

*Original Research Article***Determinants of technical efficiency in duck production in southwest Nigeria**Olayinka Isiaka **Baruwa**, Akeem Abiade **Tijani**, Taiwo **Alimi***Department of Agricultural Economics, Obafemi Awolowo University Ile-Ife, Nigeria***Correspondence to:****O.I. Baruwa**, Department of Agricultural Economics, Obafemi Awolowo University Ile-Ife, Nigeria
E-mail aragbon2005@yahoo.co.uk**Abstract**

The need to complement the supply of animal products with other sources of poultry necessitates exploring the potentials of domestic duck production. Studies conducted on indigenous ducks in Nigeria have paid less attention to the resource requirements and its determinants to duck production. This study therefore estimated technical efficiencies of domestic duck producers in South-western Nigeria, and identified some socio-economic factors, which influence them. A combination of purposive and random sampling was employed. Stochastic frontier production function approach using a translog production function was used to estimate the technical efficiencies of indigenous duck producers, while inefficiency model was used to determine the socio-economic factors affecting the technical efficiencies. The results showed that the level of technical efficiency ranged from 48% to 96% with a mean of 83.3%, which suggests that average duck output was 16.7% short of the maximum possible level. This implies that productive efficiency could still be improved using the subsisting resource base. The study concluded that mounting capacity building programmes for duck farmers generally, and availability of credit could increase the productivity of duck enterprise if monitored.

Keywords: stochastic production frontier; efficiency; management; Muscovy; Mallard; Pekin duck.

INTRODUCTION

Poultry enterprise is important in Nigeria's livestock production due to the fact that poultry production has relatively short generational interval and thus guarantee quick returns. Broiler kept for 6 weeks (42 days) are ready for market while layers, after 18 weeks would start producing eggs which can last for 12 to 18 months laying period. Poultry enterprise utilises labour more effectively than other livestock enterprises in an intensive management system (Egbuomwan, 2006).

Policy thrusts of government at all levels are geared to favour poultry farming. For example, the ban on importation of processed poultry meat and other product by Nigerian government is to stimulate the growth of domestic poultry industry for job creation and to provide market for local produce of poultry products.

Despite the advantages of poultry over other livestock, the poultry industry in Nigeria is facing a number of problems, the major problem being the high and rising costs of production inputs such as feed, day-old chicks, medications and low level of technical expertise (Ogundipe and Sanni, 2002).

These problems to a large extent have reduced the number of poultry enterprises in Nigeria and have also contributed to the low intake of protein from animal sources in the nutrition of most Nigerians (Dietmar, 2005).

Duck, which is not popularly produced in Nigeria, is another potential source of animal protein (Ola et al., 2004). Duck requires water and this makes it popular in areas where paddy rice predominate. However, Melvin (1994) and William (2001) observed that water for swimming is not necessary for successful duck production. Prevalence of the extensive system in the study area corroborated the reports of Oguntunji and Ayorinde (2015) that the extensive management system, feeding of low quality feed, provision of sub-standard housing, absence of routine veterinary care was practiced by majority of duck farmers in Nigeria.

The importance of efficiency in increasing agricultural output has been widely recognized by researchers and policymakers alike. Technical efficiency analysis in agriculture has been an area of focus in developing countries because of the importance of productivity growth in agriculture for overall economic development.

Technical efficiency increase does constitute a major component of total factor productivity growth, especially in developing countries (Brümmer et al. 2006). Productivity growth can be factored into technological progress, technical efficiency and increase in input usage (Kwabena and Victor, 2014). For developing countries, the high cost of capital limits the increase in input usage and technological progress that can promote output growth. The challenge to policymakers is that of improving technical efficiency in order to attain large gains in output using the existing technology and input envelope. This will enhance profitability as well as contribute to environmental quality as incremental production does not involve additional input. Emphasis should therefore be on full exploitation of the existing technologies before shifting to advanced new technologies, which are often, capital intensive.

Conceptual framework

In this study, the stochastic frontier production model was employed to estimate technical efficiencies of domestic duck producers. The idea of frontier function can be illustrated with a farm using ‘n’ inputs ($X_1, X_2 \dots X_n$) to produce output Y. Efficient transformation of inputs into output is characterised by the production function $f(X_i)$, which shows the maximum output obtainable from various input vectors. The stochastic frontier production function assumes the presence of technical inefficiency of production. Hence the function is defined by:

$$Y_i = f(X_i; \beta) \exp(V_i - U_i) \quad i = 1, 2 \dots n \tag{1}$$

Where:

- Y_i ... is the output of i-th farm;
- X_i ... is the input variables used by the i-th farm, β 's are production coefficients to be estimated;
- V_i ... is a random error, which is associated with random factors not under the control of the farmers such as weather conditions, diseases, etc.;
- U_i ... is random variable that is assumed to account for technical inefficiency in the production (inefficiency measure).

The model is such that the possible production Y_i is bounded above by the stochastic quantity $f(X; \beta) \exp(V_i)$, hence the term stochastic frontier. V_i is assumed to be independently identically distributed (iid) $N(0, \sigma_v^2)$ random error, independent of the U_i s; and U_i s are non-negative random variables, associated with technical inefficiency in production, which are assumed to be independently and identically distributed as either half normal or truncated normal or exponential or two parameter gamma distribution.

The farm-specific stochastic production frontier (SPF) representing the maximum possible output (Y^*) can be expressed as:

$$Y^* = f(X_i; \beta) \exp(V_i) \tag{2}$$

Equation (2) may be rewritten using equation (1)

$$Y_i = Y^* \exp(-U_i) \tag{3}$$

Thus, technical efficiency of the i^{th} farm, denoted by TE_i , is given by:

$$TE_i = \frac{Y_i}{Y^*} = \exp(-U_i) \tag{4}$$

Where Y^* is the maximum possible output.

In short, the difference between Y and Y^* is embedded in U_i . If $U_i = 0$, then Y is equal Y^* . This means production lies on the stochastic frontier and hence technically efficient and the farm obtains its maximum possible output given the level of inputs. If $U_i > 0$, production lies below the frontier and the farm is technically inefficient.

The efficiencies are predicted using the predictor that is based on the conditional expectation of $\exp(-U_i)$ (Coelli, 1994; Battese and Coelli, 1995). In the SPF model, the variance parameter (σ_u^2 and σ_v^2) is the sum of the variances of u and v , i.e., $\sigma_u^2 + \sigma_v^2$ and the parameter γ is the ratio of the variance of u to the sum of the variance of u and v . These are expressed as follows:

$$\sigma^2 = \sigma_u^2 + \sigma_v^2 \tag{5}$$

$$\text{And } \gamma = \sigma_u^2 / \sigma^2 \tag{6}$$

In terms of its value and significance, γ is an important parameter in determining the existence of a stochastic frontier; the value γ ranges from 0 to 1, if $\gamma = 0$, implies the existence of a stochastic production frontier. Similarly, $\gamma = 1$ implies that all the deviations from the frontier are entirely due to technical inefficiency (Coelli, 1996). The use of generalised likelihood-ratio test is another way of testing if technical inefficiency effects are absent in the model. This is used for testing the significance of the model just as the F-test in ordinary least square computations. It is also used in testing the functional form of the model (e.g. Cobb Douglas versus transcendental logarithmic or translog) and is more or less equivalent to the Chow test (Greene, 2008) in ordinary least squares estimation.

The application of the SPF methodology requires the selection of a particular functional form for the production function. The choice is dictated by a necessary trade-off between flexibility of the functional form and ease of estimation and interpretation. Two of the most popular functional forms in economic literature correspond to the Cobb-Douglas and the transcendental logarithmic (translog) functions (Lira et al., 2014). The first one is attractive due to its simplicity (and because of the logarithmic nature of the production function that makes econometric

estimation of the parameters a very simple matter), easy to interpret and estimated but imposes important restrictions on the technology such as scale and output elasticities that do not vary with input or output levels and substitution elasticities among inputs that are all equal to unity.

Yin (2000) points out that this function may be criticised for its restrictive assumptions such as unitary elasticity of substitution and constant returns to scale and input elasticities. The translog, on the other hand, is flexible in the sense that it can provide a local, second-order approximation to any function, but it is more difficult to estimate due to the larger number of parameters and attendant problems of multicollinearity among the regressors. Hence, with five inputs, the translog production function requires the estimation of twenty parameters, compared to only five for the Cobb-Douglas. Despite its well-known limitations, the transcendental logarithmic (translog) function has been widely used in farm efficiency analysis (Okoye et al., 2006; Okoye and Onyenweaku, 2007).

It is important to examine the efficient use of the existing technology by duck farmers in the study area and also factors affecting the farmers from operating at the frontier of the existing technology. Such information will assist the policymakers in designing policies that will enable farmers to first realise the potential output from a given technology before resorting to the more expensive alternative of introducing advanced technologies. Hence, the objectives of the study are to estimate farmer-specific technical efficiencies in duck production and identify some socio-economic factors which influence them.

MATERIALS AND METHODS

This study covers the southwest zone of Nigeria. Within this zone, there are three distinct ecological sub-zones: the mangrove forest, the rain forest and the derived savannah. The zone enjoys a bi-modal rainy season which lasts from April to October and a dry season from November to March (mean annual rainfall of 135 mm and mean daily temperature of 350 °C (BBC weather centre, 2008). Agriculture, both crops and livestock farming are the major source of income for the people in the area. The people live mostly in organised settlements, towns and cities (Ojo, 2000).

The selection of respondents was multi-stage, involving random sampling method, as well as purposive sampling. Three states namely, Oyo, Osun and Lagos States were selected based on the duck production potential; four Local Government Areas (LGAs) from each state, Oyo State (Oyo West, Oyo East, Atiba and Afijio LGAs; Osun State (Iwo, Ayedire, Ejigbo and Ede LGAs; Lagos State (Epe, Eredo, Eti-osa

and Ikorodu LGAs), and five villages from each LGA, and five duck farmers from each village were selected using simple random sampling technique at each stage except the last where purposive sampling technique was employed. In all, three hundred respondents were selected. A structured questionnaire was used to collect relevant information on socio-economic variables of the respondents, quantities and prices of inputs and output in the area during the 2015/2016 production season. Stochastic production frontier (SPF) model was used to estimate technical efficiencies. In this paper, we follow the Battese and Coelli (1995) approach of modelling both the stochastic and the technical inefficiency effects in the frontier, in terms of observable variables, and estimating all parameters by the method of maximum likelihood, in a single-step analysis. The two-stage analysis of explaining levels of technical efficiency (or inefficiency) was criticised by Battese and Coelli (1995) as being contradictory, in the assumptions made in the separate stages of the analysis. This is appropriate and adequate because farm efficiency varies across farms and average production function fails to capture inefficiency associated with different factors endowment and different input prices across farms. Also the use of stochastic frontier production model is consistent with recent agricultural studies (Mbanasor and Kalu, 2008; Adepoju, 2008; Ogundari, 2009).

Two functional forms namely, Cobb Douglas and Transcendental logarithmic or translog functions were estimated and Likelihood Ratio Test (LR) was used to choose the function that better describes the data between the two functions. The test rejected the null hypothesis that the Cobb-Douglas function is an adequate representation of the data and indicated that the translog functional form better fits the data and was therefore chosen as the lead equation to model duck production technology in this study.

The translog frontier production function is specified as:

$$\ln Y_i = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + \beta_{11} \ln X_1^2 + \beta_{12} \ln X_1 \ln X_2 + \beta_{13} \ln X_1 \ln X_3 + \beta_{14} \ln X_1 \ln X_4 + \beta_{15} \ln X_1 \ln X_5 + \beta_{22} \ln X_2^2 + \beta_{23} \ln X_2 \ln X_3 + \beta_{24} \ln X_2 \ln X_4 + \beta_{25} \ln X_2 \ln X_5 + \beta_{33} \ln X_3^2 + \beta_{34} \ln X_3 \ln X_4 + \beta_{35} \ln X_3 \ln X_5 + \beta_{44} \ln X_4^2 + \beta_{45} \ln X_4 \ln X_5 + \beta_{55} \ln X_5^2 + (V_i - U_i) \tag{7}$$

- Where,
- ln = the natural logarithm (i.e., logs to base e);
- β_0 = intercept;
- i = .. the ith sample farm;
- Y = weighted output of live ducks produced (kg);
- X_1 = number of hatched/ducklings stocked;
- X_2 = quantity of concentrates and other grain based feeds (kg);
- X_3 = drugs and veterinary services (₦);
- X_4 = labour (in man-days);
- X_5 = capital input (₦) made up of depreciation charges on buildings, cages and equipment;

$\beta_1, \beta_2, \beta_3, \dots, \beta_{35}$ = vector of unknown parameters.
 V_i = random error, which represents random variations in output as a result of factors outside the control of farmers as well as effects of measurement error in output variable, left out explanatory variables from the model and a statistical noise.

U_i = random variables that accounted for technical inefficiency effects. All the variables are measured as deviations from mean values. All independent variables (X_1, \dots, X_i) are expected to be positively related with the output of duck per production cycle.

An inefficiency model used to identify the determinants of farmers' technical efficiency is presented in equation (8). The inefficiency model assumes that the inefficiency effects are independently distributed having $N(0, \sigma_u^2)$ distributed and mean u_{it} (Coelli 1996).

$$U_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + \delta_5 Z_5 + \delta_6 Z_6 + \delta_7 Z_7 + \delta_8 Z_8 + \delta_9 Z_9 + \delta_{10} Z_{10} \quad (8)$$

Where:

- U = technical inefficiency;
- δ_s = parameters estimated;
- i = i^{th} farm in the sample;
- Z_1 = age of the farmers (years);
- Z_2 = family size (number);
- Z_3 = farmer's education (1 for formal education and 0 otherwise);
- Z_4 = experience in duck production (years);
- Z_5 = gender (1 for male and 0, otherwise);
- Z_6 = production system (1 for intensive and 0, otherwise);
- Z_7 = credit acquisition (Yes = 1; No = 0);
- Z_8 = income from other farm enterprise (₦);
- Z_9 = contact and meeting of extension officers; and Z_{10} = flock size.

If $U_i = 0$ no technical inefficiency occurs, the production lies on the stochastic frontier.

If $U_i > 0$, production lies below the frontier and it is inefficient.

Because the dependent variable in equation (8) is a measure of inefficiency, farm-specific variables with negative (positive) coefficient will have a positive (negative) effect on efficiency level. The computer programme, FRONTIER 4.1 (Coelli, 1996) was used to obtain maximum-likelihood estimates of the parameters of the stochastic frontier production function and inefficiency model simultaneously.

RESULTS AND DISCUSSION

Socio-economic characteristics of duck farmers

Farmers' age varies between 21 and 95 years. The modal age bracket was between 36 and 50 years while the mean age was 51 years. At this age, farmers would have acquired much experience and at the same time, they are still energetic to meet the rigours of

farming. The majority of the respondents were male while few were female, and moreover, few females were involved in duck farming like in other farming activities. This finding agrees with Adeyemi et al. (2008) who reported that more males were involved in duck enterprise than females in Nigeria.

Majority of the respondents were literate and could read and write in both English and Yoruba language. The modal level of education was secondary education. The mean years of education was 11 years suggesting that many duck farmers had secondary education in the study area. This is in line with reports of Oguntunji and Ayorinde (2015). The mean year of experience in duck farming was 10 years. This shows that most of the respondents were not new in the business.

The study further showed that more than one breed of ducks was reared in the study area. Almost all (97.3%) the respondents in the study area reared Muscovy duck, whereas the remaining ones reared either Mallard (1.0%) or Pekin (0.7%) or both Muscovy and Pekin breeds (1%). The farmers observed that Mallard and Pekin ducks are good egg producing breeds and do not go broody compared to Muscovy. Oguntunji (2013) in his study submitted that adaptability to the environment and acceptability among the populace was the main reasons for prevalence of Muscovy ducks in the study areas. The mean flock size was 14; respondents with more than 30 flock sizes attributed it to the use of veterinary services. Majority (83%) of the farmers maintained the sex ratio of one drake to three duck for breeding.

Estimation of technical efficiency

Table 1 presents the estimated parameters of the production frontier model. The coefficients of the first order explanatory terms represent percentage change in output as a result of 1% change in factor inputs, that is, elasticity estimates. Most of these coefficients have the expected positive signs but only flock size is significantly different from zero at the 5% level. This indicated that increase in flock size will increase the output of the enterprise. In specific terms, 1% increase in flock size would increase output by about 1.1%. The statistical non-significance of labour and veterinary services is probably due to the fact that majority of the respondents used family labour and ethno-veterinary practices. The finding is in line with the results of Hui-Shung and Renato (2008) in their study on technical and socio-economic constraints of duck production in the Philippines. With respect to feed and capital inputs, the coefficients are negative and not statistically significant at 5% level. This might be due to the fact that almost (98%) of all the respondents raised their flocks on extensive low input management system, majority (74.4%) used household wastes (e.g. maize chaff) which were not traded in the open market to feed their birds and they did not construct any structure to house their birds. Hence investment in feeds and

Table 1. Maximum-Likelihood estimates for parameters of the translog stochastic frontier production function for duck farmers in southwestern Nigeria

Variable	Parameter	Coefficient	t-ratio
Production function			
Constant	β_0	1.036	5.950*
Ln(flock size)	β_1	1.084	11.791*
Ln(labour)	β_2	0.038	0.898
Ln(feed)	β_3	-0.009	-0.404
Ln(depreciation)	β_4	-0.020	-0.848
Ln(veterinary cost)	β_5	0.00023	0.012
[Ln(flock size)] ²	β_{11}	-0.037	-2.229*
Ln(flock size) × Ln(labour)	β_{12}	-0.010	-1.758
Ln(flock size) × Ln(feed)	β_{13}	0.001	0.759
Ln(flock size) × Ln(depreciation)	β_{14}	-0.0002	-0.118
Ln(flock size) × Ln(veterinary cost)	β_{15}	0.001	1.073
[Ln(labour)] ²	β_{22}	0.022	1.992*
Ln(labour) × (Ln(feed)	β_{23}	0.001	0.279
Ln(labour) × (Ln(depreciation)	β_{24}	0.001	0.296
Ln(labour) × (Ln(veterinary cost)	β_{25}	-0.002	-0.482
[Ln(feed)] ²	β_{33}	-0.0003	-0.087
Ln(feed) × Ln(depreciation)	β_{34}	0.006	1.655*
Ln(feed) × Ln(veterinary cost)	β_{35}	-0.002	-0.927
[Ln(depreciation)] ²	β_{44}	-0.001	-1.248
Ln(depreci) × Ln(veterinary cost)	β_{45}	-0.0002	-0.202
Ln(veterinary cost) ²	β_{55}	0.0007	0.669
Inefficiency Model			
Constant	δ_0	-0.285	-0.797
Age	δ_1	0.003	1.135
Household size	δ_2	-0.010	-1.004
Education	δ_3	-0.234	-1.539
Sex	δ_4	-0.052	-0.951
Experience	δ_5	-0.009	-1.370
Management practices	δ_6	0.112	1.627
Access to credit	δ_7	0.229	1.973*
Off-farm income	δ_8	-0.894E-07	-0.902
Extension visit	δ_9	0.130	1.542
Flock size	δ_{10}	0.001	0.869
Diagnosis statistics			
Sigma-square ($\sigma^2 = \sigma_v^2 + \sigma_\mu^2$)	s^2	0.090	2.197*
Gamma ($\gamma = \sigma_\mu^2 + \sigma^2$)	g	0.893	17.608*
Log of likelihood function	λ	103.880	
LR test		39.940	
Mean of exp (-U)		0.837	

Source: Computed from survey data

*Significant at 5%

Note: A negative sign of the parameters in the inefficiency function means that the associated variable has a positive effect on technical efficiency, and *vice versa*.

physical structure was minimal (Chia and Momoh, 2012). The significance of the gamma (γ) coefficient 0.893 at 5%level suggests the presence of one-sided error component, which means that the effect of technical inefficiency is significant; hence the average

production function is not an adequate representation of the data.

The estimated γ coefficient means that about 89% of the discrepancies between observed output and the frontier output are due to technical inefficiency.

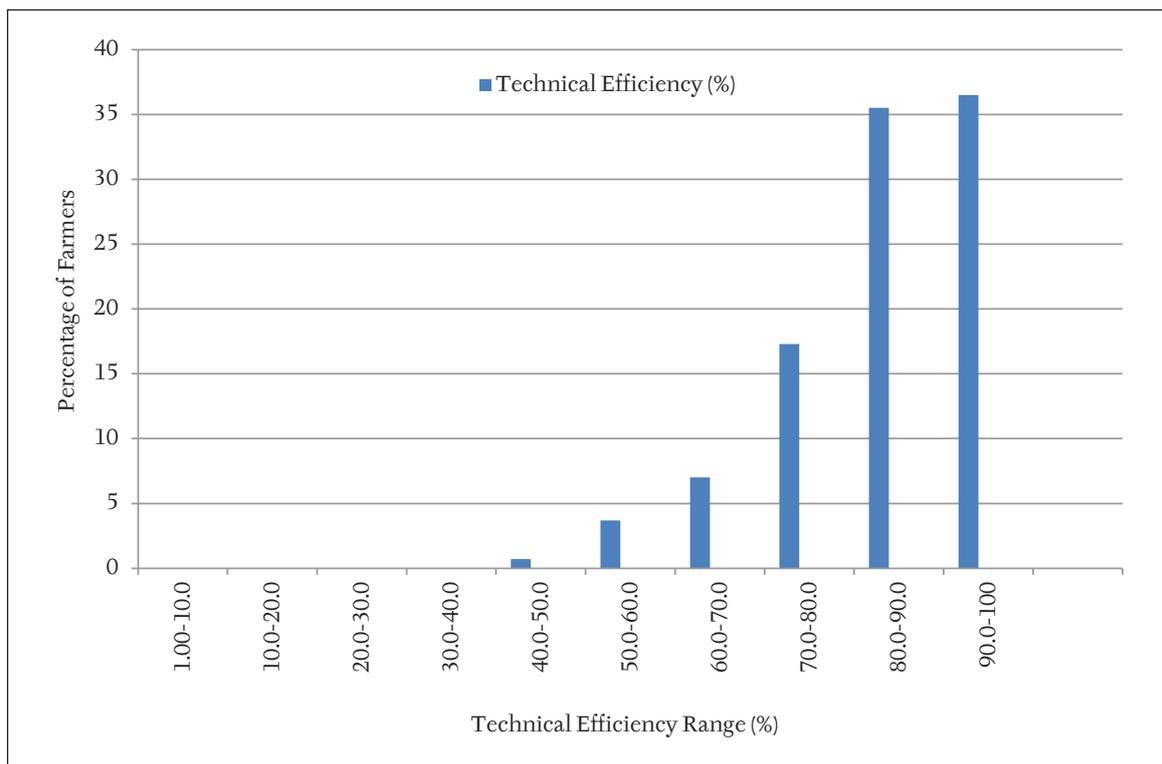


Figure 1. Frequency distribution of technical efficiencies in decile ranges

In other words, the shortfall in observed output from the frontier output is primarily due to factors, which are within the control of the indigenous farmers in the study area while the remaining was due to random effects. The significance of the sigma-square (σ^2) at 5% level implies good fit and the correctness of the specified assumptions of the distribution of the composite error term. The observed significance of σ^2 is consistent with previous studies (Hjalmarson et al., 1996; Sharma, 1999; Rahman, 2003). The estimated log likelihood function of 103.9 represents the value that maximises the joint densities in the estimated model. Because all the variables are mean differenced before estimation in the translog function, output elasticities with respect to the inputs are the coefficients of the direct Cobb-Douglas terms in the mean differenced translog equation and the returns to scale coefficient, ϵ , is the sum of these elasticities:

$$\epsilon = \sum \beta_s \tag{9}$$

Since only the elasticity estimate of flock size is statistically significant at 5% level, flock size appears to be the most important input in duck production. The return to scale (RTS) which is a measure of total resource productivity is 1.084 which indicates that duck production in the study area was in stage one (increasing return to scale). This is an inefficient stage because increase in the use of inputs will lead to more than proportional increase in output. This means that duck

producers are inefficient at their level of production and their income and output can be improved if more inputs are utilised.

Technical efficiency analysis

Predicted technical efficiencies ranged from 48% to 96% with a mean of 83.3% (Table 2), indicating that on the average, duck output fell 16.7 % short of the maximum possible level. This means that if the average farmer in the sample was to achieve the technical efficiency level of his most efficient counterpart, then the average farmer could realise a 13.2% cost saving [i.e. $1 - (83.3/96) \times 100$]. A similar calculation for the most technically inefficient farmer reveals cost saving of 50% [i.e., $1 - (48/96) \times 100$]. Majority (72%) of the respondents had technical efficiency indices greater than 80%, meaning that most of them were technically efficient given the existing technology. To give a better description of technical efficiencies among the respondents, the predicted technical efficiencies are presented in Figure 1. The figure indicates that the modal technical efficiency bracket was 90–100%. The sample frequency distribution indicates a clustering of technical efficiencies in the region of 80–100%, thereby implying that most (72%) of the farmers were efficient.

The estimated coefficients for the inefficiency function provide little explanation for the relative efficiency levels among the farmers since all but one of the socio-economic variables are non-significant at

Table 2. Frequency distribution of technical efficiency of farmers

Efficiency range (%)	Frequency	Percentage
<10	-	-
10-20	-	-
20-30	-	-
30-40	-	-
40-50	02	0.7
50-60	11	3.7
60-70	21	7.0
70-80	52	17.3
80-90	105	35.5
90-100	109	36.5
Total	300	100
Mean	83.3	
Standard deviation	10.7	
Minimum	48.0	
Maximum	96.0	

Source: Computed from survey data

all the conventional levels. Though the coefficient of the credit variable is significant, it has a sign (positive) which is contrary to *a priori* expectation. Its sign implies the greater the accessibility to credit, the less the technical efficiency. The positive sign implies that this factor contributed positively and significantly to inefficiency, i.e., the greater the access to credit, the more inefficient the farmer becomes. It is probably because of the low level of investment in duck enterprise that such loan obtained would be diverted to other uses.

This is against the findings of Okike et al. (2001) that accessibility to credit could contribute to farmers' economic efficiency.

CONCLUSION

The study revealed that the technical efficiency of farms varied due to the presence of technical inefficiency effects in the duck production industry in South-western Nigeria. To ensure widespread availability of duck meat to the populace requires increasing the stock of birds and feeding them with supplementary feeds (mostly energy supplements) of conventional commercial mash. The study revealed that the level of technical efficiency of duck production varied among producers; it varied from 48% to 96% with a mean of 83.3%. This suggests that output could be increased under the existing indigenous technology or using the subsisting resource base if the practices of the most efficient producer are presented to less efficient farmers for adoption. Potentials of the existing indigenous production system have not been fully exploited, that is, greater number of ducks could be raised under the existing indigenous production method. Micro-credit from governmental and non-governmental agencies should be made available to

rural farmers and monitored so that such loans are not diverted to other uses, thereby ensuring positive impact on profitability of the duck enterprise. Educating the populace on the nutritional importance of ducks and building the capacity of the existing and potential producers of ducks would make duck meat available and affordable as an animal protein source aimed at increasing the nutritional status of the people as well as their economic well-being.

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