Trop. J.Anim. Sci 2(1): 137- 147 (1999)
ISSN: 1119-4308

Livestock Feed Optimization Model (LFOM): A new tool based on Linear Programming for formulating least cost rations for poultry

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Target Audience: Feed manufacturers and poultry farmers

ABSTRACT

A model, Livestock Feed Optimization Model (LFOM) based on Linear Programming (LP) was developed. The essence of the model was for cost minimization in formulating poultry diets. The model was used to formulate a least cost ration for laying birds.

The performance of 75 Haco Black point of lay birds on the least cost ration (LCR) so formulated and two commercial diets was compared. Feed intake was significantly ($P < 0.05$) lower for birds on the LCR. Birds on the LCR also had better efficiency ($P < 0.05$) hence higher hen-day production.

Birds on the commercial diets had higher ($P < 0.05$) egg weight than those on the LCR. Egg shell thickness and egg surface index did not differ significantly between the treatment diets.

The LCR costed N6.40/kg less than the commercial diet. This comes to N160.00 less for a 25kg bag or N640.00 less per tonne of feed. Weekly revenue and profit from egg sale were higher for birds on the LCR than for those on the commercial diets.
Results showed that the LFOM so developed is an effective and flexible tool for minimizing cost or maximizing profit in poultry production.

Key words: Optimization model, least cost rations, layers

DESCRIPTION OF PROBLEM

The livestock feed industry in Nigeria is faced with a lot of problems. The monogastric subsector has been particularly hard hit because of its reliance on formulated concentrates and other conventional feed ingredients. The attendant low demand for poultry products as a result of the low expendable income of the populace has contributed also to the drop in poultry production.

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The poultry population in the country for example has dropped from over 40 million in 1983 to the current number of 6 million. All these factors are responsible for the insignificant value of 3.24g caput/day contributed by livestock products to the FAO recommended minimum of 35g caput/day of animal protein intake (1). One of the ways to ameliorate this problem is through the production of cheaper feeds. Whereas budgeting approach has been used to arrive at an amount that could be lower than that for conventional feeds, this approach has still not solved the problem of feed cost.

The Linear Programming (LP) approach for the development of a model or software for the optimization of monogastric feed production seems a viable alternative. The approach tries to look at the best combination of the different ingredients with an objective of cost minimization. This study was designed to assess the performance of laying birds on a least cost diet, formulated using a Linear Programming software. The performance of the birds was then compared with those on two commercial diets.

MATERIALS AND METHODS

Assumptions of Linear Programming

In using the Linear Programming to evolve an optimization model, five major assumptions are essential. These are:

Additivity assumption: This states that the activities must be additive such that when two or more inputs are used, their total product must be equal to their individual products.

Linearity assumption: This implies that the input-output ratios are constant and independent of scale. In essence, they can be added as series of liner equalities and/or inequalities.

Divisibility assumption: This entails that factors are used and outputs produced in quantities are factorial units. This is interpreted by considering resources and products as being infinitely divisible into factorial forms.

Fitness assumption: This means that there is a limit to the number of alternative activities and the resource restrictions that must be considered.

Single-valued expectations assumption: i.e. resource supplies, input-output coefficients and prices are known with certainty.

Steps in building the model

Step 1: Formulation and statement of the objectives.

Step 2: Identification and particularization of pertinent variables which constitute the core of the `model building' in LP

Step 3: Formulation of available strategies since LP problems are typified by an infinite number of available strategies.

Step 4: Prediction by pay-offs since in LP problems all variables are assumed to have no effect on the pay-offs which can be predicted with certainty for each possible strategy.

Step 5: Making the final decision by applying a test of optimality for identification by optimum LP solution that represents the specific strategy which either maximizes or minizes the objective function.

Input Data

The input data were based on:

i) the prices of all the conventional and non-conventional feed ingredients to be used in the model.

ii) the nutrient composition of the ingredients

iii) the nutrient requirements of livestock based on the NRC recommendations or reported requirements in literature pertaining to a specific regional location.

The Model

If there are n ingredients represented by $X_1, X_2, X_3, X_4 \ldots X_n$ with respective prices $P_1, P_2, P_3, P_4 \ldots P_n$, then to minimize the objective function, the problem can be represented thus:

$$A = \sum_{j=1}^{n} PjXj$$

Where A = cost of formulated ration

Pj = net price per unit of $X_1, X_2, X_3, X_4 \ldots X_n$

Xj = level of $X_1, X_2, X_3, X_4 \ldots X_n$

Each class and species of livestock has its specific requirements of nutrients for optimal production. The requirements are the constraints in the LP model. They take the form of inequalities (2) which means that the total requirements for any nutrient must be equal to or less than the total amount of that nutrient available in all the ingredients in the ration. Thus if it is desired that energy level in the ration must be less than or equal to the percentage energy of the respective ingredients (i.e. $X_1, X_2, X_3, X_4 \ldots X_n$), this can be stated as follows:

$$\text{Energy} \leq \sum_{j=1}^{n} lijXj$$

and for protein:

$$\text{Protein} \leq \sum_{j=1}^{n} mijXj$$

Thus a model specifying precisely 3 percent of a nutrient per tonne of ration can be expressed as follows:

$$0.03 \sum_{j=1}^{n} RjXj$$

For a range of between 3-10 percent per tonne, the symbolic representation is

$$0.03 \sum_{j=1}^{n} PijXj$$

$$0.10 \sum_{j=1}^{n} PijXj$$

This means that the nutrient or ingredient should be included at a level not less than 3 percent and not more than 10 percent.

These information were then used to build the model. The software so developed Livestock Feed Optimization Model (LFOM) was used to formulate a least cost diet in which maize and soyabean meal were incorporated at only 18.0% and 2.50% respectively. The proximate composition of the least cost ration and the two commercial diets are shown in Table 1.

Table 1: Proximate Composition of experimental diets

Nutrient	Commercial diet 1	Commercial diet 2	Least cost ration
Moisture (%)	5.80	4.83	5.24
Ash (%)	17.52	15.16	20.99
Crude Protein (%)	17.00	17.15	17.2
Crude fiber (%)	6.58	5.76	7.26
Ether Extract (%)	3.35	3.20	3.88
Nitrogen free extract (%)	49.75	53.90	45.43
Metabolizable energy (Kcal/kg)	2300.00	2314.00	2316.00

Thus for many ingredients the problem can be represented as

$$A = \sum_{j=1}^{n} PjXj$$

According to (2), this is subject to

$$di \leq \sum_{j=1}^{n} lijXj$$

where

di = the level of the ith nutrient

lij or mij = the per unit content of the ith nutrient in the jth ingredient

xj = the level at which the jth ingredient comes into the model and > 0

xj>0 = means that of X_1, X_2, X_3, X_4 .....or X_n should be more than 0.

In order to make the model flexible so as to get formulations that are nutritionally acceptable, the model was structured to permit for ingredient or nutrient level specificity.

Feeding Trial

Seventy five Haco Black strain point of lay birds were randomly distributed to three experimental diets in groups of twenty five with 5 replicates and 5 birds per replicate. Diets 1 and 2 were two different commercial diets purchased from the local retail agents of the two manufacturers. Diet 3 was the self formulated least cost ration. The birds were housed in steel battery cages in an open sided house with wire netting, good ventilation and 12 hours of day light. Weighed quantities of the diets were given to the birds *ad libitum* and daily refusals were pooled weekly and used to compute the weekly feed intake. The birds had unrestricted access to water. Eggs were collected daily and marked for proper identification according to treatment diets and replicates. The body weights of the birds were recorded at the beginning, middle and end of the experimental period. The study lasted for 12 weeks. All data were statistically analysed by the ANOVA method (3). Treatment means were compared by the multiple range test (4).

RESULTS AND DISCUSSION

The results of performance of layers on the experimental diets are shown in Figure 1 and egg production pattern is shown in Figure 2. Feed intake was significantly lower ($P < 0.05$) for birds on the least cost ration than for those on the other diets. The efficiency of feed utilization was also significantly ($P < 0.05$) better for birds on the least cost ration. This is because birds on this diet had significantly ($P < 0.05$) higher hen-day production and hence higher weekly egg production (Figure 2).
The egg weight of birds on the commercial diets was significantly higher ($P < 0.05$) than for those on the least cost diet. But there was no significant difference in shell thickness and egg surface index of eggs among the treatment diets (Table 2).

Table 2: Cost of egg production of layers on experimental diets

Parameters	Commercial diet 1	Commercial diet 2	Least Cost ration (LCR)	SE
Weekly feed intake (kg)/ 25 birds	19.6	20.47	18.72	
Cost of weekly feed intake (N)	458.64	476.95	317.90	
Egg shell thickness (mm)	0.35^{a}	0.36^{aa}	0.36^{aa}	±1.2
Weekly revenue (N)*	574.15	712.02	768.57	
Egg weight (gms)	52.15^{b}	53.12^{a}	50.63^{c}	±1.80
Weekly profit (N)	115.51	235.07	450.67	

* Price per tray of eggs at time of study = ₦170.00
Means with different superscripts are significantly different ($P< 0.05$).

Cost of egg production is shown in Figure 3. 1 kilogram of the least costed feed cost N6.40 less than the commercial feed. Consequently, the weekly cost of feed intake was lowest on the least cost diet. Weekly revenue and profit realised from sale of eggs on the least cost diet was higher than for the commercial diets (Figure 3).

The use of LP as a tool for providing a programme for least cost ration formulation is one of the recent advances made in livestock nutrition research. The advantage of using least cost ration has been reported (2). This author found computerised starter and finisher diets were cheaper and performed better than commercial diets. The significant lower feed intake and feed efficiency of birds on the least cost ration resulted in higher hen-day and weekly egg production of the birds. The significant difference observed in egg

Figure 1. Performance of birds on experimental diets

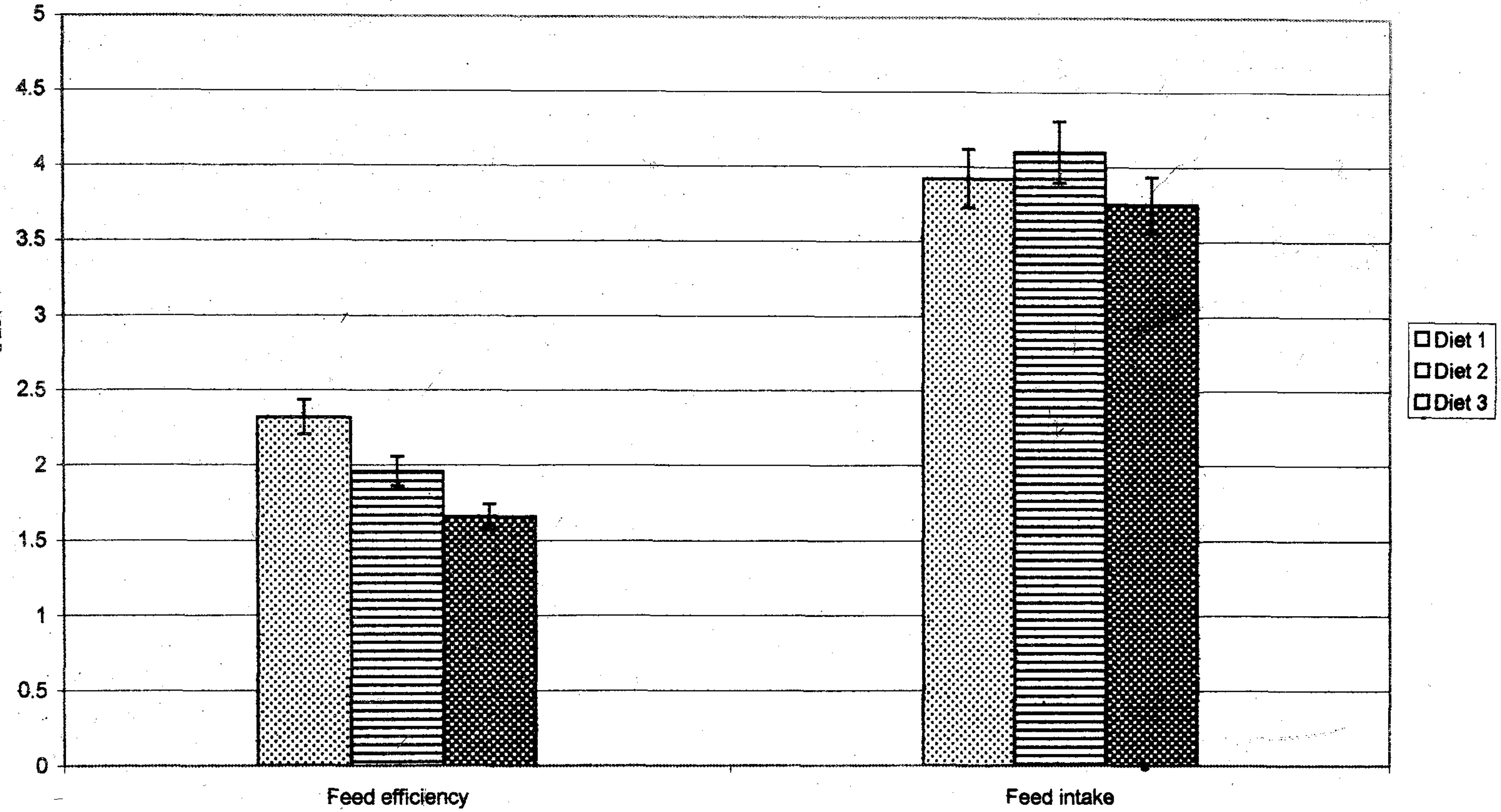


Figure 2. Egg production of birds on experimental diets

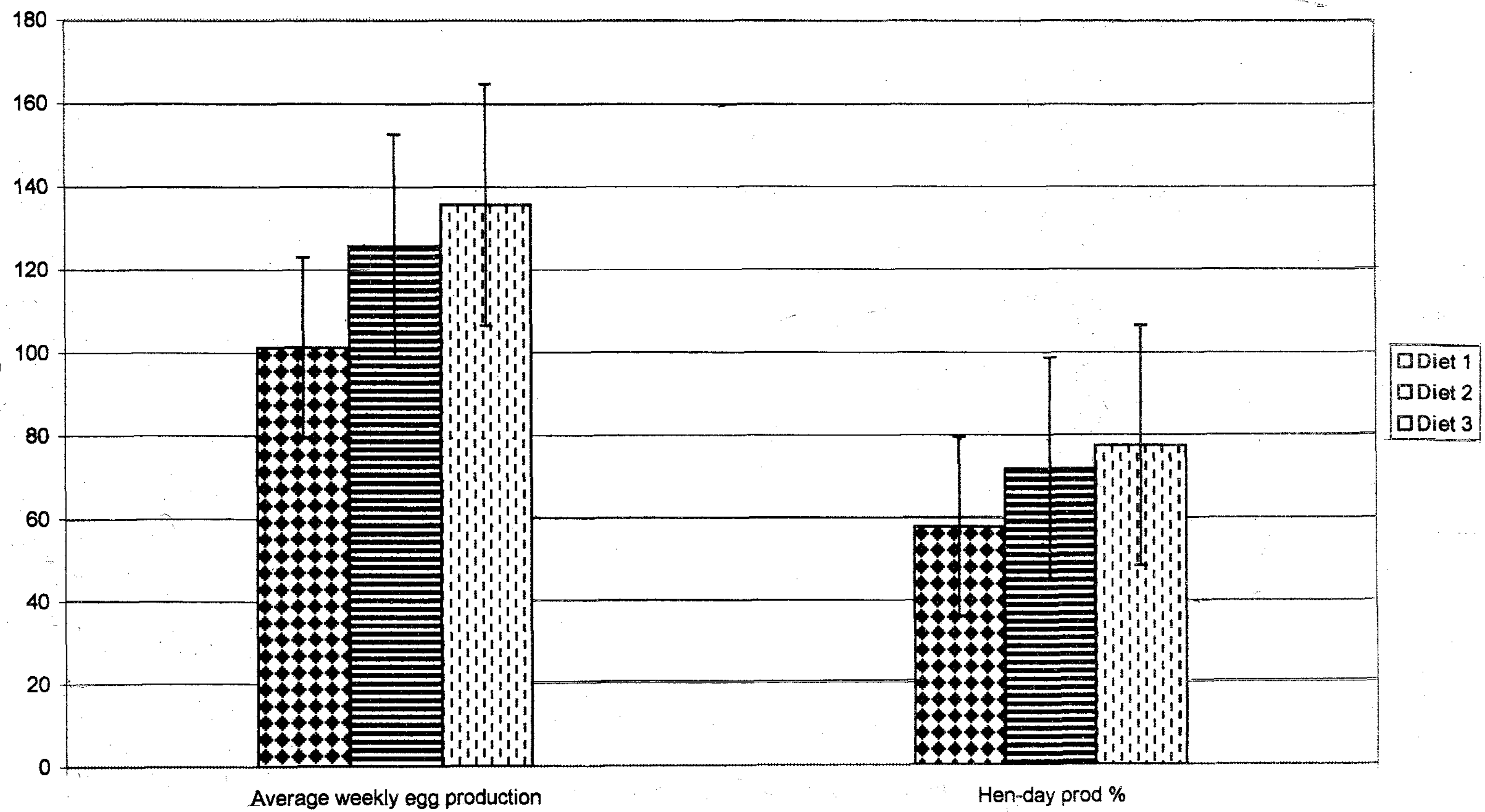
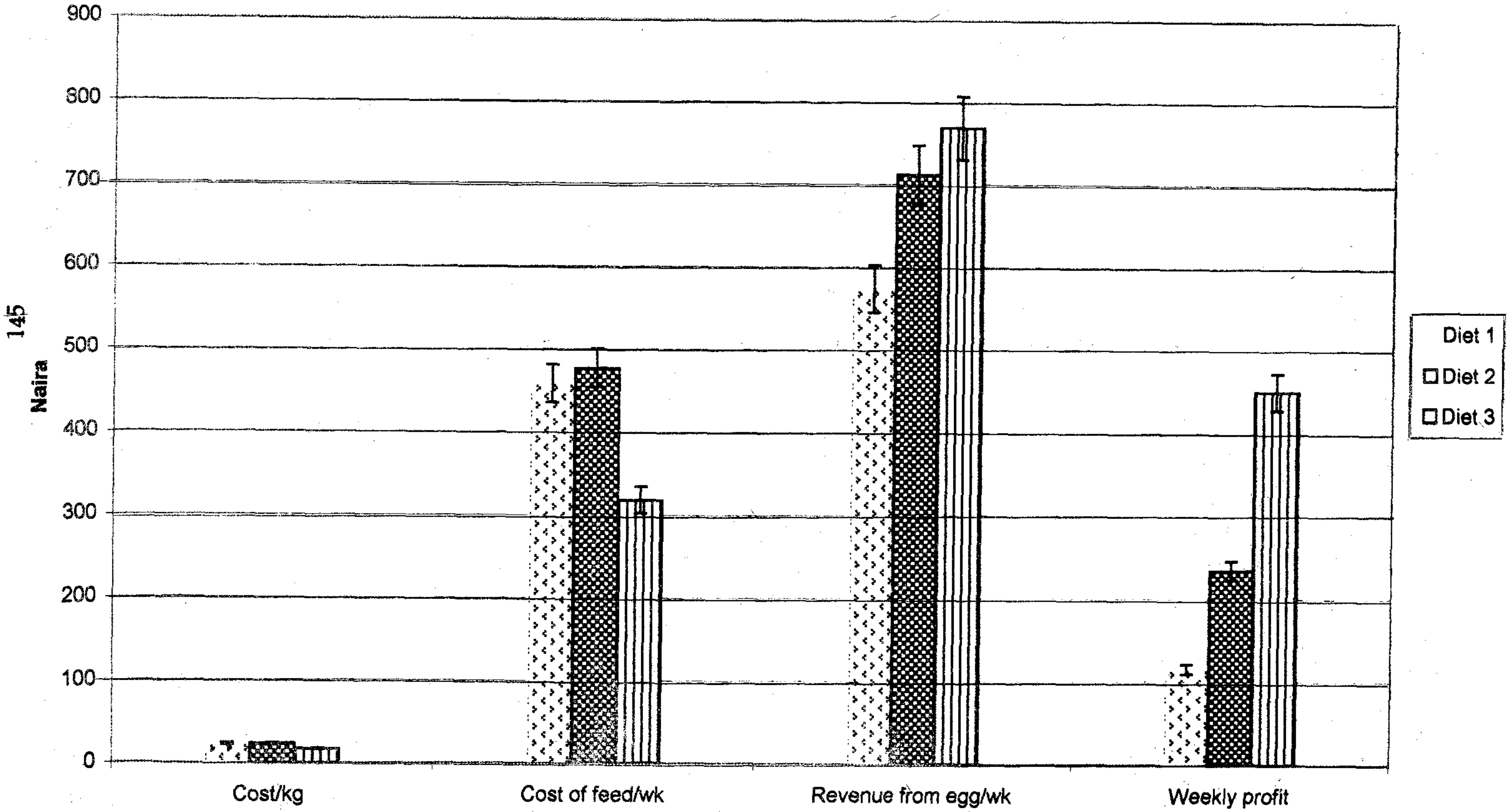


Figure 3. Cost of egg production on experimental diets



weight might be due to the absence of methionine in the least cost ration. Methionine in feed usually results in larger eggs and since supplemental methionine and lysine were not included in the least cost ration, the birds on this ration produced eggs with lower mass. The economic advantage of least cost ration for poultry production has also been reported by several authors. Successful use an LP tool to formulate least cost starter ration according to the ratio between protein quality value and energy content has been reported (5). Also an examination of methods and procedure involved in the use of LP to determine several types of least-cost poultry rations including chick starter, turkey starter, layer and broiler rations (6) suggested that the results were only as reliable as the input data used. Results of the present study are in line with earlier one (7) of a successful use of least-cost ration for swine production.

CONCLUSION AND APPLICATIONS

Results of the present study show that Livestock Feed Optimization Model (LFOM) is an effective tool for formulating least cost ration. Egg production of birds on the least cost ration was found to be better than for the two commercial diets. Results of the study could be adopted by feed manufacturers or poultry farmers who engage in producing their feeds.

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