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Application of Linear Programming on Cost Minimization of Pig Feeds (A Case Study of MOV Farms)

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Abstract

This paper discusses cost minimization for pig diet formulation. A linear programming model was formulated for minimum cost and maximum shelf life feed quality. Linear programming technique via MATLAB was employed to obtain solution using real life data collected from MOV Farms, Ilorin. The results, attained at the 7^{th} iteration gave an optimal value of the objective function obtained as $\#94,226$ per 100 kg, with the corresponding values 1.5714, 0.6929, 2.8929, 0 and 0 for x_1(pig weaner), x_2(pig growers), x_3(pig finishers), x_4(pregnant sow), x_5(lactating sow) recorded respectively. Hence, the cost of pig feeds formulation can be optimized effectively.

1 Introduction

In any pig farming, the main purpose of diet formulation and feeding techniques is to maximize profits, which does not necessarily involve maximal animal execution. In other to maximize the economic efficiency therefore, supplying indispensable nutrients as close as possible to meeting, but not exceeding, the nutritional requirements of the pig is advantageous. It is reasonable to assume that pigs with different sex and genotype can express their genetic potential for growth,

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production and/or reproduction if they are provided with the opportunity to consume the optimum amounts of all nutrients in just the proportions required to satisfy their needs. Vitamins and minerals are obviously important nutrients for pigs to perform optimally, but their requirements can be met with relatively little cost. Moughan and Verstegen [8] used a schematic approach to model pig growth from input of digested amino-acid; potential gain in protein and fat are used to calculate body weight gain, body composition and carcass composition.

Feeding behavior can be defined by criteria such as the time spent eating per day, feed consumption per day, number of feeding visits, time spent eating per visit and feeding rate. A better knowledge of pig feeding behaviors can help to clarify the role played by factors influencing feed intake, growth performance, feed utilization efficiency, the quality of the products and social inter relationships among pigs. Many alternative feeds potentially cost effective and useful in swine rations which are produced by the industries involved in grain milling, baking, brewing, distilling, packing and rendering, fruit and vegetable, vegetable oil, milk, egg,and poultry processing. By-products from these industries are regularly used in manufacturing feeds to provide required nutrients at a reduced cost. Many of the by-products from these processes can readily substitute for a portion of the energy or protein supply in a complete food. The appropriate amount to use will depend on the cost of nutrient available, digestibility, quality of protein, amino acid profile, palatability, presence of anti-nutritional factors, storage life and age of the pig for which the feed is intended.

1.1 Protein quality, digestibility and anti-nutritional factor

Protein quality refers to the amino acids content of the feed ingredients. A high level of digestible amino acid is required for Nursing pig. Tokach *et al.* [13] observed that the most economical protein source for pigs is soybeans meal. Since lysine is the most limiting essential amino acid in corn and soybean meal based rations, it is important to consider lysine when valuing replacement feeds. For example, corn glutton and wheat contain a high level of protein relative to the amount of lysine. If a ration was prepared with these ingredients based solely on the protein concentration, the pigs would not be provided with sufficient lysine to support optimum performance. As a result, rations for swine should be balanced according to the level of lysine instead of crude protein.

Digestibility is the extent to which a nutrient can be used by a pig. A feed such as alfalfa meal may be relatively high in protein but this protein might not be available to the pig due to the high fiber content of the feed.

Anti-Nutritional factors are in a feed ingredient that interfere with nutrient digestibility . It may include trypsin inhibitors, tamnins, lectins or glucosinolates e.g. raw soybean contains a trypsin inhibitor. As a result, it must be heat processed to avoid causing a decrease in performance, which might result in reduced protein digestibility and absorption.

1.2 Cost

This is one of the most difficult factor to determine when considering the use of alternative feeds, due to variation in the market price of the feeds. A producer needs to take good account of the amount of nutrients provided by the replacement feed. This can be much difficult since most feeds cannot be directly compared due to nutrient variability and relative valves mostly used for comparison purposes. Furthermore, we note that the ultimate cost of any change in ration, must also consider other factors such as transportation, special processing needs and storage. This is highly important when evaluating high moisture products such as liquid whey, distillers grains and high moisture corn. The value of alternative feed should be primarily based on their actual nutrient contribution to the ration with regard to digestibility and cost. Rations are least cost balanced, based on protein level, because protein is the most expensive primary ingredients. Nonetheless, in multitude current economic environments, energy may be more expensive per unit than protein. Rations should be reformulated to recognize this scenario and reformulated in line with feed ingredients cost changes.

Naturally, kitchen waste and poultry offal are widely available none-conventional food to reduce the cost of pig rearing. While combination of feed ingredients are to be evaluated so as to maximize weight gain at minimum cost. Feed processing technology is much more relevant towards sustainable precision in livestock farming, at a minimal cost.

Nath and Talukdar [12] noted in their work on fish farming that, feed cost control is germane in the sustainability of fish industry. The paper demonstrated how application of linear programming method to feed formulation can lead to high productivity in the sector with minimum cost.

In Anieting *et al.* [3] linear programming method was used in determining optimum production of Usmer water capacity in Uyo - Nigeria, with the data analyzed via TORA software. The result of the analysis indicated an optimum production capacity at minimum cost when 95 bags of sachet water, 65 cartons of 75cl, 10 cartons of 1.5 liters and 17 drums of refilled 10 liters of water are produced per day.

A number of researchers in the area of product mix optimization, applied linear programming technique in cost minimization.

Mohamed *et al.* [6] adopted an integer linear programming model to a diet problem of McDonald's set menu in Malaysia; Aghazadeh [1] presented five different scenarios of determining product mix using linear programming which lead to profit maximization.

Garba *et al.* [5] applied linear Programming approach to product mix company. In the same vein, Molina [7] used Linear Programming method to minimize supply cost of online clothing. Ailobhio *et al.* [2] utilized Linear Programming model in profit optimization of Lace baking Industry.

Eli [4] Adopted Linear programming method in determining the best sales package of KASMO cosmetics soap that would give maximum profit to the company. Unit sale package was recommended for the company, with a maximum profit of 14.36 naira per tablet.

Azman [9] applied the simplex method to identify the best type of bread that maximizes the Baker's cottage profit in Malaysia.

Beki and Jack [11] employed the linear programming model to ensure profit maximization in a Small Medium Enterprises company in Malaysia. The findings was able to suggest a more viable product mix via the application of linear programming that ensures optimum profitability for the company.

Chanda *et al.* [10] used linear programming to optimize the profit of a manufacturing sector using data obtained from market bread types. The research was able to identified pre-linear programming and post-linear programming application effect on product mix, with the findings that a higher profit was recorded, and that resources wastage and cost were at minimum level when linear programming was applied.

However, little or less have been done on the cost minimization of pigs feeds formulation, hence this work intends to investigate the cost of minimizing pig feeds formulation and maximizing the feed quality.

2 Methodology and Data Presentation

Linear programming model was developed for optimization of feed ingredients for minimization of costs and maximization of shelf life of the feed mixture. Formulation of pig feed consists of determination of optimum values of feed ingredients to achieve specific objectives. The optimum value's main consideration is to be given to cost of nutrient ingredients, feed quality and requirement of animal at different stages of growth. The model has to satisfy a set of constraints on nutritional levels, availability restrictions, special ingredients to be included or feed constraints.

In this work, the research objectives are taken as minimization of cost to achieve different weight stages and maximization of shelf life and nutritional value of the feed blend.

For the preparation of an optimal feed, the following criteria should be considered:

1. Cost of the feed ingredients.
2. Nutrient required for maximization of weight gain
3. Quantity of nutrient ingredients for maximum quality of the feed blend.

One of the objectives here, is to obtain a feed blend containing feed components at minimum cost for different stages of Pigs development. For this, weight gain will be achieved by maximizing the nutrient value of the feed components. It could be achieved by choosing those feed components that contain high-digestibility ingredients, which ensures higher weight gain, and reduces feed costs. Another objective is to formulate a diet having maximum nutritional value or to maximize the feed blend quality in terms of its shelf life. Shelf life can be increased by reducing the water content. Reduced water content in turn lowers the feed costs at the same weight gain with a smaller feed blend quantity. In the early phase of this work, both of these objectives are achieved through standard Optimization of Livestock technique via linear programming method, used at different stages of Pigs growth. In the second phase of the work, these objectives are attempted to be achieved by MATLAB . In the third phase of the work, the results were compared, with optimum results obtained.

3 Linear Programming Model for Minimizing Feed Mix Cost for Pig Production

The general Linear Programming Model takes the form:

$$
\begin{aligned}
&\text{Optimize} \quad Z = c_1x_1 + c_2x_2 + c_3x_3 \ldots\ldots c_nx_n \\
&\text{such that} \\
&a_{11}x_1 + a_{12}x_2 + a_{13}x_3 + \ldots\ldots a_{1n}x_n \star b_1 \\
&a_{21}x_1 + a_{22}x_2 + a_{23}x_3 + \ldots\ldots a_{2n}x_n \star b_2 \\
&a_{31}x_1 + a_{32}x_2 + a_{33}x_3 + \ldots\ldots a_{3n}x_n \star b_3 \\
&\vdots \qquad\quad \vdots \qquad\quad \vdots \qquad\quad \vdots \qquad\quad \vdots \\
&a_{m1}x_1 + a_{m2}x_2 + a_{m3}x_3 + \ldots\ldots a_{mn}x_n \star b_m
\end{aligned}
$$

Let

i= index identifying feed nutrient components with $i = 1, 2, 3, ..., m$

j=index identifying feed nutrient components with $j = 1, 2, 3, ..., m$

X_j=quantity of feed ingredients in the feed mix (decision variable)

C_j=cost of production of feeds $j = 1, 2, 3, ..., m$

X_b=the result of each quantity

BV=basic variable

CB=coefficient of the basis

Z_i=objective function

B.F.S=basic function solution

a_{ij}=coefficient of constraints

The objective of this linear programming model is to minimize total cost

$$minZ = \sum_{j=1}^{n} C_j X_j.$$

3.1 Algorithms

Problem constraints: The constraints of the model deals with limitation on the total feed quantity to be produced, nutrients availability in feed ingredients and nutritional requirements. The model summarizes as follows:

Algorithms for Simplex Method

Step 1: If the problem is minimization, convert such to maximization problem by multiplying the objective function Z by (-1)

Step 2: Ensure that the b_i's are positive.

Step 3: Convert all inequalities to equality by adding slack variables.

Step 4: Find the basic feasible solution.

Step 5: Construct the starting simplex table.

Step 6: Test for the optimality of basic feasible solution by computing $Z_j - C_j$.

If $Z_j - C_{ij} \geqslant 0$, the solution is optimal, otherwise we proceed to the next step.

Step 7: To improve on the basic feasible solution we find the in-coming vector entering the basic matrix while the out-going vector is removed from the matrix with any vector that corresponds to the most negative $Z_j - C_j$ becoming the in-coming vector, while the variable that corresponds to the minimum ratio b_j/a_j for a particular j and $a_{ij} > 0$ is the out-going vector.

Step 8: The key or pivot element is determined by considering the intersection of the arrows from both the in-coming and out-going vector. We generate the next table using the element in the next table, replace the pivot element by unity while all other elements in the remaining rows of the pivot column reduced to zero using use the relation: new row=former element in the old row - (inter sectional element of the old row) × (corresponding element of replacing row). By so doing we obtain the improved basic feasible solution (B.F.S).

Step 9: Test the new B.F.S if not found optimal, repeat the process till optimal solution is obtained.

Formulation

The general linear programming problems is presented in a tabular form as shown below.

Table 1: The general linear programming problem.

INGREDIENTS	X_1	X_2	......	X_{1n}	SOLUTION
1	a_{11}	a_{12}	......	a_{1n}	b_1
2	a_{21}	a_{22}	......	a_{2n}	b_2
⋮	⋮	⋮	⋮	⋮	⋮
m	a_{m1}	a_{m2}	......	a_{mn}	b_m
Cost(naira)	C_1	C_2	......	C_n	

The above can be interpreted as follows.

$$\text{optimize} \quad Z = C_1X_1 + C_2X_2 + \dots C_nX_n$$

$$i = 1, 2, 3, \dots n, \quad j = 1, 2, 3 \dots n.$$

In order to ensure minimization in cost of pig feeds, the following data were collected.

Table 2: The proportion of the ingredient required to make 100kg of pig weaner.

INGREDIENTS	QUANTITY(KG)	PERCENTAGE()	COST(#)
MAIZE	47	47	4,418
PAL KERNEL OIL	10	10	530
GROUNDNUT CAKE	7	7	644
FISH MEAL	4	4	2,880
LYSINE	1	1	898
SOYMEAL	21	21	3,276
PREMIX	5	5	4,500
METHIONINE	1	1	1386
SALT	0.3	0.3	21.6
BONE MEAL	1.7	1.7	127.5
SOYBEAN OIL	2	2	400
TOTAL	100	100	19,081.1

Table 3: The proportion of the ingredient required to make 100kg of pig grower.

INGREDIENTS	QUANTITY(KG)	PERCENTAGE()	COST(#)
MAIZE	55	55	5,170
PAL KERNEL CAKE	10	10	530
WHEAT meal	3	3	171
FISH MEAL	2	2	1,440
LYSINE	1	1	898
SOYMEAL	23	23	2,852
PREMIX	5	5	4,500
METHIONINE	1	1	1,386
TOTAL	100	100	16,947

Table 4: The proportion of the ingredient required to make 100kg of pig finisher.

INGREDIENTS	QUANTITY(KG)	PERCENTAGE()	COST(#)
MAIZE	65	65	6,110
PAL KERNEL CAKE	10	10	530
WHEAT MEAL	6	6	342
LYSINE	1	1	898
SOYMEAL	13	13	6,110
PREMIX	3	3	2,700
METHIONINE	1	1	1,386
SALT	1	1	72
TOTAL	100	100	18148

Table 5: The proportion of the ingredient required to make 100kg of pig pregnant sow.

INGREDIENTS	QUANTITY(KG)	PERCENTAGE()	COST(#)
MAIZE	67	67	6,298
PAL KERNEL CAKE	10	10	530
WHEAT MEAL	10	10	570
LYSINE	1	1	898
SOYMEAL	8	8	992
PREMIX	3	3	2,700
METHIONINE	1	1	1,386
TOTAL	100	100	13,374

Table 6: The proportion of the ingredient required to make 100kg of pig lactating sow.

INGREDIENTS	QUANTITY(KG)	PERCENTAGE()	COST(#)
MAIZE	65	65	6,110
PAL KERNEL CAKE	10	10	530
WHEAT MEAL	15	15	855
LYSINE	1	1	898
PREMIX	3	3	2,700
METHIONINE	1	1	1,386
SOYMEAL	3	3	372
BONE MEAL	2	2	150
TOTAL	100	100	13,001

Table 7: The quantity of finished ingredients required to make feed of pig weaner, pig grower, pig finisher, pregnant sow and lactating sow.

INGREDIENTS	P.W (A)	P.G (B)	P.F (C)	P.S (D)	L.S (E)	THE AVAILABLE
SOYMEAL	21	23	13	8	3	135
PAL KERNEL CAKE	10	10	10	10	10	74
FISH MEAL	4	2	-	-	-	70
WHEAT MEAL	-	3	6	10	15	42
LYSINE	1	1	1	1	1	13
PREMIX	5	5	3	3	3	20
MAIZE	47	55	65	67	65	300
METHIONINE	1	1	1	1	1	10
SOYBEAN OIL	2	-	-	-	-	6
BONE MEAL	1.7	-	-	-	2	10
GROUNDNUT CAKE	7	-	-	-	-	11
SALT	0.3	-	1	-	-	5

Here P.W = Pig Weaner, P.G = Pig Grower, P.F = Pig Finisher, P.S = Pregnant Sow, L.S = Lactating Sow.

Table 8: Available ingredients to produce 100 kg of pig weaner, pig grower, pig finisher, pregnant sow, lactating sow.

INGREDIENTS	MAXIMUM AVAILABLE()	COST
MAIZE	155	14,570
PAL KERNEL CAKE	74	3,922
GROUNDNUT CAKE	11	1,012
WHEAT MEAL	42	2,394
FISH MEAL	70	50,400
LYSINE	13	11,674
SOYMEAL	300	37,200
PREMIX	15	18,000
METHIONINE	3	4,158
SALT	5	360
BONE MEAL	10	750
SOYBEAN OIL	6	1,200
TOTAL		145,640

The case study farm has the objective of mixing 100 kg of feeds for pig weaner, pig grower, pig finisher, pregnant sow, and lactating sow during the production cycle at minimum cost, using twelve (12) decision variables and 17 constraints.

Table 9: List of decision variables.

x_1	Quantity of maize
x_2	Quantity of pal kernel cake
x_3	Quantity of groundnut cake
x_4	Quantity of wheat meal
x_5	Quantity of fish meal
x_6	Quantity of lysine
x_7	Quantity of soymeal
x_8	Quantity of premix
x_9	Quantity of methionine
x_{10}	Quantity of salt
x_{11}	Quantity of bone meal
x_{12}	Quantity of soybean oil

Table 10: Market price of ingredients.

INGREDIENTS	COST PER KG(#)
MAIZE	94
PAL KERNEL CAKE	53
GROUNDNUT CAKE	92
WHEAT MEAL	57
FISH MEAL	720
LYSINE	898
SOYMEAL	124
PREMIX	900
METHIONINE	1386
SALT	72
BONE MEAL	75
SOYBEAN OIL	200

Data analysis from Table 7

Let the quantity of feed for pig starter, pig grower, pig finisher, pregnant sow, lactating sow be: x_1, x_2, x_3, x_4, x_5, respectively.

Objective function

$$\text{Min } Z = 19{,}081.1x_1 + 16{,}947x_2 + 18147x_3 + 13{,}374x_4 + 13001x_5 \quad (2.1)$$

The constraints

$$\text{SOYBEAN MEAL} = 21x_1 + 23x_2 + 13x_3 + 8x_4 + 3x_5 \leq 135 \quad (2.2)$$
$$\text{PAL KERNEL CAKE} = 10x_1 + 10x_2 + 10x\text{"}3 + 10x_4 + 10x_5 \leq 74 \quad (2.3)$$
$$\text{FISH MEAL} = 4x_1 + 2x_2 + 0x_3 + 0x_4 + 0x_5 \leq 70 \quad (2.4)$$
$$\text{WHEAT MEAL} = 0x_1 + 3x_2 + 6x_3 + 10x_4 + 15x_5 \leq 42 \quad (2.5)$$
$$\text{LYSINE} = 1x_1 + 1x_2 + 1x_3 \; 1x_4 + 1x_5 \leq 13 \quad (2.6)$$
$$\text{PREMIX} = 5x_1 + 5x_2 + 3x_3 + 3x_4 + 3x_5 \leq 20 \quad (2.7)$$
$$\text{MAIZE} = 47x_1 + 55x_2 + 65x_3 + 67x_4 + 65x_5 \leq 300 \quad (2.8)$$
$$\text{METHIONINE} = 1x_1 + 1x_2 + 1x_3 + 1x_4 + 1x_5 \leq 10 \quad (2.9)$$
$$\text{SOYBEAN OIL} = 2x_1 + 0x_2 + 0x_3 + 0x_4 + 0x_5 \leq 6 \quad (2.10)$$
$$\text{BONE MEAL} = 1.7x_1 + 0x_2 + 0x_3 + 0x_4 + 2x_5 \leq 10 \quad (2.11)$$
$$\text{GROUNDNUT CAKE} = 7x_1 + 0x_2 + 0x_3 + 0x_4 + 0x_5 \leq 11 \quad (2.12)$$
$$\text{SALT} = 0.3x_1 + 0x_2 + 1x_3 + 0x_4 + 0x_5 \leq 5 \quad (2.13)$$

By adding slake variables to change the inequalities to equalities, the equations becomes

$$\text{Min } Z = 19{,}081.1x_1 + 16{,}947x_2 + 13{,}650x_3 + 13{,}374x_4 + 13001x_5 \quad (2.14)$$

The constraints

$$\text{SOYBEAN MEAL} = 21x_1 + 23x_2 + 13x_3 + 8x_4 + 3x_5 + x_6 = 135 \quad (2.15)$$
$$\text{PAL KERNEL CAKE} = 10x_1 + 10x_2 + 10x\text{"}3 + 10x_4 + 10x_5 + x_7 = 74 \quad (2.16)$$
$$\text{FISH MEAL} = 4x_1 + 2x_2 + 0x_3 + 0x_4 + 0x_5 + x_8 = 70 \quad (2.17)$$
$$\text{WHEAT MEAL} = 0x_1 + 3x_2 + 6x_3 + 10x_4 + 15x_5 + x_9 = 42 \quad (2.18)$$

$$\text{LYSINE} = 1x_1 + 1x_2 + 1x_3\ 1x_4 + 1x_5 + x_{10} = 13 \quad (2.19)$$
$$\text{PREMIX} = 5x_1 + 5x_2 + 3x_3 + 3x_4 + 3x_5 + x_{11} = 20 \quad (2.20)$$
$$\text{MAIZE} = 47x_1 + 55x_2 + 65x_3 + 67x_4 + 65x_5 + x_{12} = 300 \quad (2.21)$$
$$\text{METHIONINE} = 1x_1 + 1x_2 + 1x_3 + 1x)_4 + 1x_5 + x_{13} = 10 \quad (2.22)$$
$$\text{SOYBEAN OIL} = 2x_1 + 0x_2 + 0x_3 + 0x_4 + 0x_5 + x_{14} = 6 \quad (2.23)$$
$$\text{BONE MEAL} = 1.7x_1 + 0x_2 + 0x_3 + 0x_4 + 2x_5 + x_{15} = 10 \quad (2.24)$$
$$\text{GROUNDNUT CAKE} = 7x_1 + 0x_2 + 0x_3 + 0x_4 + 0x_5 + x_{16} = 11 \quad (2.25)$$
$$\text{SALT} = 0.3x_1 + 0x_2 + 1x_3 + 0x_4 + 0x_5 + x_{17} = 5 \quad (2.26)$$

Since we are minimizing cost, the objective function is multiplied by (-1) to change to maximization problem, thus we have

$$\text{Max } Z = -19,081.1x_1 - 16,947x_2 - 18,148x_3 - 13,374x_4 - 13001x_5 \quad (2.27)$$

The constraints

$$\text{SOYBEAN MEAL} = 21x_1 + 23x_2 + 13x_3 + 8x_4 + 3x_5 + x_6 = 135 \quad (2.28)$$
$$\text{PAL KERNEL CAKE} = 10x_1 + 10x_2 + 10x"3 + 10x_4 + 10x_5 + x_7 = 74 \quad (2.29)$$
$$\text{FISH MEAL} = 4x_1 + 2x_2 + 0x_3 + 0x_4 + 0x_5 + x_8 = 70 \quad (2.30)$$
$$\text{WHEAT MEAL} = 0x_1 + 3x_2 + 6x_3 + 10x_4 + 15x_5 + x_9 = 42 \quad (2.31)$$
$$\text{LYSINE} = 1x_1 + 1x_2 + 1x_3\ 1x_4 + 1x_5 + x_{10} = 13 \quad (2.32)$$
$$\text{PREMIX} = 5x_1 + 5x_2 + 3x_3 + 3x_4 + 3x_5 + x_{11} = 20 \quad (2.33)$$
$$\text{MAIZE} = 47x_1 + 55x_2 + 65x_3 + 67x_4 + 65x_5 + x_{12} = 300 \quad (2.34)$$
$$\text{METHIONINE} = 1x_1 + 1x_2 + 1x_3 + 1x)_4 + 1x_5 + x_{13} = 10 \quad (2.35)$$
$$\text{SOYBEAN OIL} = 2x_1 + 0x_2 + 0x_3 + 0x_4 + 0x_5 + x_{14} = 6 \quad (2.36)$$
$$\text{BONE MEAL} = 1.7x_1 + 0x_2 + 0x_3 + 0x_4 + 2x_5 + x_{15} = 10 \quad (2.37)$$
$$\text{GROUNDNUT CAKE} = 7x_1 + 0x_2 + 0x_3 + 0x_4 + 0x_5 + x_{16} = 11 \quad (2.38)$$
$$\text{SALT} = 0.3x_1 + 0x_2 + 1x_3 + 0x_4 + 0x_5 + x_{17} = 5 \quad (2.39)$$

$$x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8, x_9, x_{10}, x_{11}, x_{12}, x_{13}, x_{14}, x_{15}, x_{16}, x_{17} \geq 0$$
$$x_i, \quad i = 1, 2, 3, 4, ...$$

The simplex table for the analysis of the obtained result is presented as follows.

Table 11: Simplex table.

BV	CB	x_1	x_2	x_3	x_4	x_5	x_6	$x_{...}$	x_{18}	x_b
x_6	0	21	23	13	8	3	1	...	0	135
x_7	0	10	10	10	10	10	0	...	0	74
x_8	0	4	2	0	0	0	0	...	0	70
x_9	0	0	3	6	10	15	0	...	0	42
x_{10}	0	1	1	1	1	1	0	...	0	13
x_{11}	0	5	5	3	3	3	0	...	0	20
x_{12}	0	47	55	65	67	65	0	...	0	300
x_{13}	0	1	1	1	1	1	0	...	0	3
x_{14}	0	2	0	0	0	0	0	...	0	6
x_{15}	0	1.7	0	0	0	2	0	...	0	10
x_{16}	0	7	0	0	0	0	0	...	0	11
x_{17}	0	0.3	0	0	0	0	0	...	1	5
Z_j	0	0	0	0	0	0	0	0	...	0
C_j	0	19081.1	16947	13650	13374	13001	0	...	0	
Z_j - C_j		-19,081.1	-16947	-18148	-13374	-13001	0	...	0	

4 Analysis and Discussion of Results

In this section, we present mathematical solution of the linear programming minimization problem of the pig feeds quantities and cost using the simple approach in the package MATLAB. The main goal here was to determine the optimum cost of the five livestock feeds considered in this study per 100 kg for the purpose of enlightening pig owners and pig feeds manufacturers alike on cost, quality and quantity efficiency of the various feeds type.

Since the problem here is a minimization type, we minimized the objective function in equation 2.1 subject to the constraints of equation 2.2 to equation 2.13 using data set presented in Tables 1 through 5 as obtained from MOV Farms, Fatima Farm Settlement, km8, Leyland Motor Road, Wofun, Iwo-road, Ibadan, Oyo state.

However, the method employed by the simplex function applied in this study is three phases tableau simplex method. The method was treated manually as presented in section two.

The solution of the minimization problem as obtained from the Linprog in MATLAB reveals that the optimal value of the objective function is #94,226 per 100 kg with corresponding values 1.5714, 0.6929, 2.8929, 0 and 0 for x_1(pig weaner), x_2(pig growers), x_3(pig finishers), x_4(pregnant sow), x_5(lactating sow), respectively.

The value 0 obtained for x_4 and x_5 indicates the presence of pregnant sow and the lactating sow in the other feed composition.

Table 12a: Objective function.

Variables	X_1	X_2	X_3	X_4	X_5
Coefficients	19081.1	16947	18148	13374	113001

Table 12b: Optimal solution.

Variables	X_1	X_2	X_3	X_4	X_5
Coefficients	1.5714	0.6929	2.8929	0	0

The MATLAB CODE used in obtaining solution to the problem reads:

```
format long
 syms A B F X
 F=[-19081.1 -16947 -18148 -13374 -13001 ];
 A=[21 23 13 8 3;
    10 10 10 10 10;
    4 2 0 0 0;
    0 3 6 10 15;
    1 1 1 1 1;
    5 5 3 3 3;
    47 55 65 67 65;
    1 1 1 1 1;
    2 0 0 0 0;
    1.7 0 0 0 2;
    7 0 0 0 0;
    0.3 0 1 0 0;
    -1 0 0 0 0;
    0 -1 0 0 0;
    0 0 -1 0 0;
    0 0 0 -1 0;
    0 0 0 0 -1];
  B=[135;74;70;42;13;20;300;10;6;10;11;5;0;0;0;0;0]
 [X,Fval,exitflag,output]=linprog(F,A,B)
```

The output from the MATLAB is this

```
Optimization terminated.

X =

   1.571428571478265
   0.692857142961742
   2.892857142594295
   0.000000000271683
   0.000000000137931

Fval =

   -9.422600714623454e+004

exitflag =

     1

output =
         iterations: 7
          algorithm: 'large-scale: interior point'
        cgiterations: 0
            message: 'Optimization terminated.'
     constrviolation: 1.817159045458539e-008
```

5 Summary and Conclusion

In this paper, attempt has been made to identify possible minimum cost of production of pig feeds for different growth levels.

The linear programming model obtained revealed that the minimum cost of production of feed is #94,226 per 100 kg with corresponding values 1.5714, 0.6929, 2.8929, 0 and 0 for x_1(pig weaner), x_2(pig growers), x_3(pig finishers), x_4(pregnant sow), x_5(lactating sow), respectively.

The values 0 recorded against Pregnant Sow and Lactating Sow indicates the presence of their feeds in the other ones.

This model might have some limitations, however, if the farm applies the solution through this study, it will be able to minimize the feed cost, which will result in increased profitability. In future, a more optimized model of this problem can be developed by getting rid of possible limitations.

6 Recommendation

Based on the previous analysis, we recommend that pig farmers who aim for efficient and effective pig farming should adopt cost minimization techniques. These proven techniques are also recommended for adoption by companies engaged in product mix to minimize total production costs and consequently increase the overall profit margin.

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