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Linear Programming Models Application in Nigeria Broiler Poultry Rations: Transport Logistic Distributions and Optimized Nutrients Diet Formulation

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ABSTRACT

The diet issue was one of the first problems to be described as linear programming. The objective of the diet issue is to choose a combination of foods that will satisfy daily nutritional demands while being as affordable as possible. A balanced diet is necessary for chicken's growth, livability, and ability to mature to its complete genetic potential. The profitability of live birds must be maximized, and feed costs per kg of body weight must be reduced. The early nutrient diet incorporates several feed ingredients needed for the bird's diet to be balanced. The general mathematical model is built as $Minimise\ Z = \sum_{j=1}^{n} C_j X_j$ *subject to twelve restrictions received from a local farm. It comprises ten variables and nine decision factors for each type of ration. In order to make the model usable, an* Excel Solver *application was deployed to solve it. The model and sensitivity analysis results were generated, and they were compared with the procedures followed by the real cases. When compared to the present formulation, the linear programming model's proposed optimal formulation reduces feed formulation costs for both starter and finisher broiler birds on the farm by roughly 7.48% and 9.96%, respectively. The model also considerably raised the quantity of metabolizable energy required for physiological structure while significantly boosting the quantity of metabolizable energy required for diet while reducing the amount of fat in the diet. Sensitivity analysis also provided valuable insight into the effects of variations in feed input costs. The incorporation of transportation model into this study has improved the efficient distribution of the new food ration from manufacturing plants to meet exporters' (and local consumers') demands while reducing the cost of distribution.*

Keywords: Dietary essentials, Linear programming, Nutrient diet, Mathematical model, Optimal formulation, Broiler.
2010 Mathematics Subject Classification: 12Y05

1.0 INTRODUCTION

In order to maintain excellent health and strength as well as to prevent and treat disease, diet is crucial. Only the appropriate foods can maintain and promote good health, and vice versa: eating the wrong kinds of foods invites illness. The human body needs a variety of nutrients to develop and sustain healthy cell tissues, glands, and organs. The body cannot carry out any of its tasks, whether they be metabolic, mental, physical, or chemical, without a particular set of nutrients. One of the most crucial elements in protecting and sustaining health is the availability of nutrients, which can only be obtained through eating.

Due to their high quality, nutritional content, and affordable price, poultry meat and eggs are in greater demand, according to Kamalakanta et al. (2020). Along with an increase in demand for chicken meat and eggs, there is a more significant requirement for poultry feed. Most of the ingredients used in feed for chickens are also utilized in food for people. As a result of market competition, the price of both of these important feed ingredients, both separately and collectively, has grown. According to this study, small chicken farms could cut their feed costs by adopting linear programming (LP). The broiler starter and finisher feed mixture are made with readily available feed components. Indian standard institutes and National Research Institutes, ICAR used the suggested standard criteria to establish the dietary nutrient demands for the broiler starter and finisher phases. Sixteen feed components were selected in order to provide the best feed mix, lower the feed mix's overall cost, and still meet nutrient requirements. The best feed composition for broiler starter and finisher was found using the Liner Programming model and the Microsoft Excel solver.

For the same performance, broiler marketing ages drop annually on average by 0.75 days. Throughout the ensuing years, this tendency is probably going to keep moving in the same way. This progress is significantly made possible by nutrition. Being a costly input (70–80% of the cost of producing broilers), feed dynamics and their impact on the quantity and quality of the end product should be understood by the poultry producer [Gunasekar, (2007)]. Optimal feed formulation calls for in-depth knowledge of various factors, such as the diet's required calorie level, the balancing of the amino acid profile and the feed's electrolytes, etc. The company's productivity and profitability could suffer if these factors are not adequately managed. Extrapolating the full genetic potential of the birds is also difficult because of environmental problems and disease outbreaks [Gunasekar, (2007)]. While creating broiler feed, nutritionists should take numerous important factors into consideration. Among these that are crucial are:

Nutritive value of raw materials
Amino acid digestibility
Amino acid and calorie ratio
Selection of suitable fat source
Calcium requirement of birds
Electrolyte balancing
Immuno-modulation
Summer management

In linear programming, a collection of linear equations and, or inequalities known as constraints are used to optimize (maximize or minimize) a function of variables known as the objective function. The objective function may be to maximize profit, minimize cost, maximize production capacity, or achieve any other metric of effectiveness. Resources such as raw material availability, market demand, production processes and equipment, storage capacity, composition/constituent needs, and more may place restrictions on what can be produced. The linear programming model typically advocates for proportionality, additivity, continuity, certainty, and finite options. One of the operations research approaches most frequently used in business, industry, and a variety of other industries is linear programming. Problems with product mix, blending, production scheduling, diet, profit planning, environment preservation, trim loss issues, and assembly-line balancing are a few of these topics [Gupta and Hira, (2009)]. Due to their rudimentary stomachs, poultry cannot synthesize the majority of the nutrients they need, making them nutritional necessities. For optimal growth, viability, and genetic expression, chicken has to be fed a sufficient amount of a balanced diet. Body temperature and digestion are two areas where poultry differ from other livestock animals. Poultry feed is made up of 2-8% Mineral sources, 30-35% Protein Sources, and 60-65% Energy Giving Materials. Water, which is regarded as the primary nutrition, should be pure, wholesome, free from physical impurities, poisonous compounds, and bacterial contamination.

In a report published in 2019, Hossameldin and Mohammed attempted to calculate the least-cost ratio of a sample of broiler farms in Al-Ahsa, Saudi Arabia. Depending on their ability to produce, the farms were split into three groups. The three-stage feeding system was utilized to estimate the least-cost ration using the linear programming technique (starter, grower, and finisher). The findings indicate that, in comparison to their current position, the ideal ration will save broiler farms in Al-Ahsa an average of SAR 234,100 while increasing their profit by 47%. Furthermore, the ideal solution demonstrated that if broiler farms used the suggested ration, the cost per bird would drop by 7.3%.

The current layout of Landmark University (LU) was made possible by creating a generation of problem-solvers using a top-notch, suitable to be applied education sector that emphasizes values and cutting-edge knowledge while making it more responsive and applicable to the contemporary demands of presentation, industrialization, and development. Landmark University's problem is deciding which of its many programs to sponsor in order to achieve the greatest benefits with the smallest amount of work. The records have been divided into both large and small projects due to the fact that many organizations depend more on the guessing approach and as a result, enterprises have all been finding it challenging to make astute business decisions. They maximize the usage of the current value (NPV) in the cram, limit the net discounted net cash run over of every job per period, and capture as derivative data the cash inflows from LU monthly financial report and financial statements from 2012 to 2017. (IP). The project's annual financial statements, which represent the disparity between the cash brought in and out for each season, were estimated and recorded. The project manager was able to choose a precise amount of the parameter initiatives that can maximize earnings thanks to the knowledge of the 10% discount for each income per period and the commensurate NPV at 10%. This was much more effective than depending on an ad hoc going to assume approach to the investment, which might have cost 160 102 for a similar venture.In order to determine how sensitive project selection is to changes in system parameters, sensitivity analysis on the project parameters was also conducted [Samuel and et al, (2015) and

Nathaniel (2019)]. The results showed that the optimal objective function and solution values for variables (x_1), (x_4), and (x_5) had no effect on the shadow prices when the cost was reduced by a small amount or percentage or added to its corresponding coefficient.

In a piece that was published, Jakia et al (2022) claimed that the research employs linear programming optimization to estimate the least cost and amount of food items in order to choose a healthy diet that has sufficient nutrition workings all through the line of a week for three dissimilar age groups. After selecting a linear programming optimization approach, three data files defining the various food items with their corresponding costs and nutritional ingredients good for three different age groups are formed. The model are finally solved using the collected data in order to determine the manufacturing cost and the quantity of food items to be purchased. The perfect answer displays different food prices and serving amounts for different age groups. It also illustrates a range of complexity by gathering objective values for different age groups.

Small farmers are embracing poultry farming more and more, which has considerably enhanced Nigeria's GDP and job generation [Adebayo and Adeola, (2005); Okonkwo and Akubo, (2001)] So, effective poultry farming is essential to Nigeria's industry's long-term viability as well as high productivity. Because feeding makes up more than 70% of the total cost of producing eggs and broilers, Afolayan & Afolayan (2008) contend that strengthening the feed formulation system is the best way to increase poultry industry productivity. The feed composition issue of a typical Nigerian chicken farm using locally available feed components is addressed in this study using an accessible Excel solution and user-friendly software. Linear and nonlinear algorithms, the Pearson Square rule, and the trial-and-error method are a few of the frequently used strategies in feed formulation. The Human Square rule is an easy, well-known, and popular technique for figuring out the ideal ratios of two feed components required to supply the required amount of a specific nutrient. Protein is frequently employed in this method (Oladokun, 2012). The method enables feed component adjustments without reducing the desired protein level in the diet. It also uses a few extra nutrients, like amino acids. The most common method for producing feed at the lowest feasible cost compares the nutrients an animal requires with the nutrients provided by the materials for feed that are currently available. Moreover, there are goal programming, multi-criteria modeling, and evolutionary algorithms Sahman et al., (2009); Castrodeza et al., (2005), Dogan et al, (2000). However, Nigeria prefers to produce chicken meals by trial and error. The formulation is changed, as the name implies, to meet the nutritional requirements of the birds (Oladokun, 2012).

The main ingredients of chicken diets are a variety of feedstuffs, including cereal grains, soybean meal, animal byproduct meals, lipids, and premixes of vitamins and minerals (Longe, 1984; Alimon and Hair-Bejo, 1995). A poultry's diet should contain sufficient amounts of metabolizable energy as well as the three essential nutrients protein, vitamins, and minerals (ME). The more energy there is, the less feed the hens will actually consume because energy is essential for chicken feed (Larbeir and Leclercq, 1994). Carbohydrates, which are found in all plants, including whole grains and grain derivatives, are the easiest forms of energy to get. Cereal grains make up the majority of the carbs in poultry diets. To make food more palatable and filling, appropriate amounts of fat may be added.
Protein is necessary for every species to survive. Animals' muscles, skin, beaks, feathers, cartilage, and internal organs are mostly constituted of protein, which is also necessary for development of the eggs and other

reproductive organs, growth, and the production of antibodies to fight disease, among other things. A diet must contain both protein and amino acids, after all. It's necessary to supply some amino acids in the right quantities and in accordance with a calculated ratio to other amino acids. The responses to those essential amino acids that are present in sufficient amounts will be hampered if one of them is missing Alimon and Hair-Bejo, (1995) Fanatico (2010). The limiting amino acid in any protein is the one with insufficient concentration. For chickens, methionine is typically the first limiting amino acid, followed by lysine. Any extra protein is oxidized for energy because the body does not store a lot of protein. Protein levels are frequently stated in precise terms to be closer to the minimal requirement than other nutrients, however because protein sources are expensive and uneconomical for supplying energy, this is the case more frequently with proteins. Plant-based forms of protein include things like soy and groundnut cake, whereas animal-based sources include things like blood meal and fish meal. Minerals are present in oyster shell and limestone, both of which are high in calcium. Bonemeal is rich in calcium and phosphorus, among other minerals. Regular salt can be used to satisfy a bird's need for sodium and chloride. However, vitamin/mineral premix supplements are frequently utilized to meet trace mineral needs (Scheideler, 2009). A number of sources, including sets of tables released by the American National Research Council (NRC) in 1994, provide information on expected nutrient demands, suggested allowances, and ultimately feed specifications.

1.1 Problem Formulation

The expense of rearing broilers is largely comprised of feed. Broiler diets should be created to offer the ideal ratio of energy, protein and amino acids, minerals, vitamins, and essential fatty acids in order to ensure optimum growth and performance. It is commonly accepted that any business or corporation should choose the proper dietary nutrient levels depending on financial factors. Minimizing feed cost per kg of live weight is equivalent to increasing live bird profitability. By using linear programming(LP) model, we will be able to optimize the nutrient diet needed for broilers while paying the least amount of money, taking the least amount of risks, and best satisfying the daily minimum requirements for each type of nutrient. Also, in order to cut costs and increase the profit margin of organized systems, distribution of finished goods requires effective transportation logistics LP model. It's a novel strategy for reducing expenses and boosting earnings.

1.1 Objective of The Study

To create a broiler starter and finisher dietary ration linear programming model that reduces the overall production cost and transportation logistics.

1.3 Significance of Study

The significance of this study is to determine what a balanced diet is and how a nutritionist can choose a diet that contains acceptable nutrients required by chicken. Prior to determining the best economic feeding diets, many aspects must be taken into account. This is especially true of feeding plans for animals that are growing. The study demonstrates the elegance and usefulness of industrial mathematics in solving issues related to diet and transportation.

2.0 The Basic Feed Programme:

2.1 Broiler Starter Feeds

The objectives of the brooding phase include the creation of a good appetite and maximum early growth (0 to 10 days of age). The target seven-day body weight should be obtained, which is 179 g or greater. Ten days is the suggested dosage for broiler starter. Decisions about the Starter's formulation should be based on performance and profitability rather than cost since it only represents a very small portion of the cost of the overall feed. If the digestible amino acid is present in a sufficient quantity, the early growth of the bird can be optimized. This is essential in all modern broiler systems, but it's especially important when raising young birds, in challenging situations, or when the amount of breast meat produced is limited. In areas where wheat is grown, using some maize might be useful. Avoid saturated fats, especially when paired with wheat, and keep total fat intake low (5%) [Arbor, 2009].

2.2 Broiler Grower Feeds

Broiler Grower feed is typically ingested for 14 to 16 days. While transitioning from starter feed to growth feed, the texture will transform from crumbs to pellets. A high-quality grower feed is still needed for optimum performance. If a growth limitation is required, it should be put in place right away. To reduce feed consumption, it is preferable to adopt management techniques like meal feeding or illumination. It is not recommended to restrict growth based on dietary composition [Arbor, 2009].

2.3 Broiler Finisher Feeds

The majority of feeding expenses are incurred by broiler finisher feeds, hence economic design considerations should be used while creating these feeds. During this time, changes in body composition can occur quickly, so it's important to take into account any abnormal fat deposition and loss of breast meat yield. The desired slaughter weight, the length of the production period, and the feeding program's layout will all influence whether one or two Broiler Finisher meals are used. Drug withdrawal phases may require the administration of a specific withdrawal finisher feed. Although the practice of significant nutrient withdrawal during this period is not advised, this feed should be modified for the age of the birds [Arbor, (2009)].

2.4 Linear Programming Models

In a mathematical model where the needs are replaced by linear systems, linear programming can be used to achieve the best outcome (such as the highest profit or lowest cost) (LP, also known as linear optimization). Linear programming is a specific kind of mathematical programming. Informally, linear programming is a technique for maximizing a linear objective function while taking linear equality and inequality into account. A viable zone is a set of convex polyhedra, where a set is defined as the overlap of a fixed amount of half spaces, where each half space is specified by a linear inequality. This polyhedron's objective function is an affine function built on it with real values. In the event that such a point exists, the polyhedron point with the lowest (or highest) value of this function is found using a linear programming technique.

The Fourier-Motzkin exclusion method is named after Fourier, who at least addressed the problem of solving a set of linear inequalities. In 1939, Leonid Kantorovich developed the linear programming method. With the purpose of reducing military costs and increasing enemy deaths during World War II, Leonid Kantorovich developed the first problems with linear programming in 1939. When John von Neumann, a mathematician, developed the idea of binary oppositions as a linear optimal algorithm and applied it to the investigation of game theory in 1947, the simplex procedure was finally made public. The simplex technique had already been published at that point by George B. Dantzig.

2.5 The Diet Problem

The feeding problem was one of the first optimization problems studied in the period between the 1930s and the 1940s. The issue was motivated by the Army's goal to maintain GIs' field rations as affordable as feasible while yet offering a wholesome diet. Early on, George Stigler, who had studied the problem, employed a systematic method to arrive at an educated estimate at the best solution.He calculated that a healthy diet would cost $39.93 per year (1939 prices). In the fall of 1947, Jack Laderman of the National Bureau of Standards' Mathematical Tables Project used the recently developed simplex approach to solve Stigler's problem. The first optimization calculation of "big scale" had nine functions and 77 unknowns.Using manually operated desk calculators, it took 9 clerks 120 man days to reach the optimal solution of $39.6901. Stigler's projection was incorrect by just $0.2401 per year. He thought about three things: milk, bread, and maize. There are restrictions on the quantity of vitamin A as well as the amount of calories consumed (between 2000 and 2250). The very first column for each food includes the cost per serving, the amount of vit Per each main meal, as well as the number of calories.

Table 1: Food contents, Cost, and Minerals Contents

Food	Cost per serving	Vitamin A	Calories
Corn	$0.1801	107	72
2% Milk	$0.23001	500	121
Wheat Bread	$0.0502	0	65
.	.	.	.
.	.	.	.
.	.	.	.

Source of the table: Cmelan, 2012

Now let us say there are a total of 10 servings. As a result, the best solution to the issue is $3.1501 and includes 1.9402 portions of maize, 10 portions of milk, plus 10 portions of bread. The portion contains 1 to 2 pounds and 5208 I.U. of vit A [Cmelan, 2012].

2.5.1 Formulation in Mathematics

The diet issue can be formally expressed as a mathematical programming issue, as demonstrated below: F = set of foods

N = set of nutrients

Parameters

= size of the nutrient *j* in food *i*, ∀ *i*∈*F*, ∀ ∈*j N*

= cost per food serving *i*, ∀*i*∈*F*

= a minimum of the necessary portions of food *i*, ∀ *i*∈*F*

= maximum permitted serving size for food *i*, ∀ ∈ *i F*

= minimum amount of nutrients necessary *j*, ∀ ∈ *j N*

= maximum permitted nutrient level *j*, ∀ ∈ *j N*

Variables

= amount of food servings*i* to buy /ingest, ∀*i*∈*F*

Objective Function: Minimize the whole price of the food

Minimize $\sum i \in F$

Constraint Set 1: For each nutrient *j*∈*N*, at least attain the minimum standard required.

$\sum i \in F$ ≥ ∀,*j*∈*N*

Constraint Set 2:For each nutrient *j*∈*N*, do not go above the highest permissible level.

$\sum i \in F$ ≤ ,∀ ∈ *j N*

Constraint Set 3:For each food *i*∈*F*, choose at least the required amount of servings.

≥ ∀ ∈, *i F*

Constraint Set 4:For each food *i*∈*F*, adhere by the maximum permitted number of servings.

≤ ∀,*i*∈*F*

To fix this linear programming issue, we are able to employ the NEOS Server algorithms from the Mathematical Programming category. Each LP solver can receive data in one or more formats [Cmelan, 2012]. Optimization process models are more likely to set lower restrictions on the abundance of particular qualities in the solution than maximization models, which often set upper limits on resource availability. A model was created by Robert et al. in 2003 to lower the cost of a diet. They debated the topic of choosing prepared dishes to meet specific dietary requirements. Suppose the following precooked food varieties are available at the following prices per package:

BEEF beef - $3.1901

CHK chicken -$ 2.5902

FISH fish -$2.2901

HAM ham - $2.8901

MCH macaroni and cheese - $1.8901

MTL meat loaf - $1.9901

SPG spaghetti - $1.9901

TUR turkey - $2.4902

These suppers provide the aforementioned proportions, for every package, of the least daily needs for vitamin supplements A, C, B1 and B2: every serving of such constituents includes such vitamin supplements in the respective mixture 60%, 20%, 10% and 15% in both; CHK 8%,10%, 20percent and 20%;FISH 8%, 10%, 15percent and 10%; Pork sausage 40%, 40percent 35percent and 10%;MCH 15%, 35%, 15percent and 15%, MTL 70%, 31%, 15percent and 15%; SPG 25%, 50%, 25percent and 15%; TUR 60%, 20%, 15percent and 10%.The difficulty is figuring out the least priced mix of packets that will deliver for the week worth of meals or at minimum 700% of the daily recommendations for each nutrient. The number of packages of meat supper, chicken dinner, etc. shall be shown by the characters X BEEF, X CHK, etc. The total cost of the diet will vary according to:

Total cost =3.1901 #$$% + 2.5902 ’() + 2.2901 %*+(+ 2.8901 (,-+ 1.8901 -’(+ 1.9901 -./+
1.9901 +01+ 2.4902 .23

The total% of the vit A need is computed in a manner identical to that described above, except that the amounts of X BEEF, X CHK, and others are multiply by the % per unit instead of the price per package:

Total percentage of vitamin A daily requirement met = 60 #$$% + 8 ’() + 8 %*+(+ 40 (,-15 -’(+
70 -./+25 +01+ 60 .23

That should be at least seven hundred times greater than that. Similar formulas exist for each of the additional vitamins, and each of them must be larger than or equal to 700.

When you combine all of these, you obtain the linear program shown below:
Minimize Z =
3.1901 #$$% + 2.5902 ’() + 2.2901 %*+(+ 2.8901 (,-+1.8901 -’(+ 1.9901 -./+
1.9901 +01+ 2.4902 .23
Subject to
60 #$$% + 8 ’() + 8 %*+(+ 40 (,-15 -’(+ 70 -./+25 +01+ 60 .23≥ 700
20 #$$% + 0 ’()+ 10 %*+(+ 40 (,- +35 -’(+ 30 -./+ 50 +01+ 20 .23 ≥ 700
10 #$$% + 20 ’()+ 15 %*+(+ 35 (,- +15 -’(+ 15 -./+ 25 +01+ 15 .23 ≥ 700
15 #$$% + 20 ’()+ 10 %*+(+ 10 (,- +15 -’(+ 15 -./+ 15 +01+ 10 .23 ≥ 700
#$$%≥ 0, ’() ≥ 0, %*+(≥ 0, (,-≥ 0, -’(≥ 0, -./ ≥ 0, +01 ≥ 0, .23≥ 0

Despite being far from what we could have hoped for, the best option is swiftly discovered.The cost is kept to a minimum by a routine diet of 46 ^{2}53 macaroni and cheese bundles A brief review of this neatly demonstrates 15% ×46 ^{2}53 = 700% of the need for additional vitamin C, along with the need for vitamins A, B1, and B2; It only costs \$1.8901 ×46 ^{2}53= \$88.2047.

3.0 METHOD

3.1 Model Development:

The balanced diet model formulation combines a number of feed ingredients to provide the bird with a well-balanced diet. A variety of conditions must be satisfied by the model, such as those relating to dietary restrictions, ingredient accessibility, specific requirements, demand restrictions, energy needs, and cost constraints. The generic mathematical model can be applied to each type of ration and is constructed as follows based on the available ingredients:

3.1.1 Notations:

Let **i** = feed dietary supplements with i = 1,2,...m **j**
= feed components with j =1,2,…n
67= the amount of the feed ingredient j in the feed mix (decision variable)
N= total quantity (Kg) of feed to be produced
Z= The feed formulation's total cost of the feed ingredients
89= cost per unit of a feed ingredient j
:;9= amount (in fraction of **Xj**) of nutrient i available in feed ingredient j
<;= nutritional need (part of N) of component I for a type of birds

Objective function

The LP model that has been provided for achieving the objective function is as follows:

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Subject to:

$\sum_{j=1}^{n} X_j \quad \sum_{j=1}^{n} X_j = N$ (Demand Requirement)

$a_{ij} \sum_{j=1}^{n} \quad {}_{j=1}^{n} \quad \geq b_i$ ( ) (Minimum Requirement)

${}_{j=1}^{n} \quad \sum_{j=1}^{n} \quad \leq b_i$ ( ) (Maximum Requirement)

$\sum_{j=1}^{n}$ = @ (Restrictedconstraints)

≥ 0 (Non – Negativity constraints)

These restrictions were related to the dietary needs of each bird and ingredient limitations. The cost and nutritional value of each item served as the parameter, and the variables in the models were their composition. The primary source of information on feedstuff specifications, restrictions placed on the chosen feedstuffs, and dietary nutritional needs for broilers was NRC (1994). The price of the feedstuffs utilized in the diet formulation was determined by surveying the feedstuff market prices that were in effect in Nigeria.From standardized tables and sources [Aduku, (1993); Tacón, (1993); NRC, (1994)], the analysis of feed components and minimum and maximum amounts of different feedstuffs utilized in diet was acquired. The nutritional and restriction levels of ME, protein, limiting amino acids, calcium, phosphorus, fiber, and fat recommended by

NRC (1994) will be used in this investigation. Yellow maize (corn), soya, fish, powder, vitamin/mineral, salt, lysine, oyster shell, bone meal, methionine, wheat bran, and calcium di-phosphate are the substances that are most frequently used in the creation of rations for adjacent farms and broiler feed producers. These feedstocks were used in this study.

Tables 2& 3: Broiler ration formulation limits by a conventional Nigerian feed mill on nutrients and livestock feed:

Ingredients	Costs (₦/kg)	Crude Protein %	Fats %	Crude Fibre %	Ca%	P, %	Lysine %	Methionine %	ME (Kcal /kg)
Maize, x_1	58.01	8.801	4.01	2.0	0.0101	0.0901	0.2501	0.1801	3432
Soyabean, x_2	150.01	44	3.501	6.5	0.201	0.201	2.801	0.5901	2230
Wheat bran, x_3	60.01	15.701	-	5.101	0.14	1.1501	0.5901	0.4201	1300
Oyster shell, x_4	15.01	-	-	-	21	18.501	-	-	-
Bone meal, x_5	50.01	-	-	-	38	1.501	-	-	-
Table salt, x_6	90.01	-	-	-	-	-	-	-	-
Lysine, x_7	700.01	60	-	-	-	-	100	-	-
Methionine, x_8	1300.01	60	-	-	-	-	-	100	-
Broiler premix, x_9	550.01	-	-	-	-	-	-	-	-

Tables 3: Broiler ration formulation limits by a conventional Nigerian feed mill on nutrients and livestock feed:

Parameter	Starter Ration	Finisher Ration
Crude Protein (kg)	20.8701	19.2501
Fats (kg)	3.5501	3.5101
Available Phosphate (kg)	0.5801	0.5601
Lysine (kg)	1.2601	1.1601
Crude Fibre (kg)	4.0901	4.1101
Calcium (kg)	1.8601	2.2001
Methionine (kg)	0.4201	0.4001

Metabolizable Energy (Kcal/kg)	2826.3901	2766.6701
Salt (kg)	0.301	0.301
Premix (kg)	0.301	0.301
Weight (kg)	100	100

3.1.2 Model Building

The following is the broiler starting ration linear programming model:

Min Z = $58.01 + 150.01\,_{H} + 60.01\,_{J} + 15.01\,_{K} + 50.01\,_{L} + 90.01\,_{N} + 700.01\,_{P} + 1300.01\,_{Q} + 550.01\,_{R}$

Subject to:

$\sum_{i=1}^{9} x$ ≥ 100 (Demand requirement)

$0.08801 + 0.4401x_2 + 0.15701x_3 + 0.601x_7 + 0.601x_8 \geq 20.870101$ (Crude Protein Minimum Needed)

$0.0401 + 0.03501x_2 \leq 3.5501$ (Fats Needed)

$0.0201 + 0.06501x_2 + 0.05101x_3 \leq 4.0901$ (Crude Fibre Needed)

$0.000101 + 0.00201\,_{H} + 0.001401\,_{J} + 0.2101\,_{K} + 0.3801\,_{L} = 1.8601$ (Calcium Needed)

$0.000901 + 0.00201x_2 + 0.011501x_3 + 0.18501x_4 + 0.01501x_5 \geq 0.5801$ (Phosphate present)

$0.002501 + 0.02801x_2 + 0.005901x_3 + 1.00x_7 \geq 1.2601$ (Lysine Needed)

$0.001801 + 0.005901x_2 + 0.004201x_3 + 1.00x_8 \geq 0.4201$ (Methionine Needed)

$3432.01x_1 + 2230.01x_2 + 1300.01x_3 \geq 2826.3901$ (Metabolizable Energy)

$_{N} = 0.301$ (Salt Needed)

$_{R} = 0.301$ (Premix Needed)

$, _{H}, _{J}, _{K}, _{L}, _{N}, _{P}, _{Q}, _{R} \geq 0$ (Non-Negativity Constraints)

We present the broiler finisher ratio linear programming model as:

Min Z = $58.01 + 150.01\,_{H} + 60.01\,_{J} + 15.01\,_{K} + 50.01\,_{L} + 90.01\,_{N} + 700.01\,_{P} + 1300.01\,_{Q} + 550.01\,_{R}$

Subject to:

$\sum R \quad \geq 100.01$ (Demand Units)

$0.08801 + 0.4401x_2 + 0.15701x_3 + 0.601x_7 + 0.601x_8 \geq 19.2501$ (Crude Protein Minimum Needed)

$0.0401 + 0.03501x_2 \leq 3.5101$ (Fats Needed)
$0.0201 + 0.06501x_2 + 0.05101x_3 \leq 4.1101$ (Crude Fibre Needed)

$0.000101 + 0.00201\,H + 0.001401\,J + 0.2101\,K + 0.3801\,L = 2.201$ (Calcium Needed)

$0.000901 + 0.00201x_2 + 0.011501x_3 + 0.18501x_4 + 0.01501x_5 \geq 0.5601$ (Phosphate Present)

$0.002501 + 0.02801x_2 + 0.005901x_3 + 1.00x_7 \geq 1.1601$ (Lysine Needed)

$0.001801 + 0.005901x_2 + 0.004201x_3 + 1.00x_8 \geq 0.401$ (Methionine Needed)

$3432.01x_1 + 2230.01x_2 + 1300.01x_3 \geq 2766.6701$ (Metabolizable Power)

$N = 0.301$ (Salt Needed)

$R = 0.301$ (Premix Needed)

$\geq 0, i = 1, \dots, 9$ (Non-Negativity Constraints)

The Simplex Method, which was developed using the aforementioned data, was solved using the Excel Solvers software application.

3.2 Transportation Model Description

1. A linear programming-based transportation model is often described by the information below:

2. A collection of *m supply* sites where a commodity is manufactured or supplied from. Supply *point i* has a maximum capacity of a_i *units*.

3. A collection of *n demand points* to which the good is supplied or distributed.

4. A variable cost of c_{ij} is incurred for each unit made at source point *i* and delivered to demand point *j*.

Let it be the number of goods in units available at plant*i* (*i* = 1, 2, 3,… ,m) and let @ be the number of demand good in units required at depot*j* (*j* = 1, 2, 3,… ,m).

Determine the quantity to be distributed from plant*i* to depot*j* in order to keep the overall transportation cost to a minimum. The supply constraints at the sources and the demand specifications at the depots must also both be met precisely [Tizik and Tsurkov, (2012); Anders and Bernhard, (1997)].

= number of units transported from supply point *i* to demand point *j,* then the general formulation of the transportation problem is

$\min \sum_{i=1}^{i=m} \sum_{j=1}^{j=n}$ i s.t.

$\sum_{j=1}^{j=n} x_{ij} \leq a_i$ $(i = 1, 2, \dots, m)$ (Supply constraints) ii

$\sum$ $\geq b_j$ $(i = 1, 2, \dots, m)$ (Demand constraints)

iii where ≥ 0 $(i = 1, 2, \dots, m; j = 1, 2, \dots, n)$

iv In other words, the scheme will be equal if the two sets of requirements are consistent and

$$\sum_{i=1}^{m} \quad = \sum_{j=1}^{n} @ \text{ v}$$

3.2.1 Matrix Terminology

To illustrate the solution approach, we will use a simple example of a distributor with three warehouses and six customers. Because of the simple structure of the transportation problem, it is easier to visualize the problem in matrix form as shown below:

Table 4: Transport Matrix Model

Sources (Plants)	**Destinations (Depots)** 1		**2**		**3**		**4**		**5**		**6**		**Available Goods**
A			H	H	J	J	K	K	L	L	N	N	:v
B	H	H	HH	HH	HJ	HJ	HK	HK	HL	HL	HN	HN	:w
C	J	J	JH	JH	JJ	JJ	JK	JK	JL	JL	JN	JN	:x
Demands for Goods	<v		<w		<x		<Y		<z		<[		

4.0 Findings and Discussion:

The suggested model was created using a typical Excel solver tool so that Nigerian small-scale farmers may easily use it to determine the ideal nutrition combination and improve the performance of their poultry. Tables 5 through 10 highlighted the disparity between the indicated optimum composition and the formulation already in use.

4.1 Old and New ration feed for starter broiler

Table 5: Old and New ration feed for starter broiler

Decision Variables	Objective Coefficient	Existing ration formulation		Proposed optimal ration formulation	
Ingredients	Cost (₦/kg)	Quantity (kg)	Cost (₦)	Quantity (kg)	Cost (₦)
Maize, x1	58.01	50	2900.01	31.27	1813.66
Soyabean, x2	150.01	35	5250.01	30.52	4578
Wheat bran, x3	60.01	10	600.01	29.03	1741.8
Oyster shell, x4	15.01	3	45.01	8.36	125.4
Bone meal, x5	50.01	2	100.01	0.00	0
Salt, x6	90.01	0.3	27.01	0.30	27
Lysine, x7	700.01	0.1	70.01	0.16	112
Methoinine, x8	1300.01	0.1	130.01	0.06	78
Premix, x9	550.01	0.3	165.01	0.30	165
Total		100	9, 287.09	100	8, 640.8601

Table 6: Sensitivity analysis of the proposed optimal feed ration for starter

Cell	Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
B20	SOLUTION X1:Maize	31.2701	0.00	58.01	169.6297923	21.16223288
C20	SOLUTION X2:Soya beans	30.5201	0.00	150.01	202.4343262	75.0904473
D20	SOLUTION X3:Wheat bran	29.0301	0.00	60.01	16.8971673	116.1742835
E20	SOLUTION X4:Oyster shell	8.3601	0.00	15.01	31.73785688	3832.568681
F20	SOLUTION X5:Bone meal	0.00	57.3401	50.01	1E+30	57.34035672
G20	SOLUTION X6:Salt	0.3001	0.00	90.01	1E+30	1E+30
H20	SOLUTION X7:Lysine	0.1601	0.00	700.01	3650.304956	448.1822994
I20	SOLUTION X8:Methionine	0.0601	0.00	1300.01	120829.4719	1067.903732
J20	SOLUTION X9:Premix	0.3001	0.00	550.01	1E+30	1E+30

Constraints

Cell	Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
K8	DEMAND LHS	100	42.59691125	100	22.04010174	20.13307524
K9	SALT LHS	0.3	47.40308875	0.3	20.13307524	0.3
K10	PREMIX LHS	0.3	507.4030888	0.3	20.13307524	0.3
K11	CALCIUM LHS	1.86	-131.4138631	1.86	4.227945799	1.554450857
K12	FATS LHS	2.319015507	0	3.55	1E+30	1.230984493
K13	CRUDE FIBRE LHS	4.09	-760.5812226	4.09	0.856886702	0.645018371
K14	PHOSPHATE LHS	1.969306265	0	0.58	1.389306265	1E+30
K15	LYSINE LHS	1.26	469.7115319	1.26	11.2924083	0.148780339
K16	METHIONINE LHS	0.42	1069.711532	0.42	11.2924083	0.06159284
K17	MET. ENERGY LHS	213122.3821	0	2826.39	210295.9921	1E+30
K18	CRUDE PROT. LHS	20.8701	312.8192614	20.8701	1.81952375	7.326496438

According to the availability of local feedstuffs, the starter ration of 31.2701 kg of yellow maize, 30.5202 kg of soyabean, 29.0301 kg of wheat bran, 8.360 kg of oyster shell, 0.160 kg of lysine, 0.06 kg of methoinine, 0.301 kg of salt, and 0.301 kg of premix mix is the recommended optimum ration for starter broilers. This ration provides all the nutrition a starting broiler needs. Compared to the current formulation cost of $9,287.09, the value of the ration is roughly $8,640.8601. When viewed in a bigger capacity, this cost saving amounts to around 646.1402, which is roughly 7.4801% and pretty considerable. Clearly, feed formulation that is based on reliable mathematical programming is more cost-effective.

The excess resources (fat, metabolizable energy, and phosphate) have shadow prices that are visible to be zero. That suggests that there isn't any economic benefit to assigning an additional amount of that resource, whereas an increase in the quantity of the remaining supplies will lead to a rise in the objective function value to the extent of the shadow price. For example, within the permitted rise and decrease, a unit rise in the total amount of feed output will result in a 42.59 increase in the target value. The outcomes from the Excel Optimizer software are displayed in the tables below in rows 7 through 9:

Table 7: Current and proposed ration formulations for starting broilers' chemical compositions

Chemical composition of ration	**Existing ration formulation**	**Proposed optimal ration formulation**
Crude Protein	20.8701	20.8702
Fats	3.5501	2.3201
Available Phosphate	0.5801	1.9701
Lysine	1.2601	1.2602

Crude Fibre	4.0901	4.0901
Calcium	1.8601	1.8601
Methionine	0.4201	0.4202
Metabolizable Energy	2,826.3901	213,122.402
Cost	₦ 9, 287.09	₦ 8, 640.8602

4.2 Current and Planned Finisher Broiler Ration Formulations Table 8: Current and Planned Finisher Broiler Ration Formulations

Decision Variables	**Objective Coefficient**	**Existing ration formulation**		**Proposed optimal ration formulation**	
Ingredients	Cost (₦/kg)	Quantity (kg)	Cost (₦)	Quantity (kg)	Cost (₦)
Maize, x1	58.01	50	2900	25.09	1455.22
Soyabean, x2	150.01	30	4500	24.16	3624
Wheat bran, x3	60.01	14	840	39.95	2397
Oyster shell, x4	15.01	4	60	9.97	149.55
Bone meal, x5	50.01	2	100	0.00	0
Salt, x6	90.01	0.3	27	0.30	27
Lysine, x7	700.01	0.1	70	0.18	126
Methoinine, x8	1300.01	0.1	130	0.04	52
Premix, x9	550.01	0.3	165	0.30	165
Total		100	8, 792	100	7, 995.77

Table 9: Sensitivity analysis and the suggested finisher formulation ratio

Cell	**Name**	**Final Value**	**Reduced Cost**	**Objective Coefficient**	**Allowable Increase**	**Allowable Decrease**
B20	SOLUTION X1:Maize	25.0901	0.00	58.01	169.6297923	21.16223288
C20	SOLUTION X2:Soya beans	24.1601	0.00	150.01	202.4343262	75.0904473
D20	SOLUTION X3:Wheat bran	39.9501	0.00	60.01	16.8971673	116.1742835
E20	SOLUTION X4:Oyster shell	9.9701	0.00	15.01	31.73785688	3832.568681
F20	SOLUTION X5:Bone meal	0.00	57.3401	50.01	1E+30	57.34035672
G20	SOLUTION X6:Salt	0.3001	0.00	90.01	1E+30	1E+30

H20	SOLUTION X7:Lysine	0.1801	0.00	700.01	3650.304956	448.1822994
I20	SOLUTION X8:Methionine	0.0401	0.00	1300.01	120829.4719	1067.903732
J20	SOLUTION X9:Premix	0.3001	0.00	550.01	1E+30	1E+30

Constraints

Cell	Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
K8	DEMAND LHS	100	42.59691125	100	29.73687182	16.15136586
K9	SALT LHS	0.301	47.40308875	0.301	16.15136586	0.3
K10	PREMIX LHS	0.301	507.4030888	0.301	16.15136586	0.3
K11	CALCIUM LHS	2.201	-131.4138631	2.201	3.39178683	2.030084858
K12	FATS LHS	1.84913525	0	3.5101	1E+30	1.66086475
K13	CRUDE FIBRE LHS	4.1101	-760.5812226	4.1101	0.61767965	0.887621745
K14	PHOSPHATE LHS	2.37440899	0	0.5601	1.81440899	1E+30
K15	LYSINE LHS	1.1601	469.7115319	1.1601	9.059113711	0.176494031
K16	METHIONINE LHS	0.401	1069.711532	0.401	9.059113711	0.044398686
K17	MET. ENERGY LHS	191917.2968	0	2766.6701	189150.6268	1E+30
K18	CRUDE PROT. LHS	19.2501	312.8192614	19.2501	2.158451067	5.800384248

In addition, the optimal ration suggested for finisher broilers is made up of 25.0901 kg of yellow maize, 24.1601 kg of soy, 39.9501 kg of wheat straw, 9.9701 kg of oyster shell, 0.1801 kg of lysine, 0.0401 kg of methoinine, 0.301 kg of sodium chloride, as well as 0.301 kg of premix mix, depending on the availability of local feedstuffs. This ration provides all the nutritional requirements of the finisher broiler. In comparison to the existing formulation cost of $8,792.01, the ration costs roughly $7,995.77. When included into a larger capacity, this cost savings comes to about $796.2301, or about 9.96%. This is also economical when based on strong mathematical programming. As can be observed, there are no shadow prices for the excess components (fat, metabolized energy, and phosphate). It implies that increasing the allotment of that resource has no positive economic effects, while increasing the allotment of the additional resources will increase the objective value to the point where it is equivalent to the shadow price. A unit boost to the overall amount of feed generated, for instance, will lead in a 42.59 rise in the objective function value within the range of rise and fall allowed.

Table 10: Current and proposed ration formulations for finisher broilers' chemical compositions

Chemical composition of ration	Existing ration formulation	Proposed optimal ration formulation
Crude Protein	19.2501	19.2501
Fats	3.5101	1.8501

Available Phosphate	0.5601	2.3701
Lysine	1.1601	1.1601
Crude Fibre	4.1101	4.1101
Calcium	2.2001	2.2001
Methionine	0.4001	0.4001
Metabolizable Energy	2,766.6701	191,917.301
Cost	₦ 8, 792.01	₦ 7, 995.7701

4.3 Set up of the Transportation Model

For an efficient and thorough distribution (transportation) model, we begin by displaying the prices of a bag of the new food ration, which weighs 25.01kg, in a few chosen locations (deports from plants) (sources). We presumptively included the cost of shipping goods from farms to distribution centers in the price of purchasing a bag of food from farms.

Table 11: Estimate Costs of a bag of poultry feed per depot as at 17th July, 2022 in Naira.

Source\Deports	**Ikire**	**Ijebu Ode**	**Otta**	**Osogbo**	**Owo**
Ibadan	₦8800	₦8850	₦8950	₦8500	₦8850
Abeokuta	₦8900	₦8800	₦8830	₦8900	₦8950
Akure	₦8960	₦8990	₦9000	₦8840	₦8810

For easy computation we convert the transportation costs in Table 4.1 to US dollars using the standard exchange rate as at July 15, 2022.

1 NGN = 0.0024USD

1 USD = 415.33NGN

NGN= Nigerian Naira

USD = United States Dollars

(source: www.xe/currencyconverter/amount...)

Table 12 Costs of a bag of Ration Feed per Deport in USD at the CBN official rate

Source\Deports	**Ikire**	**Ijebu Ode**	**Otta**	**Osogbo**	**Owo**
Ibadan	21.19	21.31	21.55	21.31	21.31
Abeokuta	21.43	21.19	21.26	21.43	21.55
Akure	21.57	21.65	21.67	21.28	21.21

The table below shows the costs of transporting a 25kg bag of the new rationing feed from sources to deports as displayed in the right corners of the table.

Table 13 Costs of transporting a bag of Ration Feed from a Source to Deport in Naira

Sources\Deports	Ikire	Ijebu-Ode	Otta	Osogbo	Owo	Plants Capacity (bags)
Ibadan	100.21	235.71	256.95	300.71	464.29	**8000**
Abeokuta	220.16	100.50	100.50	364.11	350.00	**10000**
Akure	300.00	400.00	464.29	250.00	75.00	**12000**
Depot requirements	**8000**	**6000**	**5000**	**5000**	**6000**	**30000**

Since the total number of demand (depot requirements) is equal to the total estimated capacity for the 5 depots the transportation problem is balanced, hence we construct the initial transportation problem using the Northwest Corner Method.

Table 14 for Tableau 1 the for Northwest Corner Method

Sources\Deports	Ikire	Ijebu-Ode	Otta	Osogbo	Owo	Plants Capacity (bags)
Ibadan	8000	235.71	256.95	300.71	464.29	8000-8000 = 0
Abeokuta	220.16	6000	4000	364.11	350.00	10000-10000 = 0
Akure	300.00	400.00	1000	5000	6000	12000-12000 = 0
Depot requirements	8000-8000 = 0	6000-6000 = 0	5000-5000 = 0	5000-5000 = 0	6000-6000 = 0	**0**

The first row indicates that a total of 8000 bags of ration feed per day were delivered to Ikire from the Ibadan plant, and because this fills the needs of the depot, we proceed to the next location, Ijebu Ode, and empty the remaining anticipated plant capacity there. It continues in this manner until all necessary demands are satisfied and all available bags at sources are emptied, regardless of the cost per location from a source. Second row receives the supply of 6000 bags of the fresh feed to Ijebu Ode depot to satisfy the depot requirements:

Table 15. Computing the cost of shipment of the allocation of goods to Deports from Sources

From Sources To:	Bags shipped x Per Unit Cost	Total cost (₦)
Ikire	8000 x 100.21	801680.00
Ijebu Ode	6000 x 100.50	603000.00
Otta	4000 x 100.00	400000.00
Otta	1000 x 464.29	464290.00
Osogbo	5000 x 250.00	1250000.00
Owo	5000 x 75.00	375000.00
Total Cost on Transportation		**2768970.00**

The solution is practical provided that the supply and demand limitations are met. However, the shipping costs along each of the routes were completely disregarded by this route-leading methodology, resulting in a high distribution (transportation) cost of **2768970.00** naira. Finally, we apply the Vogel Approximation Method, also known as the Least Penalty Method, to see if the outcome of the North-West Corner strategy is the best distribution for lowering transportation costs.

4.4 Vogel Approximation Optimal Result

The first Vogel approximation table is produced from Tableau 1.1 by adding some sets of integers V and J to the top row and right column so that V+J equals the cost of transportation in each cell where the first Tableau allocated items, and then adding the other cells as shown below:

Table 16 for Tableau 2 – VAM 1

	V	**-200.21**	**-210.00**	**0.50**	**-213.79**	**-388.79**
	J	**Ikire**	**Ijebu-Ode**	**Otta**	**Osogbo**	**Owo**
Ibd.	**100.00**	100.21 6	-110.00	100.50	-113.79	-288.79
Abk.	**99.50**	-100.71	100.50	100.0 0	-114.29	-289.29
Akr.	**463.79**	263.58	253.79	464.29	250.00	75.00

As illustrated in the following Tableau, we now deduct each sum from the transportation expense across the remaining cells where allocations were made and not made:

Table 17 for Tableau 3 – VAM 2

V		**-200.21**	**-210.00**	**0.50**	**-213.79**	**-388.79**
J		**Ikire**	**Ijebu-Ode**	**Otta**	**Osogbo**	**Owo**
Ibd.	**100.00**	0	345.71	156.45	414.50	753.08
Abk.	**99.50**	320.87	0	0	478.40	639.29
Akr.	**463.79**	36.42	146.21	0	0	0

Tableau 3 - VAM 2 shows that there are no negative entries following the most recent operations, which only indicates that the initial distributions and allocations made using the North-West Corner Method produced the best results and that there is no need to continue optimizing the distribution network.

Computing the optimal solution cost of shipment of the distribution of the new food ration

From Sources To:	**Bags shipped x Per Unit Cost**	**Total cost (₦)**
Ikire	8000 x 100.21	801680.00
Ijebu Ode	6000 x 100.50	603000.00
Otta	4000 x 100.00	400000.00
Otta	1000 x 464.29	464290.00
Osogbo	5000 x 250.00	1250000.00
Owo	5000 x 75.00	375000.00
Total Cost on Transportation		**2768970.00**

Adding together all the distribution expenses for the new food restrictions comes to **N2,768,970.00**, or **$666.92** USD.

5.0 CONCLUSION

In the best-case scenario, a linear (LP) Simplex Method design for broiler nutritional meals (starter and finisher) has been shown to be effective in reducing the total cost of production used in this research (N7995.77 production costs as compared to the old portion N8792.00 production costs) and optimizing the model. Manufacturers charge N8450.00 (transportation costs included) for distribution to deport owners; deports charge N8500.00 to retailers; retailers charge N8550.00 to farmers; and each innovator continues to make the corresponding profits. To ensure that the resulting solution is both affordable and suitable for starter and finisher broiler chicks, additional restrictions can be added to the suggested optimal model, which is flexible and adaptable. We also observe that the manufacturers could establish an ideal network of distributions of the finished and packaged 25kg bags of the new rations from the three plants (Ibadan, Abeokuta, and Akure) to five different ports where retailers can buy from (Ikire, Ijebu Ode, Otta, Osogbo, and Owo), which minimizes the cost of transportation for the business' investors. It is currently recommended to conduct more study in the field of model modification to include major natural compounds as a replacement for some of the expensive chemicals, such as premix, lysine, and methionine, because they also serve the same nutritional purpose.

REFERENCES

1. Adebayo, O.O. and R.G. Adeola, (2005), *Socio-Economic Factors Affecting Poultry Farmers in Ejigbo Local Government Area of Osun State*, J. Hum. Ecol., 18(1): 39-41
2. Afolayan, M.O. and M. Afolayan, (2008),*Nigeria Oriented Poultry Feed Formulation Software Requirements,* Journal of Applied Sciences Research, 4(11): 1596-1602
3. Alimon, A.R. and M. Hair-Bejo, (1995),*Feeding systems based on oil palm by-products in Malaysia. In: Proceedings of the First Symposium on the Integration of Livestock to Oil palm production,* Kuala Lumpur, Malaysia, 105-113.
4. Arbor Acres (2009). *Broiler Nutrition Supplement*, Aviagen IncorporatedCummings Research Park, 5015 Bradford DriveHuntsville, AL 35805 USA
5. Anders S. and Bernhard T (1997): *A framework efficiency model for goods transportation with an application to regional less than truckload distribution,* Transport Logistics, Vol 1, No 2, pp 139 – 151.
6. Bassam Al-Deseit (2009). *Least-Cost Broiler Ration Formulation Using Linear Programming Technique*, Journal of Animal and Veterinary Advances, Volume 8, Issue 7 pp 1274-1278.
7. Castrodeza, C., P. Lara, and T. Pena, 2005. *A Multicriteria fractional model for feed formulation: economic*, nutritional and environmental criteria. Agricultural Systems 86 76–96
8. Dantzig G.B. (1990). *The Diet Problem*. Article Interfaces 20(4), 1990, 43-47.
9. Dogan, I., N. Dogan, A. Akcan, (2000),*Using Goal Programming in Rational and Economical Animal Nutrition,* Turk J Vet Anim Sci 24: 233–238.
10. GunasekarK. R. (2007). *Formulating Feed for Broiler Performance*, Courtesy of Avitech Animal Health Pvt. Ltd. Unpublished.
11. Gupta P.K. and Hira D.S. (2009). Operations Research. Revised and Reprinted Ed. ISBN: 81-219-0281-9. Published by S. Chad & Company Ltd.
12. Hossameldin Hamed Mansour and Mohammed Al-Mahish (2019), *A Linear Programming Approach to Minimizing Broiler Ration Costs: The Case of Broiler Farms in Al-Ahsa, Saudi Arabia,* Scientific Papers Series Management, Economics Engineering in Agriculture and Rural Development, Vol 19; Issue 3, 2019, pp: 393-398, Print ISSN: 2284-7995, E-ISSN: 2285-3952.
13. Jakia Sultana, Md. Mehedi Hasan, Samiha Islam Tanni, Umme Ruman, Shamima Islam (2022), *An Approach to Diet Cost Optimization for Different Age Groups Using Linear Programming,* Open Access Journal, Vol 9. No. 1 January 2022. ISSN Online: 2333-9721, ISSN Print: 2333-9705. https://doi.org/10.4236/oalib.1107905.

14. Kamalakanta Muduli, John Rimwa, Jitendra Narayan Biswai (2020), *Broiler Poultry Feed Cost Optimization Using Linear Programming Technique,* Journal of Operations and Strategic Planning, February 2020. https://doi.org/10.1177/251660X1989610.
15. Labier, M., and B. Leclercq, (1994). Nutrition and feeding of poultry. Nottingham University Press, Loughborough, Leicestershire, England.
16. Longe, O.G., (1984),*Effects of Increasing the Fibre Content of a Layer Diet*, Brit. Poult. Sci. 25:187-193.
17. National Academy PressWashington, D.C. (1994),Nutrient Requirements of Poultry. Ninth Revised Edition, Subcommittee on Poultry Nutrition Committee on Animal Nutrition Board on Agriculture National Research Council.
18. Nathaniel Kayode Oladejo (2019), *Application of Optimization Principle in Landmark University Project Selection Under Multi-Period Capital Rationing Using Linear and Integer Programming,* Open Journal of Optimization, Vol. 8, No. 3, September, 2019.
19. Okonkwo, W.I., and C.O. Akubuo, (2001), *Thermal Analysis and Evaluation of Heat Requirement of a Passive Solar Energy Poultry Chick Brooder in Nigeria*, Journal of Renewable Energy, 9: 1
20. Oladokun,V.O.and Johnson, A. (2012), *Feed Formulation Problem in Nigerian Poultry Farms: A Mathematical Programming Approach,*American Journal of Scientific and Industrial Research ISSN: 2153-649x doi:10.5251/ajsir.2012.3.1.14.20.
21. Olorunfemi, T.O.S., (2007),*Linear Programming Approach to Least-Cost Rations Formulation for Poultry*, Information Technology Journal,Vol. 6, Pp: 294-299.
22. Rardin, R.L., (1998),Optimization in Operations Research. Prentice Hall
23. Sahman, M.A., M. Cunkas, S. Inal , F. Inal, B. Coskun,and U. Taskiran, (2009),*Cost Optimization of Feed Mixes by Genetic Algorithms*, Advances in Engineering Software 40 965–974
24. Samuel, O. O., Olusegun, A. O., Adebimpe, O. A. and Akinbowale, T. T. (2015), *Optimized Nutrients Diet Formulation of Broiler Poultry Rations in Nigeria Using Linear Programming,* Journal of Nutrition and Food Sciences, S14, 1-6, https://doi.org/10.4172/2155-9600. S14 - 002.
25. Taha, H.A., (2007),Operations Research: An Introduction. 8th ed. Pearson Education, Inc., USA
26. Tizik A.P. and Tsurkov V.I. (2012), *Iterative Functional Modification Method for solving a Transportation Problem,*Automation and Remote Control, Vol 73, no 1 pp 134 - 143

General Comment

The paper is generally too worded and appear too verbose unnecessarily. The line spacing appears absurd and the author should be advised to follow the laid down rules of journal on font size and spacing.

The analysis is unnecessarily too robust for a journal paper. It should be concise and precisely addressing important aspect of the subject matter of discussion.

There are quite a number of typographical errors and semantic problems that needed to be fixed.

Author’s Comment

The paper is a two-in-one study that tries to improve food rationing for poultry farmers at minimized product cost using the Simplex method via Excel Solver and at the same time the transportation model incorporated into the study played significant role in minimizing the cost distribution (transportation) from the plants (sources) to deports (destinations). This is main reason for the size of the paper and the analysis were the outputs from the software used, Excel Solver. All the typographical errors highlighted by the Reviewer had been taken care of. In general, I appreciate the good work of the Reviewer on this article.