequalities, and the objective function to be minimized or maximized is linear, then we have a linear programming problem (Meyer, 1985). Therefore, a linear programming is the problem of maximizing or minimizing a linear function subject to a limited number of linear constraints. Such that:

$$Min/Max\ \sum_{j=1}^{n} c_j x_j$$

Subject to

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

With $x_j \geq 0$ for i = 1,2 …………m

j = 1,2 ……………….n

Where x_j are the decision variable

c_j is the co-efficient of the objective function

a_{ij} is the co-efficient of the constraints.

bi is the boundary associated with the constraints.

Mathematical Formulation of the Model

With the nine constraints imposed on five set of local ingredients, and the nutrient requirement to be met, the following assumptions are made:

1. All ingredients into the ration are infinitely divisible.
2. All the coefficients are known with certainty.
3. The total of all activities equals the sum of individual activities.

Mathematically, in algebraic terms our model has the form below:

$$Minimize\ (Z) = \sum_{j=1}^{n} c_j x_j \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots . (i)$$

Subject to

$$\sum_{j=1}^{n} a_{ij}x_j \geq (\leq, =) b_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(ii)$$

$$\sum_{j=1}^{n} x_j = q \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(iii)$$

$$l_i q \leq \sum_{j=1}^{n} a_{ij}x_j \leq u_i q \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(iv)$$

$$x_j \geq 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(v)$$

Where Z is the total cost of the feed per bag.

C_j is the cost of ingredient j.

x_j is the quantity of ingredient j.

a_{ij} is the quantity of nutrient *i* in ingredient j.

bi is the required amount of nutrient *i* in the feed.

q is the weight value of the feed.

l_i is the lower limits of nutrient *i* in a bag of the feed

u_i is the upper limits of nutrient in a bag of the feed.

The inclusion of (iv) is necessary because we need to set an upper limits due to undesirable characteristics or simply to avoid unevenness of nutrients especially if this nutrient costs less than other nutrients and lower limits due to some desirable characteristics.

The model is designed to consider five selected locally sourced ingredients maize (yellow), soya beans meal (SBM), wheat offal, bone meal (BM) and limestone, constrained with the nutrient requirement namely, crude protein, metabolizable energy, ether extract(oil), crude fibre, lysine, methionine, calcium and available phosphorus.

The case study farm “Morac farms Ltd”, Ogun- state, Nigeria, has an existing layers feed formulation of 25kg per bag. 13kg of maize, 5.5kg of SBM, 3.5kg of wheat offal, 1kg of BM and 2kg of limestone. Since the inclusion per bag of amino acids like lysine, methionine, premix (vitamins) and salt (minerals) are of regulatory use, they are all exempted from the model. The various nutrient level composition of each ingredient is obtained by Pearson's square method in the table 1.

Decision variables:

Let x_1 be one unit of the quantity of yellow maize.

Let x_2 be one unit of the quantity of SBM.

Let x_3 be one unit of the quantity of wheat offal.

Let x_4 be one unit of the quantity of BM.

Let x_5 be one unit of the quantity of limestone.

Table 1: Derived nutrient composition of existing feed formulation

Ingredient	Price #(kg)	Quantity (kg)	Crude Protein%	Energy ME Kcal	Ether Extract %	Crude Fibre %	Lysine %	Methionine %	Calcium %	Available Phosphorus %
Maize (yellow)	100	13	5.2	1785.7	20.8	0.04	0.13	0.09	0.05	0.05
SBM	152	5.5	9.24	594	0.77	0.43	0.62	0.13	0.04	0.13
Wheat offal	54	3.5	2.38	261.8	0.49	1.00	0.13	0.04	0.01	
BM	65	1							1.48	0.6
Limestone	30	2							2.8	

The information in table 1 together with nutrient requirement can thus be expressed in LP form as given below:

$Min(z)= 100x_1 + 152x_2 + 54x_3 +65x_4 + 30x_5.$

subject to

$x_1 + x_2 + x_3 + x_4 + x_5 = 25$ (demand requirement)

$5.2 x_1 + 9.24 x_2 + 2.38 x_3 \geq 16.5$ (crude protein)

$1785.7x_1 + 594x_2 + 261.8x_3 \geq 2530$ (metabolizable energy)

$20.8x_1 + 0.77x_2 + 0.49x_3 \geq 3.7$ (Ether extract)

$0.04x_1 + 0.43x_2 + 1.00x_3 \leq 6.5$ (Crude fibre)

$0.13x_1 + 0.62x_2 + 0.13x_3 \geq 0.7$ (Lysine)

$0.09x_1 + 0.13x_2 + 0.04x_3 \geq 0.27$ (Methionine)

$0.05x_1 + 0.04x_2 + 0.01x_3 + 1.48x_4 + 2.8x_5 \geq 3.5$ (Calcium)

$0.05x_1 + 0.13x_2 + 0.6x_4 \geq 0.45$ (Available Phosphorus)

With $x_1, x_2, x_3, x_4, x_5 \geq 0$

The following upper and lower limit are also imposed on the ingredient (kg)

x_1 is between 13-12kg

x_2 is between 6-5kg

x_3 is between 5- 3.5kg

x_5 is between 2- 2.5kg

Cost Analysis of Existing Feed Formulations

Table 2: Quantity and Cost of Existing Layers Feed

Ingredient	Quantity(kg)	Cost/kg(#)	Cost of ingredient
Maize	13	100	1300
SBM	5.5	152	836
Whaetoffal	3.5	54	189
BM	1	65	65
Limestone	2	30	60
Total	25		2450

Source: Morac Farms Nig. Ltd, Ogun State

Table 3a: Nutrient composition of existing formulation.

Nutrient	Composition
Crude Protein	16.82
Energy	2641.5
Ether (oil)	3.34
Crude Fibre	1.47
Lysine	0.88
Methionine	0.26
Calcium	4.38
Phosphorus	0.78

Table 3b: Nutrient composition of LP Formulation.

Nutrient	Composition
Crude Protein	16.1
Energy	2562.98
Ether (oil)	3.28
Crude Fibre	3.61
Lysine	0.82
Methionine	0.25
Calcium	3.56
Phosphorus	0.77

Analysis and Discussion

The proposed model in this paper was initially not feasible until when we extended the LP model to elastic programing model. The extended model was then solved by TORA package. The optimum solution of the model is obtained as #2,373.19, with 12.66kg of maize, 5.00kg of SBM, 3.84kg of wheat offal, 1kg of BM and 2.5kg of limestone. This ration meets all the nutritional requirement needed for layers. The following tables make a comparison of the results of the model and the existing trial and error formulation of the farm under study.

Table 4: Cost Implication of Existing and LP Formulation

Ingredient	Cost per kg (#)	Quantity(kg)	Cost(#)	Quantity(kg)	Cost(#)
MAIZE	100	13	1300	12.66	1266
SBM	152	5.5	836	5	760
WHEAT OFFALS	54	3.5	189	3.84	207.36
BM	65	1	65	1	65
LIMESTONE	30	2	60	2.50	75
TOTAL		25	2,450	25	2,373.36

Conclusion

The model developed has been successful in reducing the total cost of producing 1 bag of layers mash by #76.64 with appreciable increase in the minimum nutrient requirement. The model also proposed the inclusion of 12.66kg of maize, 5kg of SBM, 3.84kg of wheat offal, 1kg of BM and 2.5kg of limestone.

This is really significant when considered at a larger capacity. Morac farms consumes an average of 25 bags per day, which implies that, if the farm adopts the proposed model formulation, the farm will be able to save #1,916 per day on feed consumption. The optimum solution obtained in this study shows that utilization of LP in feed formulation is of great economic importance and this will surely increase profitability in poultry industry

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APPENDIX

NUTRIENT LEVELS OF FEED INGREDIENTS

	INTREDIENTS (DM) %		CRUDE PROTEIN	ENERGY MEK	ETHER EXTRACT	CRUDE FIBRE	LYSINE	METHIONNE	CALCIUM	PHOSPHORUS (AVAILABLE)
			%	Kcal	%	%	%	%	%	%
A	**CARBOHYDRATE**									
1	MAIZE(YELLOW)	88	10	3434	4.00	2.00	0.25	0.18	0.01	0.09
2	GUINEACORN	89	11	3300	3.00	2.00	0.35	0.10	0.04	0.32
3	MILLET	88	10	2560	4.00	8.00	0.04	0.18	0.02	0.10
4	MAIZE OFFALS	100	11	2500	2.80	12.00	0.25	0.18	1.01	0.09
5	SORGHUM OFFAS	100	9	2700	5.00	6.00	0.25	0.18	0.10	0.09
6	WHEAT	95	11.50	3060	2.00	1.00	0.33	0.18	0.02	0.06
7	MOLASSES	75	3.0	1960	0.10		0.50	0.01		
8	CASSAVA MEAL	90	2.5	3400	0.50	3.50	0.07	0.03	0.20	0.03
9	SORGHUM	97	9.50	3250	3.00	1.75	0.23	0.15	0.03	0.09
B	**PROTEIN**									
1	MORESON FFS	90	42	3300	17.00	4.50	2.80	0.65	0.20	0.50
2	MORE SOYA CAKE	90	48	2300	6.00	4.25	2.80	0.60	0.02	0.60
3	GROUNDNUT CAKE	92	45	2640	6.0	5.00	1.60	0.48	0.02	0.60
4	SOYABEAN MEAL	90	42	2700	3.50	6.50	2.80	0.59	0.20	0.30
5	SUNFLOWER MEAL	89	37	1914	1.00	18.00	1.60	1.30	0.50	0.30
6	COTTONSEED MEAL	91	25	2146	9.00	25.00	1.15	0.04	0.25	0.03
7	RAPESEED MEAL	91	32	2178	1.80	13.00	2.00	0.60	0.70	0.25
8	FISHMEAL	92	65.72	2860	4.50	1.00	4.50	1.80	6.10	3.00
9	BLOODMEAL		78	2168	1.3	2.4	5.99	0.91	0.27	0.26
10	MILK POWER	94	26	2908	0.50	0.00	2.50	0.90	1.25	0.20
11	MEATMEAL	92	55	1750	4.80	2.00	2.60	0.75	8.50	0.90
12	SHRIMP	90	31	1680	4.9	7.2	1.54	0.57		
13	BREWERS YEAST	93	30	2420	1.00	3.00	3.40	0.70	0.10	0.46

14	CHAD FISH	90	25	2527	19.58	4.98	3.80	1.50	2.89	0.37
C	**FIBRE**									
1	BREWES DRIED GRAIN	90	18	1980	600	20.00	0.90	0.40	0.20	0.16
2	WHEAT OFFALS	89	17	1870	3.50	8.50	0.90	0.25	0.10	0.00
3	CORN OFFALS	100	11	2500	2.8	12.0	0.25	0.18	0.01	0.09
4	PALM KERNEL MEAL	88	18	2175	6.00	12.00	0.64	0.39	0.21	0.16
5	RICE BRAN	90	12	2860	12.50	12.50	0.50	0.24	0.04	0.46
6	RICE HUSK	92	4	1400	9.00	30.00				
D	**Minerals**									
1	OYSTER SHELL								38.00	
2	BONE MEAL								37.00	15
3	LIMESTONE								35.00	

Source: BOA Trading and Poultry Milling Company