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Broiler Chicken Feed Mix Production Using a Non-Conventional Feed Resource (*Gliricidia sepium* leaf meal) in Ohawu, Ghana

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ABSTRACT

Globally, the poultry industry has a significant economic role, especially in Africa, where small farm holders contribute substantially to the national gross domestic product (GDP). Poultry feeding costs are rapidly increasing and account for over 60 percent of the production costs, but efficient feed formulation practices are a sustainable way of reducing the price. Ghanaian farmers use methods such as the rule of thumb, personal experience, and intuition to solve feed formulation problems. This study showed that the least-cost starter ration price decreased by 1.61%, and the least-cost finisher ration price decreased by 4.48%, indicating that non-conventional feed ingredients have a high economic value.

Keywords: Broiler chicken, Ghana, Modelling feed mix, Non-conventional feed resource, Production

Introduction

The livestock industry globally has become a business venture with ever-increasing challenges of high feed cost. This trend is evolving with respect to speedily yearning for obtaining products from livestock sources. In developed countries, the demand for products from livestock sources is dwindling which makes producers to be on the alert to do everything possible in order to cut down cost. The ever-growing human population, increased level of income and urbanization, have largely driven historical chances in demand for livestock products.

Livestock systems response differently to production and this is due to the active part science and technology plays as well as increased animal numbers. In the years to come expectations are that, increased production will largely affect high feed cost and hence the need to put the required proportion of feed ingredients together. Increasing ideas in breeding animals, their nutrition and above all animal health is a potential for increasing production and subsequently cause an increase in both efficiency and genetic gains. Globally, livestock production has experienced a galloping high feed cost. People demand made for products such as livestock in the years to come could highly be influenced by social and economic factors leading to human health issues and pricing livestock products.

The systems in livestock production occupy close to 30% of the planet's ice-free surface area of terrestrial (Steinfeld et al., 2006) as well as important global asset with $1.4 trillion value. The organization of the livestock sector is a long chain in the market, which employs nearly 1.3 billion people around the globe and provides livelihoods to 600 million deprived small-scale farmers in developing countries (Thornton et al., 2006). In most vulnerable rural communities worldwide, keeping livestock serves as a way to strategize for poverty reduction, which at the same time provides nutrition to the people and animal traction for preparing land in order to grow crops in peasant systems. Livestock products contribute seventeen (17) per cent to kilocalorie consumption, global protein consumption is about 33% however, differences between developed, and developing countries exist (Rose grant et al., 2009).

The systems of livestock comprise of the positive and negative effects on the resource base naturally, health of the public, societal equality and growth economically (World Bank, 2009). In recent times it is believed that, the production of livestock in the agricultural subsectors is the fast growing industry in countries experiencing poverty. Its share of agricultural Gross Domestic Product (GDP) is already 33% and is quickly increasing. This growth drives the increasing demand for livestock products; this demand has proven to drive growth in population, urbanizing and increase in incomes in countries that are developing (Delgado, 2005).

The global livestock sector has characteristics such as the difference in relation to countries developing and developed ones. Between 1980 and 2002, the total production of meat in the developing countries tripled, moved from 45 to 134 million tons (World Bank, 2009). In developed countries also, the production and consumption of livestock products is dwindling, even though the levels are high.

Some research quantify the maximum potential impact of locally-grown produce in terms of either reducing cost or maximizing the dietary contribution. However, this study uses a broader database and more precise data collection methods to make the measured results more consistent with the displayed situation (Ward, J.D, 2014).

Thus, producing livestock as well as marketing it in developed countries is up to 53 per cent of GDP in the agricultural sector (World Bank 2009). As the demand for livestock grows in countries that are developing as well as steady demand in developed countries, which serves a main chance for those who produce livestock in the developing world, where most often demands are met based on production locally, this is likely to be sustained in the near future.

This paper studies the problem of chicken feed ratio in Ohawu area. Using the method of Linear Programming, and data collected from Ohawu Agricultural College, nutrient requirement of poultry Ninth Revised Edition (200) and Veterinary directorate of MoFA-Ghana. And find out, the best ratio is, maize 59.23%, soybean meal 27.9%, wheat feed 8.78%, limestone 2.03%, vitamin premix 1%, lysine 0.11% and methionine 1.92%. The ration contained all the nutrition required of the broiler starter ration. The cost of the ration is about GH₵ 1228 per ton. The model saved about 1.61% per ton compare to the basic ration. The results of this study will have a positive impact on the chicken industry in the Ohawu area. Using the proportion of chicken feed in this study can reduce the cost of the chicken industry and enhance the competitiveness of the local chicken industry.

Materials and Methods

Definition and Standard forms of LP

For some decades now, feed producers formulate ration using shovels, buckets and weighing scale by way of mixing feed ingredient manually (also called trial and error method). In recent times, most feed industries have adapted computers in formulating diet to solve the problem of feed wastage. The formulation of feed involves the use of different feed ingredients by combining them to make sure that the ingredients provide the birds with proper amount of ingredients required at a particular stage of life. This practice needs people to acquire skill and knowledge pertaining to nutrients, feedstuff and nutritional requirement of birds to enable them grow well based on the adequacy of nutrient in their right proportion in order to cut down cost of production. Birds require rations that are palatable enough and at the same time not detrimental to them based on toxic effects. Nutrient requirements of birds depend on their class hence, the energy level, protein (amino acids), minerals and vitamins to enable the maintenance of various production function such as growth, reproduction and meat or egg production.

Current feed formulation for poultry, throws more light on the use of linear, quadratic and goal programming by the use of computer to formulate feed with least-cost. It has become very important for poultry producers to look for cheap alternatives sources of feed ingredient, which does not have any effect on feed quality, birds' growth performance including the economics of production. This leads to the quest to addressing price hikes of feed ingredients as a major problem for poultry producers and its scarcity. Gura, (2008) reported that, it is expected for food, feed and agro-fuels to compete especially some cereals and legumes leading to increase in the prices of poultry feed, pushing poultry producers to find alternative and locally available sources of feed. Dantzig, (1951a, b); Aletor, (1986) Ali and Leeson, (1995) indicated that, linear programming is one of the most needful techniques that are used to allocate available feed ingredients in a least cost broiler ration formulation.

For every given linear programming (LP) problem, termed the primal problem, there is a corresponding linear programming problem called the dual problem. It is clear that, linear programming problems take different forms such as; standard form, canonical form, general form etc. One important principle used in linear programming problem is that, the form of the dual problem depends on form of the primal problem.

Subsequently, an LP is in the standard form if its matrix representation is in the form

$$Max.\ C^T X \tag{1}$$

which means, it must be a maximization problem

S.t AX $\leq$ b, which means, only inequalities of the correct direction.

0 $\leq$ X, which means, that all variables must be non-negative.

In (1), the notations are expressed as X denoting the vector of variables (being determined), C and b being vectors of (known) coefficients, A as known matrix of coefficients and $(.)^T$ denoting the matrix transpose. The expression used as maximized or minimized on the other hand calls it the objective function. The inequalities expressed as the constraints specifying a convex polytope over which the objective function supposed to optimize.

It is indicative that every linear program converts to standard form

$$\begin{aligned} &Max\ C_1\chi_1 + C_2\chi_2 + \cdots + C_n\chi_n \\ &s.t\, a_{11}\chi_1 + a_{12}\chi_2 + \cdots + a_{1n}\chi_n = b_1 \\ &a_{1m}\chi_1 + a_{2m}\chi_2 + \cdots + a_{mn}\chi_n = b_n \\ &\qquad\qquad \chi_1 \geq, \cdots, \chi_n \geq 0 \end{aligned} \tag{2}$$

(2), is where the objective function maximizes, the constraints are inequalities and the variables are all non-negatives. This gives:

If the problem is min Z, convert it to max $-$Z.

If a constraint is $a_{i1}x_1 + a_{i2}x_2 + ... + a_n x_n \leq b_i$, adding a nonnegative slack variable Si in order to convert it to an equality constraint., the outcome of the constraint is $a_{i1}x_1 + a_{i2}x_2 + ... + a_n x_n + S_i \leq b_i$, given to be $S_i \geq 0$.

If a constraint is $a_{i1}x_1 + a_{i2}x_2 + ... + a_n x_n \leq b_i$, convert it into equality constraint by subtracting a nonnegative surplus variable Si. The resulting constraint is $a_{i1}x_1 + a_{i2}x_2 + ... + a_n x_n - S_i \leq b_i$, where $S_i \geq 0$.

In case variable x_j sign is unrestricted, it should be replaced everywhere in the formula by

$$\chi_j^{'} - \chi_j^{''} \tag{3}$$

Where $x_j' \geq 0$ and $x_j'' \geq 0$

Numerous approaches exist for tackling LP problems and these includes:

Simplex Algorithm

SQB Package

Graphical Method

YE'S Interior Point Agorithm

Micrsoft Excel 2003

Matlab Package

For convenience sake and use of effective technique, the best is to use the simplex algorithm and the researcher in the subsequent topics would explain this further.

Simplex Algorithm is an iterative procedure carried out systematically to determine the optimal solution from the set of feasible solutions. Firstly, to apply the simplex method, appropriate variables are introduced in the linear programming problem, and the primary or the decision variables equates to zero. The iterative process begins by assigning values to these defined variables. There is a consideration for the value of decision variables to equate to zero, because the evaluation in terms of the graphical approach begins with the origin. Therefore, x_1 and x_2 is equal to zero.

The decision maker will enter appropriate values of the variables in the problem and find out the variable value that contributes maximum to the objective function and removes those values, which give undesirable results. Thus, the value of the objective function improves through the use of this method. This procedure of substitution of variable value continues until any further improvement in the value of the objective function is possible.

The Standard Maximum Form for a Linear Program

The Simplex Method, which is the procedure we will use for solving linear programs, is easiest to explain for linear programs that are in a fixed format, we will call the standard form. A standard maximum problem is a linear program, which sets objective to maximize an objective function in the form:

$$\begin{aligned}
&Z= C_1\chi_1+C_2\chi_2+\cdots+C_n\chi_n \\
&a_{11}\chi_1+a_{12}\chi_2+\cdots+a_{1n}\chi_n \le b_1 \\
&a_{21}\chi_1+a_{22}\chi_2+\cdots+a_{2n}\chi_n \le b_2 \\
&\qquad , \\
&\qquad , \\
&\qquad , \\
&a_{m1}\chi_1+a_{m2}\chi_2+\cdots+a_{mn}\chi_n \le b_m \\
&Implaying\ that; \chi_1,\chi_2 \cdots \chi_n \ge 0 \\
&\text{and } b_j \ge 0 \text{ for } j=1,2\cdots,m
\end{aligned} \tag{4}$$

1) Characteristics of standard form for LPs

They are about maximizing, not minimizing.

They have a positivity constraint for each variable.

The other constraints are all of the form “linear combination of variables ≤ constant”

2) The Simplex Tableau

In setting out the simplex tableau or writing the objective function and the constraints in the table form (Table 1), add nonnegative slack variables Si to constraints. This helps to convert constraints into equations. The constraints take in the form:

$$\begin{aligned}
&a_{11}\chi_1+a_{12}\chi_2+\cdots+a_{1n}\chi_n = b_1 \\
&a_{21}\chi_1+a_{22}\chi_1+\cdots+a_{2n}\chi_n = b_2 \\
&\qquad , \\
&\qquad , \\
&\qquad , \\
&a_{m1}\chi_1+a_{m2}\chi_2+\cdots+a_{mn}\chi_n = b_m \\
&Implying\ that; \chi_1\chi_2 \cdots \chi_n = 0 \\
&\text{and } b_j \ge 0 \text{ for } j=1,2\cdots,m
\end{aligned} \tag{5}$$

Table 1. Chicken feed formulations

	C_j	C_1	C_2	···	Cn	0	0	···	0	
C_B	B.V.	x_1	x_2	···	x_n	S_1	S_2	···	Sn	RHS
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	0	0	···	0	0	0	···	0	0
	C_j-Z_j	C_1	C_2	···	Cn	0	0	0	0	

C_B is the objective function coefficient for each of the basic variables

Z_j is the value of the objective function that decreases to result in variable corresponding to the jth column of the matrix derived from the coefficients of the variables in the constraints to form the basis (a value of one variable is made a basic variable)

$C_j - Z_j$ is the net evaluation row, is the net change in the objective function value given a unit of the variable that corresponds to jth matrix column (derived from the variables coefficient in the constraints), is solved. From the $C_j - Z_j$ row, we locate the column that contains the largest positive number and this becomes the column of pivot. Each row divides the value in the RHS by the positive entry in the pivot column avoiding all zero or negative entries and the smallest one of these ratios gives the pivot row. The number at the pivot column intersects at pivot row giving the PIVOT.

The entries of that row in the matrix are then divide by the pivot and row operation introduced to reduce other entries in the pivot column, other than the pivot, to zero. Stopping criterion optimal solution with respect with the linear program problem are found when all figures entered in the net evaluation row ‘ $C_j - Z_j$ are all negatives or zeros. Minimizing the objective function is the standard form of LP problem comprise of a maximizing objective function. In addition, simplex method is however, adopted based on the standard form of LP problem. In a case where the problem is a minimization type, the objective function is multiplied through by -1 in order that the problem assumes maximization one.

$$Min\,F = -\,Max\,F \tag{6}$$

Type constraints is the LP problem containing ‘greater −than-equal-to (≥) this is written again in the standard form by subtracting non-negative surplus value from it:

$$a_1 x \geq b_1 \tag{7}$$

(4), is equated to $a_1x - S_1 = b_1$ and $S_1 \geq 0$, where s is described as surplus

Equality constraint is use when any of the constraint of the LP is of the form:

$$a_1\chi_1 + a_2\chi_2 + \cdots + a_n\chi_n = b \tag{8}$$

The single constraint is use to replace the following two constraints:

$a_{i1}x_1 + a_{i2}x_2 + ... + a_nx_n \leq b$ and $a_{i1}x_1 + a_{i2}x_2 + ... + a_nx_n = b$

With the use of sensitivity analysis Saltelli, Chan & Scott, (2009) indicated that, sensitivity analysis is a special type of analysis that helps in determining the sensitiveness of the optimal solution in context of changes in the data values while studying linear programming. Under the circumstances of misleading optimal solutions, the sensitivity analysis applies to the linear programming. In addition to this, there is the believed that, sensitivity analysis applies in linear programming under the condition when the values of optimal solutions are inaccurate. Furthermore, cases of cost changes where the value of cost changes by $\varkappa 1$ in the original problem and for this purpose addition of new variables is possible.

Mathematically, optimal answers to some extent can be trusted to real life imperfectly parameterized models is questionable. Some instances pertain to the usual occurrence of seasonal fluctuations in the price of feed ingredients. Rise in market price of feed ingredients during the rainy season are usual occurrences, which has the tendency to drop during the dry season when dry grains are in abundance. For that matter, it is possible to apply post optimality to the model in question.

$$Max.\ C^TX \quad \text{or } Min.\ C^TX \tag{9}$$

$$\text{S.t } Ax = b \qquad Ax = b \tag{10}$$

$$X \geq 0 \qquad X \geq 0 \tag{11}$$

Sensitivity analysis depends on the information made available to the researcher through the optimal simplex tableau. The tableau satisfies two conditions, the feasibility and optimality. In satisfying feasibility implies relation (10) and (11) method. To satisfy the optimality condition it calls for reducing cost g_i for all non-basic variables (that is the rate of change of objective function with respect to non-basic variables) are non-positive in the case of maximizing and non-negative when minimizing.

Application of Linear programming

This program applies to numerous fields of study. Business and economic fields use it a lot as well as the engineering fraternity. A number of industries use this program such as transportation, telecommunication, energy and manufacturing sector. It has played numerous roles in modelling different types of problems in planning, scheduling, routing, designs and assignments.

1) Proposed Linear Program Model

Linear programming is the use of computer method to select, allocate and evaluate limited resources with linear, algebraic constraints to arrive at optimal solution for a linear, algebraic objective function. It is applicable to an administrative and economic planning, transportation to maximize the linear functions of a numerous variable numbers, subject to certain constraints.

Patrick and Schaible, (1980) stated that, linear programming is technically a mathematical approach for deriving a value-weighting solution to a set of simultaneous equations. The variables in the model were the ingredients whereas the nutrient value of each ingredient was the parameter (Hillier and Lieberman, 1995). The LP model seeks specifically to attain the objective function:

$$\text{Minimize } Z = \sum CijXij \tag{12}$$

Subject to

$X_1 + X_2 + X_3 + ... + X_9 = b_1$

$a_{11}X_1 + a_{12}X_2 + a_{13}X_3 + ... + a_{18}X_8 \leq b_2$

$a_{21}X_1 + a_{22}X_2 + a_{23}X_3 + ... + a_{28}X_8 \leq b_3$

$a_{31}X_1 + a_{32}X_2 + a_{33}X_3 + ... + a_{38}X_8 \leq b_4$

$a_{41}X_1 + a_{42}X_2 + a_{43}X_3 + ... + a_{48}X_8 \leq b_5$

$a_{51}X_1 + a_{52}X_2 + a_{53}X_3 + ... + a_{58}X_8 \leq b_6$

$a_{61}X_1 + a_{62}X_2 + a_{63}X_3 + ... + a_{68}X_8 \leq b_7$

$a_{71}X_1 + a_{72}X_2 + a_{73}X_3 + ... + a_{78}X_8 \leq b_8$

$a_{81}X_1 + a_{82}X_2 + a_{83}X_3 + ... + a_{88}X_8 \leq b_9$

$a_{91}X_1 + a_{92}X_2 + a_{93}X_3 + ... + a_{98}X_8 \leq b_{10}$

$X_i \geq 0$, i=1, 2, 3, 4, ..., n

Where:

a_i = Technical coefficient of the components of nutrient in feedstuffs

b_i= ration constraints.

2) Assumptions of linear programming

Before one obtains a valid result from linear programming technique, the following assumptions must hold:

Linearity: (Dantzig, 1955), Additivity: (Dantzig, 1963), Divisibility, Non-negativity, Simple objective, Finiteness: (Gale et al., 1951),Certainty, Proportionality, External factors: (Harper and Lim, 1982; Taha, 1987; Wagner, 1989), Simplex algorithm: Harper and Lim (1982) stated that, the use of simplex technique happens when:

(a) two or more products are involved and

(b) two or more constraints operates, so that it is not possible to determine what product mix will cause cost minimization.

Remarks on assumptions; three assumptions exist for the feed formulation problem. Firstly, the nutrient requirements are assumed constants and independent of the final products (broiler) price.

Secondly, the quantity of each feed ingredient is certainty in the known. Finally, the diet assumes to be based on only feed cost and nutrients. Globally the diet problem suits most appropriately in formulating feed rations. Most animal nutritionist use a terminology “balancing of ration” and numerous software programs have been fashioned to determine least cost rations. Thomas et al, (1992) used LP to determine nutrient values in dairy production.

General Optimization Algorithm

1) Considering an iterate x^Z. Find the direction $\triangle x$ by solving the linear system

$$\nabla f(X^Z)\triangle X = -f(X^Z) \tag{13}$$

2) Find the step size a_Z

3) Update

$$X^Z \text{ to } X^{Z+1} = X^Z + \alpha_Z \triangle X \tag{14}$$

Definition of notations, ∇f is the derivative, gradient or Jacobean of the function f depending on the definition of the function f

Starting point, in choosing a starting point, we need two requirements. First the centrality of the point and second the magnitude of the corresponding infeasibility. These conditions are determined by solving two least squares problems, which seek to satisfy the primal and dual constraints

$$\min_{x} X^T x \; s.t \; Ax = b \tag{15}$$

$$\min_{y,x} S^T S \; S.t \; A^T y + s = C \tag{16}$$

Solutions to the problem,

$$\widetilde{X}=A^{T}(AA^{T})^{-1}b, \widetilde{y}=(AA^{T})^{-1}Ac, \widetilde{S}=c-A^{T}\widetilde{y} \tag{17}$$

There is a further consideration to shift the solution inside the positive orthant to derive the starting point:

$$W^{0}=(\widetilde{X}+\delta_{x}e, \widetilde{y}, \widetilde{S}+\delta_{x}e) \tag{18}$$

With δ_x and δ_s denoting positive quantities

Search direction takes the form $(\triangle x, \triangle y, \triangle z)$ and obtained by solving newton's equation:

$$\nabla f(x,y,z)\begin{bmatrix}\triangle x\\ \triangle y\\ \triangle z\end{bmatrix}=f(x^{z},y^{z},S^{z}) \tag{19}$$

In choosing a step size, it is needful arriving at good convergence properties of interior point methods. The chosen step size enables the positivity of x and s which needs preservation when updated. $\alpha^{\max}$, this is chosen as maximum step size until one of the variables is zero (0).

$\alpha^{\max}$ is calculated as follows:

$$\alpha_{p}^{\max}=\min\left\{-\frac{S_{i}}{(dx)i}:(dx)_{i}<0, i=1,\ldots,n\right\} \tag{20}$$

$$\alpha_{D}^{\max}=\min\left\{-\frac{X_{i}}{(ds)i}:(ds)_{i}<0, i=1,\ldots,n\right\} \tag{21}$$

$$\alpha^{\max}=\min\left\{\alpha_{p}^{\max},\alpha_{D}^{\max}\right\} \tag{22}$$

(22), is used because no variable is considered as zero (0) $\alpha=\min 1,\theta\alpha^{\max}$ is taken, as $\theta\in(0,1)$

Certainly, the choice will be $\theta\in 0.9$ or $\theta\in 0$.

Termination Criterion, so long as the barrier term exist, it keeps iterates away from the boundary, which cannot give the outcome of the exact solution. Complementarity and feasibility however, are attainable within a level of accuracy.

Therefore, termination criteria for the algorithm for use need some measure of decision. Some people may use common termination criteria such as:

$$\frac{\| Ax-b \|}{1+\| x \| \infty}\leq 10^{-p}, \frac{\| A^{T}y+s-C \|}{1+\| S \| \infty}\leq 10^{-p}, \frac{\| c^{T}x-b^{T}y \|}{1+|b^{T}y|}\leq 10^{-q} \tag{23}$$

In (23), the requirement of the value p and q depends on the specific application.

Primal dual method, it is a component of the three main interior groupings point methods. It operates simultaneous on the primal and the dual linear programming. This is how the optimal solution is found, (x^*, y^*, s^*) of

$$\begin{bmatrix} A & 0 & 0 \\ 0 & A^T & I \\ S^Z & 0 & A^Z \end{bmatrix} \begin{bmatrix} dx \\ dy \\ ds \end{bmatrix} = \begin{bmatrix} S^Z \\ r_p^Z \\ -x^Z r_D^Z + \gamma \mu_Z e \end{bmatrix} \tag{24}$$

(24), is used in the quest to apply variants of Newton's method to the immediate expression and modifying the search direction including the step lengths so that inequalities (x, s) ≥ 0 are satisfied at every iteration. X, S $S \in R^{nxm}$ are diagonal matrices of x_i, s_i respectively and $e \in R^n$ is a vector of ones.

The primal problem, is use where the linear programing gives the standard form like this:

$$\text{(P) Minimize } C^T x \tag{25}$$

$$\text{Subject to } Ax = b, x \geq 0 \tag{26}$$

(26), Imply as $c \in R^n$, $A \in R^{nxm}$ and $b \in R^m$ is the decision variable.

Implying that, the dual (D) and the primal (P) can then be stated as:

(D) Maximize $b^T y$

$$\text{Subject to } A^T y + s = c, s \geq 0 \tag{27}$$

(27), is applied with variables $y \in R^m$ and $s \in R^n$

Centering parameter (σ), enables balancing the movement towards the central path versus the movement towards the optimal solution. In case σ = 1, then the updates move towards the feasible center region. In cases where σ = o, then the updated step moves towards the direction of the optimal solution.

Duality gap (μ), is the product of the primal and dual objective functions. The theory behind this is that, the two quantities are equal and hence, the product is zero (0) at optimality. In real practice, the algorithm brings the result down to a small value. Given that:

$$\mu \equiv \frac{1}{n}(x^T s) = C^T x - b^T y \tag{28}$$

(28), is applied in such a way that as $\mu \leq \epsilon$, newton's method is applied until $\mu \leq \epsilon$ when the algorithm terminates. ϵ : is the positive fixed number.

Both the general standard minimum problem and the dual standard maximum problem are illustrated below: (Table 2).

Table 2. Standard minimum and dual standard maximum constraints

	x_1	x_2	$\cdots$	x_n	
y_1	a_{11}	a_{12}	$\cdots$	a_{1n}	$\geq b_1$
y_2	a_{21}	a_{22}	$\cdots$	a_{2n}	$\geq b_2$
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
y_n	a_{m1}	a_{m2}	$\cdots$	a_{mn}	$\geq b_m$
	$\leq C_1$	$\leq C_2$	$\cdots$	$\leq C_n$	

Primal dual algorithm helps in initializing

Choose $\beta, \gamma \in (0,1)$ and $(\varepsilon_p, \varepsilon_D, \varepsilon_G) > 0$ (29)

Choose (x^0, y^0, s^0) such that $(x^0, s^0) > 0$ and $\| x^0 s^0 - \mu_0 \epsilon \| \leq B\mu_0$ (30)

(30), is used where

$$1.\ \mu_0 = \frac{(x^0)^T s^0}{n}$$
$$2.\ Set\ Z = 0$$ (31)

$$3.\ \text{Set}\ r_p^z = b - Ax^z, r_D^z = C - Ak^T y^z - S^z, \mu_z = \frac{(x^z)^T s^T}{n}$$ (32)

4. Check the termination. If $\| r_P^Z \| \leq \varepsilon_p, \| r_D^Z \| \leq \varepsilon_D, (x^Z)^T S^{T \leq} \varepsilon_G$ (33)

The direction is Computed the by solving the system

Compute the step size

Compute the step size $\begin{bmatrix} A & 0 & 0 \\ 0 & A^T & I \\ S^Z & 0 & A^Z \end{bmatrix} \begin{bmatrix} dx \\ dy \\ ds \end{bmatrix} = \begin{bmatrix} r_p^Z \\ -x^Z S^Z + \gamma \mu_Z e \end{bmatrix}$ (34)

$$\alpha = \max \alpha' : \| x(a)s(\alpha) - \mu(\alpha)\epsilon \| \leq B(\alpha), \forall \alpha \in [0, \alpha']$$ (35)

(35) is used where

$x(\alpha) = x^Z + ad_x, S(\alpha) = S^Z + ad_s$ and $\mu(\alpha) = \dfrac{x^T(\alpha)s(\alpha)}{n}$

Update $x^{Z+1} = x^Z + \alpha_Z d_x, y^{Z+1}\alpha d_y, S^{Z+1} = S^Z d_s$ (36)

Set $Z = z+1$, and go on to step 3. (37)

Result and Discussion

The research seeks to apply linear programming technique to formulate least cost balanced ration for starter and finisher, meat type fowls with the help of local feed ingredient. The study seeks to cut down cost of producing broiler in Ohawu and its environs. The constitution of feed ingredients was maize, wheat feed, soybean meal, limestone, premix, Grilicidia Sepium, lysine, methionine and broiler concentrate. Linear programing (LP) model was constructed and designed in a fashion in such way that it reflected the combination of the various feedstuff used in the formula; nutrient components, current market prices as well as range of inclusion levels to arrive at least cost for broiler production based on availability of feedstuff in Ohawu and its environs. The objective of the model seeks to minimize production cost of one tone (1000kg) of feed after meeting the requirement of a set of constraints. The variables in the model represent ingredients, whereas the cost of each ingredient and nutritional value of each ingredient was the parameter.

The cost variation is dependent on the nutrient requirements of birds at each stage of production. The phases of growth require certain level of combination of nutrient in the feedstuff for formulation. This consideration enables the use of varied quantities of feedstuffs to formulate each diet. Feed formulation is the process of measuring the amount of feed ingredients required to combine to form a uniform mixture that is capable of providing poultry the necessary nutrients for growth. It is necessary that animal nutritionist maximize their returns through wise use of available diets. The formulation of feed is the most important aspect of raising poultry, doing all things possible to apply economic usage of feed ingredients for optimum chicken growth. The current practice of most large-scale famers is to buy their formulated feed from commercial feed mills or feed shops, in order to curb problem of formulating diets in the farm.

Chung et al., (1983) reported that, it is needful to formulate diet accurately in order to prevent the situation of large flock of animals being affected adversely. However, olorunfemeit et al, (2006) suggested that, least cost ration formulation problem in poultry can effectively be solved using linear programming technique. According to Patrick and Schaible (1980), least cost feed is the minimum cost formula that contains all the nutritional components needful for maximum performance. This research seeks to use linear model technique to formulate least-cost balance diet at different phases of growth using local feed ingredient.

Data Collection

Data collected depended on feed ingredient specification, constraint imposed on the selected feed ingredient and the dietary nutrients requirement at each phase of growth of broiler flock. The source of data collection was Ohawu Agricultural College, nutrient requirement of poultry Ninth Revised Edition (200) and Veterinary directorate of MoFA-Ghana. The cost of feedstuff was from the prevailing market prices in Ohawu and its environs through market survey. Standard tables and the internet is where the analysis of feed ingredients, minimum and maximum levels of the individual feedstuffs used in the formulae was obtained from.

Feedstuffs used in the formulation of ration at Ohawu Agricultural College include maize (x_1), wheat feed (x_2), soya bean (x_3), Limestone (x_4), premix (x_5), Grilicidia Sepium (x_6), lysine (x_7), methionine (x_8) and concentrate (x_9)

The cost attached to feedstuffs and nutrient levels of feed ingredients, constraint imposed on selected feed ingredients for broiler ration and the least-cost formula restrictions on feedstuffs and nutrients for broiler diet are those organized on the tables below (Tables 3, 4, 5, 6).

Table 3. Feedstuff costs and ingredient nutrients

Nutrients	Cost/Kg (GH₵)	Crude protein (%)	Calcium (%)	Phosphorus (%)	Lysine (%)	Methionine (%)	ME (kcal/kg)
x_1	0.80	8.8	0.1	0.34	0.40	0.18	3432
x_2	2.40	13.0	0.05	1.20	0.50	0.42	3153
x_3	1.40	48	0.20	0.37	3.2	0.59	2557
x_4	0.30	0	38	0.02	0	0	0
x_5	3.0	0	0	0	0	0	0
x_6	0.60	24.38	1.42	0.23	1.29	0.35	2,500
x_7	8.0	95	0	0	100	0	0
x_8	6.0	60	0	0	0	10	0
x_9	2.60	12.00	1.50	1.50	0.20	0.15	1,260

Table 4. The feedstuff constraint impositions for the broiler starter ration

Nutrient	Maximum	Minimum
Protein (%)	22	21
Metabolizable Energy (Kca/kg)	3150	3107
Calcium (%)	90	89
Phosphorus (%)	60	41
Lysine (%)	13	128
Methionine (%)	60	50

Table 5. The feedstuff constraint impositions for the broiler finisher ration

Nutrient	Maximum	Minimum
Protein (%)	19.50	19
Metabolizable Energy (Kcal/kg)	3160	3150
Calcium (%)	90	85
Phosphorus (%)	40	37
Lysine (%)	120	110
Methionine (%)	55	50

Table 6. The least-cost broiler ration feedstuff and nutrient restrictions

Item	Starter phase	Finisher phase
Weight (Kg)	1000	1000
Crude protein (%)	$\leq$ 21	$\leq$ 19
ME (Kcal/kg)	$\leq$ 3107	$\leq$ 3150
Calcium (%)	$\geq$ 89	$\geq$ 85
Phosphorus (%)	$\leq$ 41	$\leq$ 37
Lysine (%)	$\leq$ 128	$\leq$ 110
Methionine (%)	$\leq$ 50	$\leq$ 50

Formulation of LP for Feed Mixed

The formulation of the LP has it bases from <Table 3> and <Table 6>, which is transforms into equations in the standard form as, follows:

Minimize $Z\sum c_{ij}x_{ij}$

Where:

Z= Total cost of the ration

c_i= Ingredient cost, j=1, 2, 3,⋯⋯m

x_i= Ingredient quantity, i=1, 2, 3,⋯⋯n

Subject to

$X_1 + X_2 + X_3 + ... + X_9 = b_1$

$a_{11}X_1 + a_{12}X_2 + a_{13}X_3 + ... + a_{18}X_8 \leq b_2$

$a_{21}X_1 + a_{22}X_2 + a_{23}X_3 + ... + a_{28}X_8 \leq b_3$

$a_{31}X_1 + a_{32}X_2 + a_{33}X_3 + ... + a_{38}X_8 \leq b_4$

$a_{41}X_1 + a_{42}X_2 + a_{43}X_3 + ... + a_{48}X_8 \leq b_5$

$a_{51}X_1 + a_{52}X_2 + a_{53}X_3 + ... + a_{58}X_8 \leq b_6$

$a_{61}X_1 + a_{62}X_2 + a_{63}X_3 + ... + a_{68}X_8 \leq b_7$

$a_{71}X_1 + a_{72}X_2 + a_{73}X_3 + ... + a_{78}X_8 \leq b_8$

$a_{81}X_1 + a_{82}X_2 + a_{83}X_3 + ... + a_{88}X_8 \leq b_9$

$a_{91}X_1 + a_{92}X_2 + a_{93}X_3 + ... + a_{98}X_8 \leq b_{10}$

$X_i \geq 0$, i=1, 2, 3, 4, ..., n

Where:

a_i = Technical coefficient of nutrient components in feedstuffs

b_i= constraints of the ration

Implementation of the Proposed LP Model

Implementation of the model is in two categories:

i. LP for least cost starter ration

ii. LP for least cost finisher ration

The LP model construction for least cost starter ration had its basis from the constraints in <Table 3> and <Table 6> can be transform into standard forms with the cost as the coefficient and x the variables as presented in the objective function below:

$$\text{Min}\,Z = 0.80_{X1} + 2.40_{X2} + 1.40_{X3} + 0.30_{X4} + 3.0_{X5} + 0.60_{X6} + 8.0_{X7} + 6.0_{X8} + 2.60_{X9}$$

Subject to

$$x_1 + x_2 + x_3 + x_4 + x_5 + x_6 + x_7 + x_8 + x_9 \leq 1000$$
$$8.8x_1 + 13x_2 + 48x_3 + 24.38x_6 + 95x_7 + 60x_8 + 12.0x_9 \leq 21$$
$$0.1x_1 + 0.05x_2 + 0.2x_3 + 38x_4 + 1.42x_6 + 1.50x_9 \leq 89$$
$$0.34x_1 + 1.20x_2 + 0.37x_3 + 0.23x_6 + 1.50x_9 \leq 41$$
$$0.4x_1 + 0.50x_2 + 3.2x_3 + 1.29x_6 + 100x_7 + 0.20x_9 \leq 128$$
$$0.18x_1 + 0.42x_2 + 0.59x_3 + 0.35x_6 + 10x_8 + 0.15x_9 \leq 50$$
$$3432x_1 + 3153x_2 + 2577x_3 + 2500x_6 + 1260x_9 \leq 3107$$
$$x_1 + x_2 + x_3 + x_4 + x_5 + x_6 + x_7 + x_8 + x_9 \geq 0$$

The LP model construction for least cost finisher ration had its basis from the constraints in <Table 3> and <Table 6> can be transform into standard forms with the cost as the coefficient and x the variables as presented in the objective function below:

$$\text{Min}\,Z = 0.80_{X1} + 2.40_{X2} + 1.40_{X3} + 0.30_{X4} + 3.0_{X5} + 0.60_{X6} + 8.0_{X7} + 6.0_{X8} + 2.60_{X9}$$

Subject to

$$
\begin{aligned}
&x_1 + x_2 + x_3 + x_4 + x_5 + x_6 + x_7 + x_8 + x_9 \leq 1000 \\
&8.8x_1 + 13x_2 + 48x_3 + 24.38x_6 + 95x_7 + 60x_8 + 12.0x_9 \leq 19 \\
&0.1x_1 + 0.05x_2 + 0.2x_3 + 38x_4 + 1.42x_6 + 1.50x_9 \leq 85 \\
&0.34x_1 + 1.20x_2 + 0.37x_3 + 0.23x_6 + 1.50x_9 \leq 37 \\
&0.4x_1 + 0.50x_2 + 3.2x_3 + 1.29x_6 + 100x_7 + 0.20x_9 \leq 110 \\
&0.18x_1 + 0.42x_2 + 0.59x_3 + 0.35x_6 + 10x_8 + 0.15x_9 \leq 50 \\
&3432x_1 + 3153x_2 + 2577x_3 + 2500x_6 + 1260x_9 \leq 3150 \\
&x_1 + x_2 + x_3 + x_4 + x_5 + x_6 + x_7 + x_8 + x_9
\end{aligned}
$$

The outcome of for the LP model for the least cost starter ration of the experimental farm was aided by the use of matlab(Table 7). The solution of the optimal solution measured against the existing practice at the experimental site in <Table 8>.

The outcome of the LP model for the least cost finisher ration for the experimental farm was aided by the use of matlab(Table 9). The solution of the optimal solution measured against the existing practice at the experimental site in <Table 10>.

Table 7. The least-cost starter ration results and discussion

Decision variables	Solution Variables	Unit Cost (GH₵)	Total Cost (GH₵)	Reduced Cost (GH₵)
Maize (x_1)	592.3	0.80	473.84	-137
Wheat feed (x_2)	87.8	2.40	210.72	29.28
Soybean meal (x_3)	279	1.40	390.6	-45.6
Limestone (x_4)	20.3	0.30	6.09	8.91
Vitamin Premix (x_5)	1	3.0	3.0	6.0
Grilicidia Sepium (x_6)	0	0.60	0	63
Lysine (x_7)	1.1	8.0	8.8	-0.8
Methionine (x_8)	19.2	6.0	115.2	-109.2
Concentrate (x_9)	0	2.60	0	208
Total Reduction Cost				19.75

This research seeks to minimize cost of formulating one tone (1000 kg) of feed as set of constraints were satisfied without trading-off the nutritional value of the feed. The solution from the model through computerized solution gave; the quantity of Grilicidia Sepium and concentrate reduced to zero (o kg) because the nutritional value they give is in the other ingredients (constraint), therefore, it does not make economic sense to add the ingredients mentioned earlier to the feed. Moreover, the quantity of wheat feed, limestone, Vitamin premix, increased to compensate for the nutritional value of Grilicidia Sepium and concentrate would have contributed to the diet. However, there was maize, Soybean meal, lysine and methionine reduced to get a balance for the nutritional level of the feed. This model reduced the feed cost by GH₵ 19.7.

Table 8. The least-cost starter ration verses existing practices

Ingredients (xj)	Cost (GH₵)/kg	Existing practice		Proposed practice	
		Value (kg)	Cost (GH₵)	Value (kg)	Cost (GH₵)
Maize (x_1)	0.80	420	336	592.3	473.84
Wheat feed (x_2)	2.40	100	240	87.8	210.72
Soybean meal (x_3)	1.40	245	343	279	390
Limestone (x_4)	0.30	45	15	20.3	6.09
Vitamin Premix (x_5)	3.0	3.00	9	1	3.0
Grilicidia Sepium (x_6)	0.60	105.00	63	0	0
Lysine (x_7)	8.0	1	8	1.1	8.8
Methionine (x_8)	6.0	1	6	19.2	115.2
Concentrate (x_9)	2.60	80	208	0	0
Objective function value		1000	1228	1000.7	1208.25

Broiler starter feed costed the farmer GH₵ 1228 to produce, using the existing practice of the farm in comparison to GH₵ 1208.25 based on the feed formulation of the mathematical model. This is a valuable saving of about 1.61%. Apparently, the new feed formulation gives less cost based on valid mathematical programming.

Table 9. The least-cost finisher ration results and discussion

Decision variables	Solution Variables	Unit Cost (GH₵)	Total Cost (GH₵)	Reduced Cost (GH₵)
Maize (x_1)	684.5	0.80	547.6	-147.6
Wheat feed (x_2)	43.7	2.40	104.88	-32.88
Soybean meal (x_3)	229.2	1.40	320.88	-40.88
Limestone (x_4)	19.3	0.30	5.79	6.21
Vitamin Premix (x_5)	1	3.0	3.0	6
Grilicidia Sepium (x_6)	0	0.60	0	63
Lysine (x_7)	0.7	8.0	5.6	10.4
Methionine (x_8)	22.3	6.0	133.8	-115.8
Concentrate (x_9)	0	2.60	0	304.2
Total Reduction Cost				52.65

This research seeks to minimize cost of formulating one tone (1000 kg) of feed as set of constraints were satisfied without trading-off the nutritional value of the feed. The solution from the model through computerized solution gave; the quantity of Grilicidia Sepium and concentrate were reduced to zero (o kg) because the nutritional value they give can equally be found in the other ingredients (constraint), therefore, it does not make economic sense to add the ingredients mentioned earlier to the feed. Moreover, the quantity of limestone, vitamin premix and lysine increased to compensate for the nutritional value of lysine Grilicidia Sepium and concentrate would have contributed to the diet. However, the quantity maize, wheat feed, soybean meal and methionine reduced to get a balance for the nutritional level of the feed. This model reduced the feed cost by GH₵ 52.6.

Table 10. The least cost finisher ration verses existing practices

Ingredients (xj)	Cost (GH₵)/kg	Existing practice		proposed practice	
		Value (kg)	Cost (GH₵)	Value (kg)	Cost (GH₵)
Maize (x_1)	0.80	500	400	684.5	547.6
Wheat feed (x_2)	2.40	30	72	43.7	104.88
Soybean meal (x_3)	1.40	200	280	229.2	320.88
Limestone (x_4)	0.30	40	12	19.3	3.0
Vitamin Premix (x_5)	3.0	3.00	9	1	0
Grilicidia Sepium (x_6)	0.60	105.00	63	0	5.6
Lysine (x_7)	8.0	2.0	16	0.7	133.8
Methionine (x_8)	6.0	3.0	18	22.3	0
Concentrate (x_9)	2.60	117	304.8	0	0
Objective function value		1000	1174.2	1000.7	1121.55

Broiler finisher feed costed the farmer GH₵ 1174.2 to produce using the existing practice of the farm in comparison to GH₵ 1121.55 based on the feed formulation of the mathematical model. This study experienced a substantial gain of about 4.48%. Apparently, the new feed formulation gives less cost based on valid mathematical programming.

Conclusion

The research result of the least-cost starter ration formulation produced by the linear programming model indicated that, the starter ration contains; maize 59.23%, soybean meal 27.9%, wheat feed 8.78%, limestone 2.03%, vitamin premix 1%, lysine 0.11% and methionine 1.92%. The ration contained all the nutrition required of the broiler starter ration. The cost of the ration is about GH₵ 1228 per ton. The model saved about 1.61% per ton compare to the basic ration.

In the case of the finisher ration the results of the model showed that, it contained 68.45% of maize, soybean meal 22.92%, wheat feed 4.37%, limestone 1.93%, vitamin premix 1%, lysine 0.07%, and methionine 2.23%. This ration also contained the entire nutritional requirement needed to produce the broiler finisher diet. This ration also costed about GH₵ 1121.55 per ton. In the case of the finisher ration too, the model saved about 4.48% per ton compared to the basic ration. The result of this study shows that, the use of linear programming to solve feed mix problem is a sure way to minimize cost as well as making sure that nutrient requirement of broiler chicken is met.

This result will also enable farmers in Ghana to produce more broiler at reduced cost, which will lead to improvement in the socio-economics and societal nutrition. The linear programing model has helped in other sectors of most economies such as transportation, deployment of war troops, crops input allocation all gearing towards efficient use of resources and now is the time to rope in the poultry industry in order to increase production as well as feed the rapidly growing population.

Feed miller in Ghana will also have relieve from producing costly feed for the poultry industry which will go a long way to bring on board already shutdown poultry farm businesses since the model produces at least cost diets. Again, since there will be feed at a cheaper cost this will enable rapid growth in the industry and subsequently calls for more job for the youth.

This paper also has the following limitations. Although this method calculates the proportion of the feed, it can be seen that due to the limitation of the data collection method, the data entered into the model may not be complete. Some breeding companies may not perform the feed ratio according to this ratio, tut it will still make good profits. In addition, the research area selected in this study is also very limited, which will affect the generality of the results. Therefore, in the future, we can obtain more data, improve the scale of the database, and propose more generalized results.

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