

Modelling the feed mix for poultry production, the case of Adama Musa farms, in Ghana

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Abstract

The poultry industry has a significant importance on national economy. It is a popular industry for the small holders with tremendous contribution to Gross Domestic Product (GDP) and employment creation. Poultry feed cost represents over sixty (60) percent of the total cost of poultry production; consequently, efficient feed formulation practice is required for a sustainable poultry industry. Many Ghanaian poultry farmers, however, employ inefficient methods like rule of thumb, experiences, and intuition to handle feed formulation problem. This paper presents a deterministic linear programming model to solve blending problem facing poultry farmers, using locally available feed ingredients from the Ghanaian poultry industry. In the model, we shall minimize cost of producing a particular diet and maintain the ingredient. Over 3% reductions in the cost of producing broiler starter and finisher feed formulation compared to the existing method on the farm was achieved.

Keywords: Gross Domestic Product (GDP); Poultry Feed; Deterministic Linear Programming Model; Rule of Thumb; Blending Problem.

1. Introduction

With the exception of urban areas, most poultry production in Ghana is undertaken through the extensive farm system at the family level. This poultry provides a good source of protein and ready cash. The financial gains in turn help to sustain the family economy. However, this type of poultry production suffers from the constraints of feeding practice and overall production management, which normally increase the production cost unduly. The production cost, is normally affected by managerial cost, labour cost, inventory cost, transportation cost, cost of drugs, housing and electricity, feeding cost, etc. It has been reported that the feeding cost alone takes about sixty to seventy (60-70) per cent of the total production cost, which is of major concern to the local farmers, GPPR, [3] This situation obviously reduces the amount of animal protein the Poultry farmers could have produced for human consumption. The problem is recognized as optimizing cost factor, which depends on constraints (ingredients of the feed) and could be solved by Deterministic Linear Programming Model, (DLPM) or Mixed Integer Programming, (MIP).

Annett and Audsley [1] developed an MILP model to solve the problem of planning farming systems where environmental resources were declining. Their objective was to identify the best crop and machinery options which are profitable. This resulted in improvements of the environment, potential crop yields, and soil and farm profit.

Mohammed and Said [5] developed an LP crop mix model for a finite-time planning horizon. Given limited available resources such as budget and land acreage, the crop-mix planning model was formulated and transformed into a multi-period linear programming problem. The objective was to maximize the total returns at the end of the finite-time planning horizon.

The purpose of this paper is to do quantitative analysis of the poultry feed mix and thus develop a mathematical model for blending the poultry feed mix to minimize the feeding cost in the poultry production.

2. Linear programming and blending problem

A Linear Programming (LP) is one of the most widely used optimization techniques and perhaps the most effective. The term Linear Programming was coined by George Dantzig in 1947 to refer to problems in which both the objective function and constraints are linear as proposed by [2].

A Linear Programming is the problem of optimizing linear objective in the decision variables X_1, X_2, \dots, X_n subject to linear equality or inequality constraints on the X 's.

Standard form of Linear Programming is;

$$\text{Maximize } F = \sum_{j=1}^n C_j X_j \quad (1)$$

Subject to

$$\sum_{j=1}^n a(i, j) X_j = b_i, \quad i = 1, 2, \dots, n \quad (2)$$

$$l_j \leq X_j \leq u_j, \quad j = 1, 2, \dots, n \quad (3)$$

Where C_j are the n objective function. Coefficients, $a(i, j)$ and b_i are parameters in the m linear inequality constraints and l_j and u_j are lower and upper bounds with $l_j \leq u_j$. Both l_j and u_j may be positive or negative.

2.1. Blending problems

Blending problems arise whenever a manager is to decide how to combine two or more ingredients in order to produce one or more products. These types of problems occur frequently in the petroleum industry (such as blending crude oil to produce different octane gasoline) and the chemical industry (such as blending chemicals to produce fertilizers, weed killers), and so on. In these applications, managers should decide how much of each resource to purchase in order to satisfy product specifications and product demands at a minimum cost.

3. Formulation of LP model

Mathematical models were constructed for starter and finisher types of broiler ration using limited ingredients. The objective of the models was to minimize cost of producing a particular diet after satisfying a set of constraints. These constraints were mainly those from nutrient requirements of the birds and ingredient constraints by [6]. The variables in the models were the ingredients while the cost of each ingredient and the nutrient value of each ingredient was the parameter as described by [4]. The specified LP model for the attainment of the objective function is:

$$\text{Minimize } Z = \sum C_{ij} X_j$$

Where Z = Total cost of the ration, C_j = Ingredient cost, $j = 1, 2, 3, \dots, m$

X_i = Ingredients quantity, $i = 1, 2, 3, \dots, n$

Subject to

$$x_1 + x_2 + x_3 + \dots + x_8 = b_1$$

$$a_{11}x_1 + a_{12}x_2 + a_{13}x_3 + \dots + a_{18}x_8 \leq b_2$$

$$a_{21}x_1 + a_{22}x_2 + a_{23}x_3 + \dots + a_{28}x_8 \leq b_3$$

$$a_{31}x_1 + a_{32}x_2 + a_{33}x_3 + \dots + a_{38}x_8 \leq b_4$$

$$a_{41}x_1 + a_{42}x_2 + a_{43}x_3 + \dots + a_{48}x_8 \leq b_5$$

$$a_{51}x_1 + a_{52}x_2 + a_{53}x_3 + \dots + a_{58}x_8 \leq b_6$$

$$a_{61}x_1 + a_{62}x_2 + a_{63}x_3 + \dots + a_{68}x_8 \leq b_7$$

$$a_{71}x_1 + a_{72}x_2 + a_{73}x_3 + \dots + a_{78}x_8 \leq b_8$$

$$a_{81}x_1 + a_{82}x_2 + a_{83}x_3 + \dots + a_{88}x_8 \leq b_9$$

$$a_{91}x_1 + a_{92}x_2 + a_{93}x_3 + \dots + a_{98}x_8 \leq b_{10}$$

$$a_{101}x_1 + a_{102}x_2 + a_{103}x_3 + \dots + a_{108}x_8 \leq b_{11}$$

$$x_i \geq 0, i = 1, 2, 3, \dots, n$$

Where ai = Technical coefficients of nutrient components in feedstuffs, bi = Constraints of the ration.

Assumptions

The assumptions made in formulating the LP model include:

- i) All the projects and constraints are independent on one another.
- ii) Equal investment opportunities are assumed for the projects for each period.
- iii) The cash flows, resources and constraints are known with certainty.

4. Data collection and analysis

Secondary data were collected from the recommended nutrient requirements' schedule from Birds and Veterinary Service; Ghana limited for the study. Feedstuffs used in ration formulation for poultry farms in Dormaa Municipality include maize (x_1), soyaabeann (x_2), wheat bran (x_3), fish meal (x_4), lysine (x_5), concentrate (x_6), premix (x_7), cotton (x_8), oyster shell (x_9) and methionine (x_{10}). Cost implications of feedstuffs and nutrient levels of feed ingredients, constraints imposed on the selection of feedstuffs for broiler rations and least-cost formulation restrictions on nutrients were collated. Ten (10) decision variables and eight (8) constraints were identified and used for the LP model for least cost rations for broilers, (Tables 1, 2, 3, and 4).

Table 1: Cost Implications of Feedstuffs and Nutrient Levels of Feed Ingredients

Nutrients	Cost (GH₵)/ kg	Crude protein (%)	Fat (%)	Crude fiber (%)	Calcium (%)	Phosphorus (%)	Lysine (%)	Methionine (%)	Me (k/cal) (%)
x1	0.70	8.8	4.0	2.0	0.1	0.34	0.4	0.18	3432
x2	1.40	48	3.5	6.5	0.2	0.37	3.2	0.59	2557
x3	2.00	13	0	5.1	0.05	1.20	0.5	0.42	3153
x4	1.80	60	4.5	1.0	6.5	3.5	4.5	1.8	2950
x5	7.00	95	0	0	0	0	100	0	0
x6	2.60	12	0.25	4.75	1.50	1.50	0.2	0.15	1260
x7	3.00	0	0	0	0	0	0	0	0
x8	1.40	39.6	0	0	0.15	0.48	62.8	71.9	2350
x9	0.24	0	0	0	38	0	0	0	0
x10	5.00	60	0	0	0	0	0	10	0

Table 2: Constraint Imposed On the Selection of Feedstuffs for Starter Broiler Rations

Nutrients	Maximum level	Minimum level
Crude protein (%)	-	23
ME(Kcal/kg)	3200	2800
Calcium (%)	15	10
Phosphorus (%)	-	45
Fat (%)	50	-
Crude fiber (%)	50	-
Lysine (%)	-	11
Methionine (%)	-	5

Table 3: Constraint Imposed On the Selection of Feedstuffs for Finisher Broiler Rations

Nutrients	Maximum level	Minimum level
Crude protein (%)	-	18
ME(Kcal/kg)	3400	3200
Calcium (%)	25	10
Phosphorus (%)	-	55
Fat (%)	60	-
Crude fiber (%)	50	-
Lysine (%)	-	11
Methionine (%)	-	5

Table 4: Least-Cost Formulation Restrictions on Nutrients and Feedstuffs for Broiler Rations

Item	Starter stage	Finisher stage
Weight (kg)	1000	1000
Crude protein (%)	≤ 23	≤ 18
ME(Kcal/kg)	≤ 2800	≤ 3200
Calcium (%)	≥ 15	≤ 10
Phosphorus (%)	≤ 45	≤ 45
Fat (%)	≥ 50	≥ 60
Crude fiber	≥ 50	≥ 50
Lysine (%)	≤ 11	≤ 11
Methionine (%)	≤ 5	≤ 5

5. LP model implementation

The model is implemented in two ways:

- i) LP Model for least cost starter ration
- ii) LP Model for least cost finisher ration

5.1. Implementation of LP model for the least cost starter ration

Substituting the various ingredients in the tables 1 and 3 into the model, we have

$$\text{Min}(Z) = 0.7x_1 + 1.4x_2 + 2x_3 + 1.8x_4 + 7x_5 + 2.6x_6 + 3x_7 + 1.4x_8 + 0.24x_9 + 5x_{10}$$

Subject to:

$$x_1 + x_2 + x_3 + x_4 + x_5 + x_6 + x_7 + x_8 \leq 1000$$

$$8.8x_1 + 48x_2 + 13x_3 + 60x_4 + 95x_5 + 12x_6 + 39.6x_8 \leq 23$$

$$4x_1 + 3.5x_2 + 4.5x_3 + 0.25x_6 \leq 5$$

$$2x_1 + 6.5x_2 + 5.1x_3 + 1x_4 + 4.75x_6 \leq 5$$

$$0.1x_1 + 0.2x_2 + 0.05x_3 + 6.5x_4 + 1.5x_6 + 0.15x_8 + 38x_9 \leq 1.5$$

$$0.34x_1 + 0.37x_2 + 1.2x_3 + 3.5x_4 + 1.5x_6 + 0.48x_8 \leq 0.45$$

$$0.40x_1 + 3.2x_2 + 0.5x_3 + 4.5x_4 + 100x_5 + 0.2x_6 + 62.8x_8 \leq 1.51$$

$$0.18x_1 + 0.59x_2 + 0.42x_3 + 1.8x_4 + 0.15x_6 + 71.9x_8 + 100x_{10} \leq 0.5$$

$$3432x_1 + 2557x_2 + 3153x_3 + 2950x_4 + 1260x_6 + 2350x_8 \leq 2800$$

$$x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8, x_9, x_{10} \geq 0$$

Table 5: Solution to LP Model for Least Cost Starter Ration, Using Matlab Package

Decision variable	Variable solution	Unit Cost	Total Cost	Reduced Cost
Maize (x1)	517	0.70	361.90	-11.90
Soya bean (x2)	356.7	1.40	499.38	-219.38
Wheat bran (x3)	0	2.00	0.00	146.00
Fish meal (x4)	0	1.80	0.00	144.00
Lysine (x5)	1.40	7.00	9.80	-2.80
Concentrate (x6)	90.0	2.60	234.00	-52.00
Premix (x7)	1.00	3.00	3.00	0.00
Cotton (x8)	0	1.40	0.00	35.00
Oyster shell (x9)	32.7	0.24	7.85	4.15
Methionine (x10)	1.8	5.00	9.00	-4.00
Total Reduction Cost				39.07

From Table 5, the quantity of wheat bran, fish meal and cotton were reduced to zero (0kg) since almost the nutritional value they offer can also be found in the other ingredients (constraints). The quantity of maize, soya bean, lysine, concentrate and methionine were increased in order to supplement for the nutritional value that the wheat bran, fish meal and cotton would have offered. The quantity of oyster shell was reduced, and the quantity of premix was obtained in order to balance the nutritional level of the feed. This model reduces the feed cost by almost Gh ¢39.00.

5.2. Implementation of LP model for the least cost finisher ration

Applying the various ingredients in tables 1 and 3 into the LP model, yields

$$\text{Min}(Z) = 0.7x_1 + 1.4x_2 + 2x_3 + 1.8x_4 + 7x_5 + 2.6x_6 + 3x_7 + 1.4x_8 + 0.24x_9 + 5x_{10}$$

Subject to:

$$x_1 + x_2 + x_3 + x_4 + x_5 + x_6 + x_7 + x_8 \leq 1000$$

$$8.8x_1 + 48x_2 + 13x_3 + 60x_4 + 95x_5 + 12x_6 + 39.6x_8 \leq 21$$

$$4x_1 + 3.5x_2 + 4.5x_3 + 0.25x_6 \leq 6$$

$$2x_1 + 6.5x_2 + 5.1x_3 + 1x_4 + 4.75x_6 \leq 5$$

$$0.1x_1 + 0.2x_2 + 0.05x_3 + 6.5x_4 + 1.5x_6 + 0.15x_8 + 38x_9 \leq 1.5$$

$$0.34x_1 + 0.37x_2 + 1.2x_3 + 3.5x_4 + 1.5x_6 + 0.48x_8 \leq 0.45$$

$$0.40x_1 + 3.2x_2 + 0.5x_3 + 4.5x_4 + 100x_5 + 0.2x_6 + 62.8x_8 \leq 1.51$$

$$0.18x_1 + 0.59x_2 + 0.42x_3 + 1.8x_4 + 0.15x_6 + 71.9x_8 + 100x_{10} \leq 0.5$$

$$3432 x_1 + 2557x_2 + 3153x_3 + 2950x_4 + 1260x_6 + 2350x_8 \leq 3200$$

$$x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8, x_9, x_{10} \geq 0$$

Table 6: Solution to LP Model for Least Cost Finisher Ration, Using Matlab Package

Decision variable	Variable solution	Unit Cost	Total Cost	Reduced Cost
Maize (x1)	696.4	0.70	487.48	-46.48
Soya bean (x2)	84.9	1.40	118.86	91.14
Wheat bran (x3)	0	2.00	0.00	60.00
Fish meal (x4)	0	1.80	0.00	45.00
Lysine (x5)	0	7.00	0.00	17.50
Concentrate (x6)	168.7	2.60	438.62	-139.62
Premix (x7)	1.00	3.00	3.00	0.00
Cotton (x8)	0	1.40	0.00	5.60
Oyster shell (x9)	46.7	0.24	11.21	-1.61
Methionine (x10)	3.3	5.00	16.50	-0.50
Total Reduction Cost				31.03

From Table 6, the quantity of wheat bran, fish meal, lysine and cotton were reduced to zero (0kg) since almost the nutritional value they offer can also be found in the other ingredients (constraint). The quantity of maize, concentrate, oyster shell and methionine were increased in order to supplement for the nutritional value that the wheat bran, fish meal, lysine and cotton would have offered. The quantity of soya bean was reduced and the quantity of premix was obtained in order to balance the nutritional level of the feed. This model reduces the feed cost by almost Gh¢31.03.

5.3. Least cost starter and finisher rations compared with existing practice

The existing practices for both starter and finisher ration were compared with the mathematical model for both starter and finisher ration to see which one is more cost effective. The results were recorded in tables 7 and 8.

Table 7: Least Cost Starter Ration versus Existing Practice

Ingredient (x _j)	Cost (GH¢)/kg	Exiting practice		Proposed solution	
		Value (kg)	Cost (GH¢)	Value (kg)	Cost (GH¢)
Maize	0.70	500	350.00	517	361.90
Soya bean	1.40	200	280.00	356.7	499.38
Wheat bran	2.00	73	146.00	0	0.00
Fish meal	1.8	80	144.00	0	0.00
Lysine	7.00	1	7.00	1.4	9.80
Concentrate	2.60	70	182.0	90	234.00
Premix	3.00	1	3.00	1	3.00
Cotton	1.40	25	35.00	0	0.00
Oyster shell	0.24	50	12.00	32.7	7.85
Methionine	5.00	1	5.00	1.8	9.00
Objective function value		1001	1164.00	1000.6	1124.93

The cost of producing broiler starter feed is Gh ¢1164.00 using the existing practice of the farm compared with the Gh¢1124.93 if feed formulation is based on the proposed mathematical model. This gives a substantial savings of about 3.36%. Obviously feed formulation is more cost effective when based on valid Linear programming model.

Table 8: Least Cost Finisher Ration versus Existing Practice

Ingredient (x _j)	Cost (GH¢)/kg	Exiting practice		Proposed solution	
		Value (kg)	Cost (GH¢)	Value (kg)	Cost (GH¢)
Maize	0.70	630	441.00	696.4	487.48
Soya bean	1.40	150	210.00	84.9	118.86
Wheat bran	2.00	30	60.00	0	0.00
Fish meal	1.8	25	45.00	0	0.00
Lysine	7.00	2.5	17.50	0	0.00
Concentrate	2.60	115	299.00	168.7	438.62
Premix	3.00	1	3.00	1	3.00
Cotton	1.40	4	5.60	0	0.00
Oyster shell	0.24	40	9.60	46.7	11.21
Methionine	5.00	3.2	16.00	3.3	16.5
Objective function value		1000.7	1106.70	1001	1075.67

The cost of producing broiler finisher feed is Gh¢1106.70 using the existing practice of the farm compared with the Gh¢1075.67 if feed formulation is based on the proposed LP model. This results in substantial savings of about 2.80%. Feed formulation is more cost-effective than the existing farm practice.

6. Conclusions

The total reduction cost by the linear programming model for the least cost starter ration is Gh¢ 39.00 per ton representing 11% reduction in broiler starter feed formulations compared with the cost of the existing method on the farm. Whilst the total reduction cost by the linear programming model for the least cost finisher ration is Gh¢ 31.03 per ton representing 3% reduction in broiler finisher feed formulation.

Furthermore, the least-cost diet formulation produced by linear programming model showed that the starter ration consists of 51.7% maize, 35.67% soya bean, 0.14% lysine, 9% concentrate, 0.1% premix, 3.27% oyster shell and 0.18% methionine. This ration meets all the nutritional requirements needed for starter broiler. The cost of the ration is Gh¢1124.93 per ton.

For the finisher ration the results showed 69.64% maize, 8.49% soya bean, 16.87% concentrate, 0.1% premix, 4.67% oyster shell and 0.33% methionine ingredients. The cost of the ration is Gh ¢ 1106.70 per ton.

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