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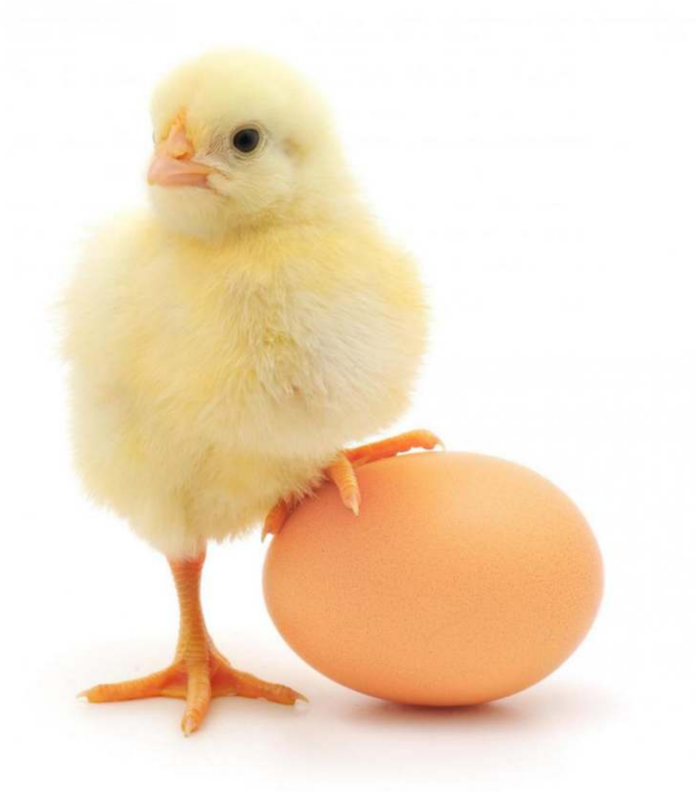

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Research Article

Technical Efficiency of Battery Cage and Deep Litter Systems in Poultry Production

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Abstract

Background and Objective: The importance of the poultry industry to the national economy cannot be overemphasized. Approximately 10% of the Nigerian population is engaged in poultry production, mostly on subsistence and small or medium-sized farms. However, the output level still remains low compared to the input. The aim of this study was to examine the technical efficiency of the battery cage and deep litter systems of poultry production in Nigeria. **Materials and Methods:** A multi-stage sampling technique was used to select 120 battery cage farmers and 120 deep litter farmers. A well-structured questionnaire was used to collect information on the farmers and the farm characteristics. The data collected were analysed using descriptive and inferential statistics. **Results:** The budgetary analysis showed that the net profit for one bird for the battery cage farmer stood at ₦587, whereas that of the deep litter farmer was ₦635. Stochastic frontier modelling showed a higher inefficiency in the deep litter system of poultry production compared with the battery cage system. The efficiencies were 79 and 60% for the battery cage and deep litter farms, respectively. Additionally, labour and flock size contributed to the inefficiencies of both the battery and deep systems of poultry production. The Chow test (F_{cal} = 0.45 and F_{tab} = 2.3) showed that there was no structural difference in the production of the battery cage and deep litter systems in the study area. **Conclusion:** The results show that even though the two systems are profitable but the battery cage system is more profitable than the deep litter system.

Key word: Battery cage, chow test, deep litter, economic analysis, poultry production, stochastic production frontier

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Agriculture in Nigeria has remained the largest sector, contributing nearly 39% to the Gross Domestic Product and employing nearly 60% of the country's workforce for the past two decades. More than 80% of the Nigerian rural population is directly or indirectly dependent on agriculture for its livelihood[1]. The agricultural sub-sectors comprises crops, fishery, livestock and forestry. The most prominent of these sub-sectors is the crop sector, followed by the livestock, in which the poultry enterprise is most dominant. The importance of poultry to the national economy cannot be overemphasised, as it has become popular industry for the smallholder farmers who contribute to the economy. The industry has assumed greater importance in improving the employment opportunity and annual food and protein production in Nigeria[2]. A report shows that approximately 10% of the Nigerian population is engaged in poultry production, mostly on subsistence and small or medium-sized farms[3,4]. The industry or sub-sector is characterized by farmers keeping a small number of birds usually for special occasions under a free-range or scavenging system of management, which is mostly common in the greater part of Africa. In view of this, the output level remains low compared to the input committed. More importantly, poultry production remains grossly inadequate, as the supply is much lower than the demand[5,6]. The poultry industry in Nigeria falls short of its aim of self-sufficiency in animal protein consumption in the country-estimated at 5 g/capita per day - which is a far cry from the F.A.O-recommended level of 35 g/capita per day[6]. As a result of the above, widespread hunger, malnutrition and under nutrition are evident in the country. The need therefore exists to increase the production of poultry and poultry products through the adoption of technically efficient modes of production. This study therefore examines the technical efficiency of battery cage and deep litter systems of poultry production.

MATERIALS AND METHODS

To enable the study to gain insight into the appropriate way of reflecting production system in the general Cobb-Douglas production, a Chow test of structural differences in the production function of deep litter systems and battery cage systems on poultry farms was conducted. The production deferential is analysed by estimating the production function equation for deep litter system and battery cage system of poultry farms and estimating the pooled regression with an intercept shifter dummy variable (D) introduced as shown in Eq. 1[5,6]:

$$\ln Q = \beta_0+\beta_1+D_1+\beta_1 \ln X_{1i}+\beta_2 \ln X_{2i}+.....\beta_4 \ln X_4+e_I \quad (1)$$

The underlying null hypothesis for the test for structural change is stated below.

H_o : No structural difference exists between the production functions of a deep litter poultry farm production system and a battery cage poultry farm production system

The test consisted of the following three stages:

- **Test for structural change:** This is an overall test of significant differences in the structural parameters (intercepts and slopes) of the production function of the two categories of farms. The tests statistic is $F_{1-\alpha/2}$, v_1, v_2, whereas the calculated F, (F_c) was obtained as:

$$F_c = \frac{\sum_{e3^2} - \sum_{ei^2} - \sum_{e2^2}}{K_3 - K_1 - K_2} \quad (2)$$

$$= \frac{\sum_{e1^2} + \sum_{e2^2}}{K_1 + K_2}$$

Where

$\sum_{e3}{}^2$ = The error sum of the square for the pooled data without a dummy variable

$\sum_{e1}{}^2$ = The error sum of the square for the battery cage system of poultry farm production function

$\sum_{e2}{}^2$ = The error sum of the square for the deep litter system of poultry farm production function

K_3 = The degree of freedom for the pooled data

K_1 = The degree of freedom for the battery cage system of poultry farm's regression

K_2 = The degree of freedom for the deep litter system of poultry farm's regression

The calculated F statistics was compared against the tabulated F-value, $F_t = F_{o.95}$, V_1, V_2 and we rejected the null hypothesis of no structural difference in the production of poultry farms if $F_c > F_t$; otherwise, we failed to reject the null hypothesis.

Test for homogeneity of slopes: When the first test revealed that some structural differences exist in the production functions of the two sub-systems, further investigation was necessary on the nature of the structural differences. The first of this was the test for homogeneity of slope. The test statistics were $F_{1-\alpha/2}$, v_1, $F_{o.95, V1 \text{ and } V2}$, whereas the calculated F, (F_c) was calculated and defined as follows:

$$F_c = \frac{\sum_{e3^2} - \sum_{ei^2} - \sum_{e2^2}}{K_3 - K_1 - K_2}$$

$$= \frac{\sum_{e1^2} + \sum_{e2^2}}{K_1 + K_2} \quad (3)$$

Where,

$\sum_{e2}^2, \sum_{e1}^2$, K_1 and K_2 are as previously defined

$\sum_{e4}^2$ = The error sum of square for the pooled regression with an intercept dummy variable

K_4 = The degree of freedom for the pooled regression with an intercept dummy variable

This statistic was compared against the tabulated F-value, $F_t = F_{o.95, V1, V2}$ and we rejected the null hypothesis that no differences existed in the slope parameters if $F_c > F_t$; otherwise, we failed to reject the null hypothesis.

Test for differences in intercepts: The final stage of the test for structural differences in production function of the two poultry production sub-systems is the test for differences in intercepts of the production functions. The tests statistics is $F_{1-\alpha/2}$, v_1, $_{V2}$, whereas the calculated F (F_c) is defined as follows:

$$Fc = \frac{\sum_{e3^2} - \sum_{e4^2}}{K_3 - K_4} \quad (4)$$

$$= \frac{\sum_{e4^2}}{K_4}$$

where, $\sum_{e3}{}^2$, $\sum_{e4}{}^2$, K_3 and K_4 are as previously defined

This statistic was compared with the tabulated F-value, $F_t = F_{o.95}$, v_1, v_2 and we rejected the null hypothesis of no difference in the intercept production functions of the deep litter system and battery cage system farms if $F_c > F_t$; otherwise, we failed to reject the null hypothesis.

The result of the Chow test is crucial at this stage. If those results suggest significant structural differences in the two production systems, the dummy variable form of the Cobb-Douglas production function needs to be introduced. Therefore, Eq. 5, which reflects the nature of the difference becomes the following:

$$\text{In } Q_i = \beta_o + \lambda_o D_1 + \beta_1 \text{ In } X_{1i} + \lambda_o D_1 \text{ In } X_{2i} + \text{-----} \beta_4 \text{ In } X_{4i} + \lambda_4 D_i \text{ In} X_4 + e_i \quad (5)$$

where, D_i is a dummy variable that takes on the value of I if the I^{th} farm is deep litter production system and 0 if otherwise. λK (K = 0, 1, ..., 4) is the change in the parameter of the K^{th} variable for deep litter poultry production system farm;

All other variables and parameters are as earlier defined.

Stochastic production frontier and technical efficiency assessment: One of the widely used methods for assessing technical efficiency differences across production units is the stochastic production frontier approach. The stochastic frontier production function builds hypothesized efficiency determinants into the inefficiency error component so that one can identify focal points for action to bring efficiency to higher levels[7].

A stochastic production frontier, may be defined as Coelli[7]:

$$Q = f(X_i, \beta)\exp(V\text{-}U) \quad (6)$$

Where

Q_i = The output of the ith farm

x_i = Vector of inputs

b = Vector of parameters to be estimated

f(x) = Suitable functional form, such as the Cobb-Douglas or Translog

V = Symmetric random error that is assumed to account for measurement error and other factors not under the control of the farmer

u_i = Non-negative error component that accounts for technical inefficiency in production

'exp' = Stands for exponential function

In this application of the Cobb-Douglas stochastic production frontiers of poultry (eggs), the production is specified as follow:

$$\ln Q_i = \beta_0 + \lambda_0 D_i + \beta_i \ln X_{1i} + \lambda_i D_i \ln X_{1i} \ldots \beta_4 \ln X_{4i} + \lambda_4 D_i \ln X_{4i} + v_i = v_i \quad (7)$$

The v_i's are the random variables associated with disturbances in production and the u_i's are the non-negative random variables associated with technical efficiency of the ith farmer and are obtained by truncation at (zero) of the normal distribution mean u_i and variance δ^2 u_i such that the following can be performed:

$$Ш_i = \delta_0 + \sum_{z=i} \delta_i Z_i \quad (8)$$

where, δ_i is a vector of the parameters of the inefficiency model to be estimated and the z_i, $z = 1,2 \cdots, 7$ are the farm and farmer-specific socio-economic variables, as well as the forms of integration and the level of integration hypothesized to influence the efficiency model, which is presented in Eq. 9:

$$\mu_i = \delta_0+\delta_1 \ln Age+\delta_2 \ln Edu+\delta_3 \ln Exp +\delta_4 Fls+\delta_5 D1+\delta_6 D_2+(VA/S) \quad (9)$$

Where

- Age = Age of the farmers or decision makers measured in years
- Edu = Level of education of the decision maker of the poultry enterprise measured as years of formal education
- Exp = Experience of the decision maker of the poultry enterprise measured in years
- Fls = Flock size of the poultry farms measured in numbers
- D_1 = Dummy variable that takes on the value of 1 if the farm privately produces the feed used in the farm and 0 if otherwise
- D_1 = Dummy variable that takes on the value of 1 if the poultry farm owns a feed mill and 0 if otherwise
- VA/S = Value-added-sales ratio, a proxy for the extent of the production system. The parameters of model and associated technical inefficiency terms for each farm were estimated by the stochastic production frontier procedure in the computer program[7]

METHODOLOGY: The study was conducted in the southwest geopolitical zone of Nigeria where most of the poultry farms in the country are located. The zone comprises six states: Lagos, Ogun, Oyo, Osun, Ondo and Ekiti. A multi-stage sampling technique was used to select the respondents. The first stage involved the purposeful selection of Oyo and Ogun states from the six states in the zone. The two states were selected because they had the highest number of poultry farms in the zone in the year 2012[8]. The second stage of the sampling involved a purposive selection of two Local Government Areas (LGAs) in each of the six states where battery cage and deep litter poultry farmers are predominant. The LGAs selected were identified to have the highest number of poultry farms in the respective states. In the third stage, four communities from each of the selected LGAs were randomly selected to give a total of 48 communities. The number of poultry farmers that used battery cage and deep litter system of poultry production in each communities were used in the fourth stage, where four or five respondents were randomly selected from each of the selected communities, yielding a total of 240 respondents.

Method of data analysis: The technical efficiency estimation is as follows[9]:

$$\ln Q = \ln \beta_o+\beta_1 \ln X_1+\beta_2 \ln X_2+\beta_3 \ln X_3 +\beta_4 \ln X_4+ \beta_5 \ln X_5 \quad (10)$$

Where

- Q = The value of the output (crate)
- X_1 = The quantity of feed per farm (kg)
- X_2 = The labour in man days
- X_3 = The veterinary costs per farm (₦)
- X_4 = The other expenses (electricity, transportation, water supply etc.) (₦)
- X_5 = The farm size (number of birds)

RESULTS AND DISCUSSION

The results of the budgetary analysis are presented in Table 1. The analysis shows that the variable cost incurred by farmers of both systems, i.e., the battery cage and deep litter system of poultry production, includes the medication, water supply, electricity, transportation, feed, labour and other inputs. The results indicate that the feed cost was the highest cost incurred in both systems of production: 50% in the deep litter and 31% in the battery cage systems. The table indicates that the feed cost was high in the deep litter system poultry farming (₦53, 737.618) compared to the cost to farmers practicing the battery cage system (₦40, 818.269).

Although, the feed cost incurred in both systems of production is high, this simply confirms that feed is a major ingredient in any system of poultry production. Notably, the values for feed obtained in the study were far lower than those obtained in some previous studies[10].

Furthermore, various substitutes are becoming available to the farmers for feed formulation, leading to the substitution of costly feed ingredients with less costly ones. In that case, the overall cost of feed is rapidly declining but much more in the battery cage than in the deep litter system. Other costs incurred include those for labour, which was observed to account for 7.4% in the deep litter and 11% in the battery cage systems, with the cost of medication being approximately 5.2 and 4.5% of the total cost of the deep

Table 1: Average costs and returns in ₦ per system for poultry farms

Items	Deep litter system	Percentage	Battery cage system	Percentage	All farms	Percentage
Gross revenue						
Broilers and cockerels	292342.8600	24.0	503325.0000	15	429481.2500	16.6
Eggs	424121.5500	35.0	2384939.6000	72	1698653.3000	65.7
Spent layers	493297.6200	41.0	436884.6200	13	456629.1700	17.7
Total GR	1209762.0000	100.0	3325149.2000	100	2584763.6000	100.0
Variable cost						
Medication	5611.9048	5.3	5849.6795	5	5766.4583	5.8
Water supply	278.5714	0.3	124.3590	0.1	178.3333	0.2
Electricity	764.2857	0.7	935.2564	0.7	875.4167	0.9
Transportation	3191.6667	3.0	5026.9231	4	4384.5833	4.4
Feed	53737.6180	50.0	40818.2692	31	21940.0410	22.0
Labour	7916.6667	7.4	13794.8720	11	11737.5000	12.0
Other variable inputs	6121.0714	5.7	11384.1030	9	9542.0417	9.6
Total VC	77621.7830	72.0	77933.4622	60	54424.3746	55.0
Gross margin						
A. gross revenue	1209762.0000		3325149.2000		2584763.6000	
B. Total VC	77621.7830		41933.4622		54424.3746	
A-B = GM	1132140.2170		3283215.7380		2530339.2250	
Fixed costs						
Cage	-		4461.0027		3298.6101	
Feeder	33.0714		144.7972		105.6932	
Vehicle	7491.2892		18463.6750		14683.2730	
Crate	11.9841		33.6325		26.0556	
Bucket	4.2857		10.8974		8.5833	
Shovel	20.5215		23.7179		22.5992	
Borehole	4044.9263		4758.9744		4509.0575	
Crusher	3571.4286		3098.2906		3263.8889	
Wheel barrow	172.1939		249.0840		222.1726	
Poultry house	3920.6349		5346.1538		4847.2222	
Feed mill	6666.6667		8076.9231		7583.3333	
Generator	1738.0952		3901.9231		3144.5833	
Mixer	1428.5714		3493.5897		2770.8333	
Scale	254.7619		224.7863		235.2778	
TFC	29358.4021	27.4	52287.4479		44721.1833	
TC	106980.1851		130220.9101		99145.5579	
Net farm income						
C. Gross margin	1132140.2170		3283215.7380		2530339.2250	
D. Total fixed Cost	30498.2831	28	52287.4479	40	44721.1833	45
C-D = NFI	1102781.8150		3230928.2900		2485618.0420	
OPR (%)	6.4000		2.3000		2.1000	
RTS (%)	91.2000		97.2000		96.2000	
NFI of 1 bird	587.0000		635.0000			

Source: Field survey, 2017

litter and battery cage systems, respectively. Furthermore, the water cost was the least variable cost (0.3 and 0.1%, respectively) in both systems.

The low values observed for medication is not an indication that this resource is less important. If the appropriate medical care is not taken, a 90% loss in the farm can occur[11]. The indication however, is that more attention to medication is needed on the farms, as this can help prevent disease and reduce mortality.

The fixed cost figure, however, reveals that the capital expenditure on fixed assets with respect to poultry farms practicing the battery cage system is higher (approximately 40%) than that of the deep litter system farmers. This is because of the huge investment made by this group of farmers on capital equipment such as battery cages.

Gross revenues for both groups of poultry farms are observed to have come from the sales of broilers and cockerels, eggs and spent layers. Importantly, certain factors, such as the laying rate of birds, flock size and type of production system, normally affects the gross farm revenue. Those revenues reveal that poultry farms with battery cage system of production have higher gross revenue than poultry farmers using the deep litter system of production. This is as a result of the income realized from the sales of eggs, which is lower in farms practicing deep litter system with the battery cage farms. Similarly, the gross margin and gross revenue of

Table 2: Maximum likelihood estimate, ordinary least squares and inefficiency function of the battery cage poultry production system

Explanatory variables	Parameters	OLS	MLE
General model			
Constant	β_0	12.375* (8.980)	12.084* (11.009)
Quantity of feed	β_1	0.008 (0.337)	0.012 (0.749)
Labour	β_2	0.120 (0.713)	0.352** (2.057)
Veterinary cost	β_3	-0.003 (- 0.020)	0.021 (0.179)
Other expenses	β_4	-0.369** (- 2.276)	-0.253*** (-1.780)
Flock size	β_5	0.565* (5.141)	0.418* (3.768)
Inefficiency equation			
Constant	δ_0	0	0.832 (0.836)
Age	δ_1	0	-0.026 (- 0.722)
Education	δ_2	0	-0.399* (-2.615)
Farming experience	δ_3	0	0.357* (2.582)
Flock size	δ_4	0	-0.000 (-1.189)
Poultry farm privately producing feed	δ_5	0	1.048 (0.977)
Poultry farm owns a feed mill	δ_6	0	1.048 (0.977)
Diagnostic statistics			
Sigma square	Σ	1.420	2.437* (3.630)
Gamma	Γ		0.670* (5.231)
Log likelihood function	LIF	-121.220	-112.121
Log likelihood test	LR		18.198

Source: Field Survey, 2017, Figures in parenthesis are T-values *significant at 1%, **Significant at 5%, ***Significant at 10%, Mean Efficiency: 0.650 Minimum: 0.008, Maximum: 0.888, MLE: Maximum likelihood estimate, OLS: Ordinary least squares

poultry farms using the deep litter system was lower than for the farms using battery cage and lower than the average gross margin with gross revenue of all farms. The deep litter system is known to accommodate fewer birds compared to the battery cage system; consequently, the fewer eggs are yielded under this system.

Furthermore, as shown in the table, the net farm income of the deep litter poultry farmers was lower than the average net income (₦2485618) of all farms and that of the battery cage farmers. The net farm income of farmers using battery cage system is approximately 2.9 and 1.3 times the net income of farmers using deep litter system and all farms, respectively[9]. Additionally, the net farm income of one bird for the deep litter poultry farmers (₦587) is lower than that of the battery cage poultry farmers (₦635).

Table 1 also reveals that deep litter system farmers incurred higher costs of operation than their battery cage counterparts. The higher operating ratio (6.4%) experienced by deep litter system farmers may be due to the large expenses on feed and low sales on eggs. Similarly, the ratio on returns to scale for deep litter farmers was also lower (91%) than that of the battery cage counterparts, which was approximately 97%.

Furthermore, the operating margin of the deep litter system farmers was low, requiring a need for greater sales and a reduction in feed wastage to allow adequate returns on investment by these farmers.

Conclusively, both systems of poultry production were assessed to be profitable. However, the battery cage poultry farmers make more profit than the deep litter system farms in the study area.

As shown in table 2 and 3, both the battery cage and deep litter systems of production, education and farming experience have significant effects on efficiency. While education reduces inefficiency in the battery cage system, it accounted for inefficiency in the deep litter system. The inefficiency-reducing effect of education in the battery cage system might be connected with the technicalities associated with the battery cage system of poultry production. In both systems, farming experience enhances inefficiency. In addition to the significant variables that are common to both systems, flock size has a negative and significant effect on the inefficiency modelled for the deep litter system. This implies that flock size has an efficiency-increasing effect. Age, education level and other expenses are the explanatory variables that exert a significant effect on the efficiency of the farmers in the results of the inefficiency model for all farms. The coefficients of age and education are negative, signifying that both variables have an inefficiency-reducing effect.

Table 3 reveals that flock size, labour and other expenses are the explanatory variables that significantly influence poultry production in the battery cage system. Both coefficients of flock size and labour are significant at the 1% probability level. On the other hand, other expenses have a negative and significant effect on poultry production and it is significant at the 10% probability level. A 1% increase in these variables will have effects that correspond to the respective values of their individual coefficient.

Table 3: Maximum likelihood estimate, ordinary least squares and inefficiency function of deep litter poultry production system

Explanatory variables	Parameter	OLS	MLE
General model			
Constant	β_0	10.471* (3.265)	16.958 (13.600)
Quantity of feed	β_1	-0.026 (- 0.804)	-0.048* (-4.083)
Labour	β_2	0.180 (0.689)	0.274 (1.772)
Veterinary cost	β_3	0.091 (0.354)	0.006 (0.035)
Other expenses	β_4	-0.093 (-0.287)	-0.270* (-3.157)
Flock size	β_5	0.343 (1.588)	-0.052 (- 0.580)
Inefficiency equation			
Constant	δ_0	0	-5.407* (-3.523)
Age	δ_1	0	-0.033 (-0.608)
Education	δ_2	0	0.452* (3.696)
Farming experience	δ_3	0	0.364* (2.947)
Flock size	δ_4	0	-0.0009* (-3.208)
Poultry farm privately producing feed	δ_5	0	-1.121 (-1.362)
Poultry farm owns a feed mill	δ_6	0	-1.121 (-1.362)
Diagnostic statistics			
Sigma square	Σ	1.842***	4.548* (4.791)
Gamma	Γ		0.999 (186391.300)
Log likelihood function	LIF	-69.180	-62.222
Log likelihood test	LR		13.916

Source: Field Survey, 2017, Figures in parenthesis are T-values *significant at 1%, **Significant at 5%, ***Significant at 10%, Mean efficiency: 0.294, Minimum: 0.002, Maximum: 0.999, MLE: Maximum likelihood estimate,

The production function of the deep litter system shows that feed and other expenses have a negative and significant effect on poultry production (Table 2). This implies that an increase in each of these variables will have a reduction effect on the output. The reduction effect of feed on output is contrary to expectation especially in the battery cage system. In a deep litter system, the quantity of feed is not measured but poured for the birds indiscriminately; some of this feed will neither be converted to flesh or extra eggs, as it will simply be passed as waste.

The production function estimate of all farms indicates that labour and flock size have positive and significant effects on poultry production (Table 3). They are both significant at the 1% probability level[5,9,12]. All the significant explanatory variables have an output-increasing effect.

The pooled results in Table 4 are plausible and in accordance with a priori expectations[5,12]. On the other hand, years of poultry farming experience, contrary to expectation, has an efficiency-reducing effect. This might be due to overdependence on acquired experiences at the expense of new innovation.

Chow's test of significance difference in production function

Test for structural (technical) changes or differences in the production function of battery cage and deep litter systems:

$$F_e = \frac{\sum_{e3^2} - \sum_{e1^2} - \sum_{e2^2}}{K_3 - K_1 - K_2}$$

$$= \frac{\sum_{e1^2} - \sum_{e2^2}}{K_1 - K_2}$$

$$\sum_{e3}{}^2 = 171.6737,\ \sum_{e1}{}^2 = 100.2297,\ \sum_{e2}{}^2 = 67.2532$$

$$K_1 = 72,\ K_2 = 36,\ K_3 = 114$$

$$F_c = \frac{(171.6737\text{-}100.2297\text{-}67.2532)/(114\ \text{-}72\text{-}36)}{(100.2297\text{+}67.2532)/(72\text{+}36)}$$

$$= \frac{4.1908/6}{167.7829.108}$$

$$= \frac{0.6985}{1.5508} = 0.4504$$

$$F_{tab} = F_{1\text{-}x},\ V1,\ V2 = F_{1\text{-}0.05},\ K\text{-}1,\ N\text{-}k$$

Where

X = 0.05

K = 6-no of visible

N = 120

Therefore:

F_{tab} = $F_{0.05}$, 5,114

F_{tab} = 2.3

Since $F_t > F_c$ hence, we fail to reject the null hypothesis of no structural difference.

Table 4: Maximum likelihood estimate, ordinary least squares and inefficiency function of all farms

Explanatory variables	Parameters	OLS	MLE
General model			
Constant	β_0	12.046 (9.760)	12.792* (12.910)
Quantity of feed	β_1	0.003 (-0.138)	0.008 (0.588)
Labour	β_2	0.141 (1.068)	0.438* (3.120)
Veterinary cost	β_3	-0.036 (- 0.310)	0.006 (0.059)
Other expenses	β_4	-0.301** (- 2.149)	-0.252** (-2.141)
Flock size	β_5	0.554* (5.941)	0.317* (2.917)
Inefficiency equation			
Constant	δ_0	0	2.590 (1.464)
Age	δ_1	0	-0.085*** (-1.844)
Education	δ_2	0	-0.286** (-2.117)
Farming experience	δ_3	0	0.388* (3.512)
Flock size	δ_4	0	-0.001 (-1.564)
Poultry farm privately producing feed	δ_5	0	0.479 (0.574)
Poultry farm owns a feed mill	δ_6	0	0.479 (0.574)
Diagnostic statistics			
Sigma square	Σ	1.522	3.395* (3.909)
Gamma	Γ		0.772* (7.739)
Log likelihood function	LIF	192.404	183.319
Log likelihood test	LR		18.170

Source: Field survey, 2017, Figures in parenthesis are T-values *Significant at 1%, **Significant at 5%, ***Significant at 10%, MLE: Maximum likelihood estimate, OLS: Ordinary least squares

Test for homogeneity of slope

$$F_c = \frac{\left[\sum e4^2 - \sum e1^2 - \sum e2^2\right] / \left[K_4 - K_1 - K_2\right]\left[\sum e2^2 + \sum e2^2\right] / \left[K_1 + K_2\right]}{\sum e4^2 = 169.2353,\ K_4 = 113}$$

$$F_c = \frac{(169.2353 - 100.2297 - 67.2532) / (113 - 72 - 36)}{1.5508}$$

$$= \frac{1.7524 / 5}{1.5508}$$

$$= \frac{0.3505}{1.5508} = 0.8708$$

Here k = 7, N = 120

$$F_{tab} = F_{0.95},\ 6,\ 103 = 2.19$$

Since $F_t > F_c$, we fail to reject the null hypothesis of no differences in the slope parameters.

Test for differences in intercepts

$$F_c = \frac{\left[\sum e3^2 - \sum e4^2\right] / \left[K_3 - K_4\right]}{\sum e3^2 - \sum e4^2}$$

$$= \frac{[171.6737 - 169.2353] / [114.113]}{169.233 / 113}$$

$$= \frac{(2.4384) / 1}{1.4977}$$

$$= 1.6281$$

$$F_{tab} = F_{0.95},\ K\text{-}1,\ N\text{-}K$$

$$F_{0.95},\ 1,\ 118 = 3.92$$

Since $F_t > F_{cal}$, we fail to reject the null hypothesis of no difference in the intercepts production of deep litter and battery cage farming systems.

Technical efficiency in poultry farms: The result of the technical efficiency analysis of the battery cage system, deep litter and all forms of poultry production are presented in Table 5. The mean technical efficiency (0.29) of the deep litter system is lower than that of the battery cage system (0.65), which in turn, is lower than that of all farms that have technical efficiency of 0.86. This implies that the battery cage system is more efficient than the deep litter system. However, the result proves that combination of both battery cage and deep litter systems will enhance efficiency.

The technical efficiency of the battery cage and deep litter systems varies from 0.008-0.89 and 0.002-0.99, respectively (Table 6), while that of all farms ranges from 0.005-0.86 (Table 7). The frequency distributions of the technical efficiency of battery cage system shows that most of the farms are within 70 and 79% levels of efficiency, whereas approximately 60% of the deep litter farms have technical efficiency as low as 2% and no greater than 19%. The pooled data, however, show a better picture in that the majority (approximately 70 percent) have technical efficiency that ranges from 50-70%.

Table 5: Decile range for battery cage system technical efficiency

Technical efficiency range	Frequency	Percentage
<0.1	2	1.3
0.10-0.19	4	2.6
0.2-0.29	6	3.9
0.3-0.39	5	2.6
0.4-0.49	2	1.3
0.5-0.59	22	14.0
0.6-0.69	42	26.9
0.7-0.79	60	38.5
0.8-0.89	14	8.9
Total	156	100.0

Source: Field survey, 2017, Mean efficiency: 0.6502

Table 6: Decile range for deep litter system technical efficiency

Technical efficiency range	Frequency	Percentage
<0.1	28	33.3
0.10-0.19	22	26.2
0.2-0.29	6	7.2
0.4-0.49	5	11.9
0.5-0.59	4	4.8
0.6-0.69	2	2.4
0.8-0.89	6	7.1
0.9-0.99	6	7.1
Total	84	100.0

Source: Field survey, 2017, Mean efficiency: 0.294

Table 7: Decile range for all farms technical efficiency

Technical efficiency range	Frequency	Percentage
<0.1	6	2.5
0.10-0.19	16	6.7
0.2-0.29	6	2.5
0.3-0.39	14	5.8
0.4-0.49	26	10.8
0.5-0.59	50	20.8
0.6-0.69	62	25.8
0.7-0.79	52	21.7
0.8-0.89	8	3.3
Total	240	100.0

Source: Field survey, 2017, Mean efficiency: 0.55, Minimum: 0.005 Maximum: 0.863

CONCLUSION

This study has advanced the frontier of knowledge about the efficiency of the battery cage and deep litter modes of poultry production. The results indicate that the battery cage system is more efficient than the deep litter mode of production. While most farmers operating with the battery cage are within 70-79% efficiency, those in the deep litters system are approximately 60% efficient. Therefore, the need exists for better extension activities to encourage farmers' adoption of the battery cage system as part of an overall desire to improve the livelihood of smallholder poultry farmers in Nigeria.

SIGNIFICANCE STATEMENT

This study determined that the battery cage system is more technically efficient than the deep litter or scavenging mode of poultry production in terms of structural differences, the homogeneity of the slope and differences in intercepts; that is, this study confirmed that the production function of the battery cage is superior to that of the deep litter system. For instance, while most farmers using the battery cage achieve a 70-79% technical efficiency, those using deep litter are worse off, with an approximately 60% efficiency. Therefore, the need exists for policies and interventions to encourage the adoption of the battery cage system.

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