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Comparative Analysis of Profitability and Technical Efficiency of Fish Farming Using Different Rearing Techniques in Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

In Nigeria, fish farming has emerged as a fast growing sector and a viable alternative to declining capture fisheries. The paper attempts to evaluate and compare the profitability and technical efficiency of different rearing techniques among fish growers in Lagos State, Nigeria using budgetary technique and Stochastic Frontier production model. Concrete tanks system is the dominant form for rearing fish, occupying 58.3% of the total tank and pond area. All the rearing techniques show some level of appreciable profit with concrete tanks delivering the highest net profit. The benefit: cost ratios for different techniques varied between 0.82 in earthen pond to 5.20 in concrete tank. The mean technical efficiencies are 0.84, 0.86, 0.95 and 1.0 in plastic tank, concrete tank, earthen pond and fibre tank respectively. Adhering strictly to the recommended fish management practices were found to be critical for improved fish farming in the country. Efforts should be directed in reducing cost of feed by removing tariffs on imported feed or production of locally fish meal which formed the main cost component of fish feed. This study also compares the technical efficiency of four different rearing techniques. The results of analysis indicate variation in the distribution patterns of technical efficiency estimates from the four techniques. The mean levels of technical efficiency are 86%, 95%, 84% and 100% for concrete tanks, earthen pond, plastic and fibre tanks respectively.

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1. INTRODUCTION

The depletion of global fisheries around the globe coupled with increased consumer demand for seafood has created an impetus to expand seafood production through aquaculture, or fish farming. It has been projected that aquaculture production can increase fish production by 50 million metric tons by 2050 [1]. With increase in human population, global annual per capita consumption of fish is expected to amplify from the current rate 16 kg to 21 kg in 2030 [2,3]; aquaculture has great potential of meeting this increased demand. The sector is being regarded as the fastest growing segment of food production in the world, with an average annual growth rate of 8.9% over the last three decades, surpassing both terrestrial livestock meat production and capture fisheries [4]. It can therefore contribute to food security in the developing world, especially the malnourished populations in Africa.

In the entire African region, only Egypt has achieved the scale of change observed in Asian countries [5]. Nigeria is reported to have maintained its leading position in terms of volume of (30,677) tonnes and value of US$77253, 000 [6]; FAO reported that fish production in Nigeria increased tremendously from 18104 tonnes in 1994 to over 85087 tonnes in 2007 [7]. The observed shifts have been attributed to changes in market demand [8]. Within the country, much variation can be found in terms of production, consumption, technology, ecosystem type and institutional characteristics. The choice of system used and species grown is increasingly influenced by the emergence of a growing middle-class, urbanization and growth of the export trade in fish and fish products.

Against this background, the main objective of this paper is to evaluate and compare the technical efficiency and determinants of existing rearing techniques among fish growers in Nigeria. Developing appropriate policies for aquaculture development requires a detailed understanding of the variation between systems and the most viable options for farmers. An economic analysis of alternatives aquaculture technologies becomes important if Nigeria is to achieve the economies of scale in fish production. The overall goal of the study is to enhance commercial production of fish in Nigeria. The cost of production offers the potential to help in identifying production system for fish culture most likely to be commercially viable. Information on production costs is quite limited since it must be location, facility and species specific. The contribution is critical as a guide to future research funding in the various species and production systems suitable for commercial production. Also, an understanding of these relationships could provide the policymakers with information to design programmes that can contribute to measures needed to expand the food fish production potential of the nation.

2. MATERIALS AND METHODS

2.1 Data

Primary data for the study were drawn from 700 hundred fish farmers in Lagos State using snowball techniques and intensive farm-survey of the sample of fish farmers of the Lagos State Agricultural Development Authority. Data were collected through frequent visits to the farmer's plot using structured questionnaire. Data included labour time disaggregated by source, gender, age, and field operation. The quantities and the price of all purchased inputs were also collected during this time. Output and price data on all the quantities of fish harvested were collected.

2.2 Data Analysis

Budgetary technique was used to obtained information on profitability among different techniques or enterprises. An enterprise budget is in three parts: income, costs and profit [9]. The various inputs used in fish farming production include fingerling stocked, fertilizer, and chemicals including hormones and feed supplement and labour. Labour was measured by the total number of work-hours per week including paid and unpaid labour. Fixed input cost (FC) refers to the cost of the fixed resources while operating cost refers to variable costs associated with the day-to-day running of the farm. Data on variable costs include amount spent on feed, fingerling/juvenile, fuel, electricity, maintenance, repairs, veterinary services, transportation, medication and labour.

Depreciation rate was determined using the straight line method in accordance with the standard industry practice. A salvage value of zero Naira (₦0.00) was used for all plants, equipment and ponds at the expiration of the useful life. Land value was excluded from the analysis in order to focus on the profitability of the techniques of operation itself (land appreciate). The opinion [10] was that land value can be an investment in its own right and considering the economic value of the land in the study area, it is expected that land would continue to appreciate. However, any capital appreciation in land over the period of operation does not represent an economic return from the various techniques in operation. All income was recorded on a pre-tax basis to ensure the actual performance of the various techniques. This assumption eliminated the differing tax rates that are available depending on the structure of the operation and multiplicity of tax existing in the state. In addition, the assumption of owner investment was applied (i.e. no borrowings, interest, etc.).

2.3 Analytical Framework

Since [11] seminal paper, there has been a growing interest in methodologies and their applications to efficiency measurement. While early methodologies were based on deterministic models, stochastic production frontiers were first developed by [12,13]. The specification allows for a non-negative random component in the error term to generate a measure of technical inefficiency, or the ratio of actual to expected maximum output, given inputs and the existing technology.

Also, in a number of studies on efficiency measurement [14,15,16], the predicted efficiency indices were regressed against a number of household/farm characteristics, in an attempt to explain the observed differences in efficiency among farms, using a two-stage procedure. Other authors [17,18] extended the stochastic production frontier model by suggesting that the inefficiency effects can be expressed as a linear function of explanatory variables, reflecting farm-specific characteristics. The advantage of [18] the model is that it allows estimation of the farm specific efficiency scores and the factors explaining efficiency differentials among farmers in a single stage estimation procedure [19]. The present paper adopted this procedure in comparing the technical efficiency of fish farming using different rearing techniques.

2.4 Empirical Model

The study used a Cobb-Douglas functional form to specify the stochastic production frontier. For other authors [20], they argued that as long as interest rests on efficiency measurement and not on the analysis of the general structure of the production technology, the Cobb-Douglas production function provides an adequate representation of the production technology. Moreover, in one of the very few studies examining the impact of functional form on efficiency while [21] concluded that functional specification has a discernible but rather small impact on estimated efficiency'. That is why the Cobb-Douglas functional form has been widely used in farm efficiency analyses both in developing and developed countries [22,23]. The specific model estimated is given by:

$$\text{Ln Y} = \beta_o + \sum_{m=1}^{8} \beta_1 \ln X_1 + v_i - u_i$$

and $$u_i = \delta_o + \sum_{m=1}^{8} \delta_m z_{mi}$$

where Y denotes the quantity of fish harvested of the ith farmer measured in kilograms.
X_i are inputs used.

I = 1, denotes seed - the total number of fish seeds stocked in ponds.
I = 2, denotes the total of family labour, exchange labour, and hired labour in mandays.
I = 3, denotes fertilizer (quantity in Kg).
I = 4, denotes organic manure (quantity in kg).
I = 5, denotes feed (total dry weight of formulated feed, feed ingredients (kg/ha).
I = 6, denotes total land under fish farming in hectares
I = 7, denotes fuel (quantity of fuel used in litre)
I = 8, denotes other inputs (such as chemical, water, maintenance and depreciation). $v_i s$ are assumed to be independently and identically distributed N (0, σ_v^2) two sided random errors, independently of the $u_i s$; and the $u_i s$ are non-negative random variables, associated with the inefficiency in production, with are assumed to be independently distributed as truncations at zero of the normal distribution with mean,

$$\mu_i = \delta_o + \sum_m \delta_m z_{mi} \text{ and variance } \sigma_u^2 \left| N\left(\mu, \sigma_u^2\right) \right| \;|$$

ln = natural logarithm.
zmi = variables representing socio-economic characteristics of the farm to explain inefficiency, m.
m = 1, education (number of completed years of schooling for the farmer).
m = 2, pond area (ha)
m = 3, age (number of years of the farmer).
m = 4, machinery.
m = 5, experience
m = 6, fish farm management index (total number of fish management and monitoring practices used such as continuous feeding, sorting, daily observation, harvesting, etc)

m = 7, water management index (total number of water management and quality monitoring practices used such as water purification, adding fertilizer or manure, etc).

m = 8, feed management index (total number of feed management and monitoring practices used such as supplementary feeding, etc.).

We follow [24] in replacing the variance parameters, σ_v^2 and σ_u^2, with $\gamma = \sigma_u^2 / \left(\sigma_v^2 + \sigma_u^2\right)$, and $\sigma_s^2 = \left(\sigma_v^2 + \sigma_u^2\right)$ in the estimating model. This is done so that a grid search over value of c between 0 and 1 can be used to obtain good starting values for the iterative search routine used to obtain the maximum likelihood estimates. Following [25,26] the farm-specific estimates of technical efficiency
is defined by:

$$EFF_i = E[\exp(\text{-ui})| \ \xi_i\ ] = E\left[\exp(-\delta_0 - \sum_{m=1}^{M} \delta_m z_{mi}) | \xi_i \right],$$

where $\xi_i = v_i - u_i$, E is the expectation operator. This is achieved by obtaining the expressions for the conditional expectation u_i upon the observed value of ξ_i. The method of maximum likelihood is used to estimates the unknown parameters, with the stochastic frontier and the inefficiency effects functions estimated simultaneously.

3. RESULTS AND DISCUSSION

3.1 Classification of Fish Farming Techniques by Rearing (Holding) System

The major rearing (holding) systems used in the study area can be categorized as earthen pond (dugout), concrete, fibre and plastic tanks (Table 1). The rearing units were in different shapes and sizes. More than half (58.3 %) of the fish farmers used concrete tanks in rearing fish. Next in importance were fish farmers using plastic having one-fifth and above. Fish farmers using fibre tank accounted for less than 3.0 % and earthen pond operators accounted for 16.5 %. The gradual shift by fish farmers from earthen pond to other rearing techniques was attributed to pressure on the available land or water bodies in Lagos State. Others claimed that tanks are easily drainable, very easy to manage and movable (particularly fibre and plastic tanks). It was also observed during the study that most of the farms still operating on earthen ponds were located in the rural and peri-urban areas of Lagos State.

Table 1. Classification of the fish farms based on holding techniques

Rearing unit	Frequency	Percentage	Cumulative ercentage
Concrete	303	58.3	58.3
Earthen (Dug out)	86	16.5	74.8
Fibre	15	2.8	77.7
Plastic	116	22.3	100.0
Total	520	100.0	100.0

3.2 Profitability Analysis of Fish Farms by Rearing Techniques

Mean fish output obtained by fish farmers using different rearing techniques is presented in Table 2. Fish output varied from 7,434kg in earthen pond to 22,563kg in plastic tank. Fish output obtained by fish farmers using tanks was almost three times of earthen pond system. The F-test (18.38) indicated that the mean fish output obtained from all the rearing techniques are significantly different from one another and it implies that fish output depends on the rearing or holding tanks. The mean comparison shows that fish farmers using plastic tank has the highest fish output and is significantly different from earthen pond but not from fibre and concrete tanks. Ranked second was concrete tank which was higher and significantly different from earthen pond but not from fibre and plastic tanks.

The result obtained for fish yield was similar with fish output. Mean fish yield produced by fish farmers varied from 21,160kg/ha/season in earthen pond rearing technique to 59,139kg/ha/season in plastic tank. The overall mean was 46,911.02kg/ha/season. The F-test (5.39) result was equally significantly different implying that fish yield also depends on the rearing technique. The mean comparison indicated that fish farmers using plastic tank has the highest yield 59,139kg/ha/season and is not significantly different from concrete and fibre tanks but is significantly different from earthen pond. Concrete and fibre tanks ranked second.

The mean revenue generated by fish farmers from different rearing techniques was ₦2,386,244 in earthen pond and ₦8,845,775 in plastic tank. This shows that revenue generated from plastic, fibre and concrete tanks tripled that of earthen pond. The F-test (10.89) indicated that there was a significant difference in the mean revenue accrued to the different rearing technique. The plastic tank has the highest mean which was significantly different from earthen pond but not from concrete and fibre tanks.

Table 2. Summary of economic analysis by rearing techniques

Economic indices	Concrete tank	Earthen pond	Fibre tank	Plastic tank	Overall mean	F
	Mean					
Output (Kg)	21,560^{a}	7,434^{b}	17,013^{a}	22,563^{a}	19,025.92	18.38*
Yield (Kg/ha)	49,786^{ab}	21,160^{b}	34,601^{ab}	59,139^{a}	46,911.02	5.39*
Revenue (₦)	8,151,975^{a}	2,508,720^{b}	7,141,723^{a}	5,818,980^{a}	6,664, 462	19.63*
Variable cost (₦)	1,493,611^{a}	970.0^{b}	1,876,331^{a}	1,529,824^{a}	1,270,882	21.96*
Depreciation (₦)	159,516^{ab}	127,481^{b}	210,181^{a}	172,216^{ab}	159,145.6	1.39
Total cost (₦)	1,653,127^{a}	835,619^{b}	2,086,512^{a}	1,702,041^{a}	1,546,982	6.67*
Profit (₦)	6,498,848^{a}	963,100^{c}	5,055,211^{ab}	4,116,940^{ab}	5,000,046	23.16*
Profitability	6.79^{a}	3.86^{b}	4.56^{b}	6.54^{a}	6.08	10.86*
Efficiency:						
Technical	0.98^{a}	0.86^{c}	0.97^{ab}	0.92^{b}	0.94	26.62*

Note: Means with same letter are not significantly different

The cost structure, returns and benefit-cost ratios for different holding techniques are presented in Table 3. The cost constituents were the annual cost of all inputs and output. Percentage of variable cost to total costs constituted 91.65% in earthen pond, 89.68% in concrete tank, 88.87% in plastic tank and 87.61% in fibre tank. The cost of inputs fluctuated according to the required intensity of their use across different rearing techniques. Feed was the most important cost component; it varied from 55.78 to 68.57 percent of variable cost of production in concrete tank and in earthen pond and above 50% of the total cost of production. This was in line with [27,28]. The other significant costs were fish seed, labour, fuel and transportation. Fish seed cost was very low in earthen pond, accounting less than 1 percent of TVC and TC respectively. This could be attributed to sourcing of fingerlings by some farmers from the wild.

The high operating cost in fibre, concrete and plastic tanks were due to pond maintenance, replacement of broken plastics and the need to service and maintain machineries such as generating set. The F-test (21.96) shows that there was a significant difference in the mean variable costs of all the rearing facilities (Table 2). Fibre tank has the highest variable cost and is significantly different from earthen pond but not from concrete and plastic tanks. The variable cost of plastic and concrete tanks were equally significantly different from earthen pond.

Depreciation (fixed cost) by rearing techniques is presented in Table 3. Machinery, vehicles and rearing tanks in that order accounted for over 90% of the fixed cost items and less than 13% of the TC. The depreciation cost were N127,481, N159,516, N172,216 and N210,181 in earthen pond, concrete, plastic and fibre tanks respectively. Overall depreciation cost was N159,145.6. The F-test (1.39) in Table 2 shows no significant difference in the mean depreciation cost of all the rearing techniques. The DMRT result on depreciation costs of various rearing techniques shows that fibre tanks had the highest depreciation cost but not significantly different from other rearing techniques.

The total cost of fish farming using various rearing techniques varied from ₦1,545,552 in concrete tanks to ₦1,696,698 in fibre tank. The mean total cost varied from ₦835,619 in earthen pond system to ₦2,086,512 with overall mean of ₦1,546,982. This implies that total cost of fish farming was one and half times lower in earthen than in concrete, plastic and fibre.. The F-test (6.67) in Table 3 indicated that total cost accrued to each of the rearing technique was significantly different. The mean comparison shows that fibre tank has the highest total cost and was significantly different from earthen pond but not from plastic and concrete tanks. The mean comparison of plastic tank and earthen pond did not show any significant difference.

The mean profits by rearing techniques in Table 3 indicated that earthen ponds have the least mean profit of ₦963,100 and the highest was plastic tank (₦6,498,848). Profit generated by fish farmers using plastic tank was three and half times lower in earthen pond than plastic tank. The F-test (23.16) indicated that there was a significant difference accrued to various rearing techniques. The mean comparison shows that plastic tank has highest mean profit and significantly differs from earthen pond but not from concrete and fibre tank. It further implies that profit is best in plastic tank. The mean profit of fibre tank was higher and better than earthen pond but not significantly different.

Profitability levels of various techniques were from 0.82, 5.20, 3.46 and 4.40 in earthen pond, concrete tank, platic tank, plastic tank and concrete tank in that order. The profitability level in earthen pond was less than one implying that rearing fish in earthen in Lagos State might not be profitable afterall. The F-test (10.86) shows that there was a significant difference in the profitability level. Concrete tank has the highest profitability level and is significantly different from fibre tank and earthen pond but not from plastic tank and it implies that both concrete and plastic tanks are the most profitable rearing techniques. The mean profitability of plastic tank ranked second and is also significantly different from earthen pond and fibre tank. Thus, the mean profitability level of both fibre tank and earthen pond are not significantly different from each other even though the profitability level of the former was higher than that of the latter.

Table 3. Costs and returns for different rearing systems in fish farming

Economic parameter	Earthen			Concrete			Plastic			Fibre		
	Earthen	**% of VC**	**% TC**	**Concrete**	**% of VC**	**% TC**	**Plastic**	**% of VC**	**% TC**	**Fibre**	**% of VC**	**% TC**
Output ('000)	6977.08			23244.06			16580.50			21683.68		
Price (Naira/kg)	370			370			370			370		
Revenue (N'000)	2581520.12			8600303.63			6134783.90			8022962.27		
Variable costs (N'000)												
Feed	972227.27	68.57	62.84	773190.27	55.78	50.03	883740.35	64.25	57.10	972227.27	65.40	57.30
Seed	10500.00	0.74	0.68	345278.58	24.91	22.34	263085.92	19.13	17.00	288299.91	19.39	16.99
Labour	48490.58	3.42	3.13	163704.70	11.81	10.59	142750.00	10.38	9.22	166681.82	11.21	9.82
Fuel	172659.55	12.18	11.16	64807.31	4.68	4.19	49120.61	3.57	3.17	26136.36	1.76	1.54
Transportation	160593.02	11.33	10.38	7119.48	0.51	0.46	5751.05	0.42	0.37	3056.82	0.21	0.18
Water	9400.58	0.66	0.61	10659.74	0.77	0.69	10525.20	0.77	0.68	7269.39	0.49	0.43
Fertilizer	4013.25	0.28	0.26	225.47	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Lime	1846.63	0.13	0.12	518.83	0.04	0.03	0.00	0.00	0.00	0.00	0.00	0.00
Chemicals	13816.47	0.97	0.89	1489.93	0.11	0.10	3315.79	0.24	0.21	0.00	0.00	0.00
Electricity	20760.00	1.46	1.34	16479.06	1.19	1.07	15296.84	1.11	0.99	20760.00	1.40	1.22
Maintenance	3627.91	0.26	0.23	2563.32	0.18	0.17	1941.23	0.14	0.13	2085.71	0.14	0.12
Total Variable costs	1417935.27			1386036.68			1375527.00			1486517.29		
% TVC to Total costs	91.65			89.68			88.87			87.61		
Fixed Costs (N'000)												
Machinery	53084.87	41.11	3.43	61664.53	38.66	3.99	74393.21	43.20	4.81	61818.18	29.41	3.64
Vehicle	52906.98	40.97	3.42	56085.06	35.16	3.63	54287.75	31.52	3.51	45564.42	21.68	2.69
Building	1666.67	1.29	0.11	7898.20	4.95	0.51	6901.73	4.01	0.45	30454.55	14.49	1.79
Pond	21470.09	16.63	1.39	33867.99	21.23	2.19	36633.39	21.27	2.37	72344.16	34.42	4.26
Total Fixed Costs	129128.61			159515.78			172216.09			210181.31		
% TFC to Total costs	8.35			10.32			11.13			12.39		
Total costs (TC)	1547063.87			1545552.46			1547743.08			1696698.60		
Gross margin	1163584.85			7214266.94			4759256.90			6536444.98		
Net Profit	1034456.24			7054751.16			4587040.81			6326263.68		
Profitability	0.82			5.20			3.46			4.40		

3.3 Empirical Results

Inference about the stochastic frontier production model is based on the maximum likelihood estimates. The maximum likelihood estimates of the parameters of the models are obtained using the frontier computer programme, Frontier 4.1 [25]. The lower section of Table 4 reports the results of testing the hypothesis that the efficiency effects jointly estimated with the production frontier function are not simply random errors.

Table 4. Maximum likelihood estimates of stochastic frontier production function

Independent variables	**Coefficient**	**Rearing unit**			
Production function		**Earthen**	**Concrete**	**Plastic**	**Fibre**
Intercept	*βo*	-0.10 (-0.74)	1.63 (2.66)*	0.93 (2.75)*	7.05 (12.12)*
Ln (Seed)	*β1*	0.99 (6.42)*	0.44 11.16)*	0.41 (5.9)*	0.23 (3.44)*
Ln (Labour)	*β2*	-0.02 (0.88)	0.08 (1.61)	0.11 (1.45)	0.55 (1.88)
Ln (Fertilizer)	*β3*	0.01 (1.33)	0.28 (8.47)*	-	-
Ln (Organic manure)	*β4*	0.07 (0.65)	0.01 (0.32)	-	-
Ln (Feed)	*β5*	0.06 (2.56)*	0.07 (3.13)*	0.39 (6.97)*	0.25 (4.53)*
Ln (Land)	*β6*	0.01 (2.87)*	0.10 (2.58)*	0.27 (3.56)*	0.38 (3.38)*
Ln (Fuel)	*β7*	0.02 (2.15)*	-0.02 (-0.26)	0.43 (0.85)	-0.36 (-0.01)
Ln (Capital)	*β8*	0.02 (3.39)*	0.21 (5.99)*	0.32 (2.97)*	0.03 (5.03*
Variance parameters					
$\sigma_s^2 = \left(\sigma_v^2 + \sigma_u^2\right)$		0.72 (8.05)*	0.69 (2.(19)	0.55 (2.03)*	0.96 (3.68)*
$\gamma = \sigma_u^2 / \left(\sigma_v^2 + \sigma_u^2\right)$		0.99 (7.04)*	0.98 (8.49)*	0.99 (2.73)*	0.84(6.21)*
Log likelihood		139.25	54.15	32.27	99.86
χ^2		19.53	19.31	14.33	17.67
Inefficiency effects					
Constant	δ_o	-0.05 (2.41)*	-0.16 (2.62)*	-0.51(-2.04)*	-0.75 (-6.07)*
Education	δ_1	0.01 (2.36)*	0.07 (2.63)*	-0.19 (-1.99)*	0.03 (3.03)*
Pond area	δ_2	0.05 (0.74)	0.02 (2.43)*	-0.87 (-2.12)*	0.13 (1.13)
Age	δ_3	0.01 (3.01)*	-0.03 (-2.43)*	0.21 (2.01)*	0.02 (2.02)*
Machinery	δ_4	-0.01 (-0.22)	-0.08 (-0.28)*	-0.16 (-1.34)	-0.02 (3.02)*
Machinery	δ_5	-0.02(-2.56)*	0.23 (2.53)*	0.21 (2.42)*	0.16 (4.16)*
Fish farm management	δ_6	0.03 (5.73)*	0.19 (2.78)*	0.82 (3.59)*	-0.06 (-6.06)*
Water management	δ_7	0.03 (2.82)*	0.15 (3.31)*	0.87 (4.11)*	-0.04 (-3.04)*
Feed management	δ_8	0.01 (0.21)	0.09 (2.02)*	1.58 (3.35)*	-0.12 (-2.19)*
Primary activity	δ_9	0.23 (1.67)	0.10 (0.23)	- 0.48 (-0.17)	0.06 (2.01)*
Return to scale		1.16	1.17	1.93	1.08

Figures in parenthesis are asymptotic t ratios.
** Significant at 5% level (P < 0.05).*

The key parameter is $\gamma = \sigma_u^2 / \left(\sigma_v^2 + \sigma_u^2\right)$, which is the ratio of the errors in Eq. (1a) and is bounded between zero and one, where if γ = 0, inefficiency is not present, and if γ = 1, there is not random noise [18]. For the estimated model, the variance parameter γ was 0.99 (earthen pond); 0.98 (concrete tank); 0.99 (plastic tank) and 0.84 (fibre tank), which were quite high and were close to 1 in all models and is significantly different from zero, thereby, establishing the fact that a high level of inefficiencies exists in these rearing units used by the fish farmers in Lagos State, Nigeria. This value confirms significant presence of technical inefficiency in the production of the fish farmers represented by the data.

The function coefficients for the MLE are approximately 1.16 (earthen), 1.17 (concrete), 1.93 (plastic) and 1.08 (fibre) which indicates increasing returns to scale. This result is similar to the findings of [29]. The estimated model have all the expected for the rearing unit with the exception of labour in earthen pond, fuel in concrete and fibre tanks. Moreover, the corresponding variance- ratio parameters γ * imply 99.0%, 98.0%, 99.0% and 84.0% of the differences between observed and the maximum production frontier for earthen pond, concrete, plastic tank and fibre tank respectively were due to the existing differences in efficiency levels among the fish farmers. A set of hypothesis on different inefficiency specifications using Likelihood Ratio (LR) test statistic was also tested. The null hypothesis that γ = 0 is rejected at the 5% level of significance in all cases confirming that inefficiency exit and are indeed stochastic (LR statistics 19.53; 19:31,14.33 and 17.67 > $\chi^2_{(1,0.95)} = 2.71$).

The t-ratios of the estimated coefficients indicate that all the variables in the models are significant at 5% level of significance except labour in all the rearing units as well as organic manure in concrete and earthen pond. Use of organic manure and fertilizer application in plastic and fibre tanks were not common occurrence among the fish farmers. Fuel was significant in earthen and consequentially insignificant in other rearing tanks. The elasticity of mean value of output is estimated to be an increasing function of fish seed, an increasing function of fertilizer, an increasing function of organic manure, an increasing function of fish feed an increasing function of fuel as well as an increasing function of capital.

The technical efficiency by rearing techniques is presented in Table 4. The mean technical efficiencies of fish farmers by were 0.86, 0.95, 0.84 and 1.00 in earthen pond, concrete tank, plastic tank, and fibre tank respectively. The degree of technical efficiency scores indicated that all the rearing techniques operate close to the frontier. The estimated mean overall was 0.94 which means that 6.0 % increase in production is possible with the present state of the rearing techniques. The F-test (26.62) from the Duncan Multiple Range shows that there was a significant difference in the technical efficiency of the various rearing techniques. Fibre tank has the highest technical efficiency ratio and was significantly different from earthen pond and plastic tank but not from concrete tanks. This means that, TE indices are dependent of the rearing techniques in the State.

The results also indicate that technical efficiency (TE) indices range from 28% to 86% for the concrete tank, with an average of 86.0% (Table 4). This indicates that, if the average farmer in the sample was to achieve the TE level of its most efficient counterpart, then the average farmer could realize a 14% cost savings. A similar calculation for the most technically inefficient farmer reveals cost savings of 69% (i.e., 1- [28/97]). Table 5 also shows that, TE range from 36% to 100%; 36% to 84%, and 100% for earthen pond, plastic tank and fibre tank rearing techniques respectively, with an average of 95%, 84% and 100%. This means that, if an average fish farmer using earthen pond was to achieve the TE level of its most efficient counterpart, then the average farmer could realize a 5% cost savings (i.e., 1-

[95/100]). The same rearing technique reveals cost savings of 59% for the most technically inefficient fish farmer (Table 5).

A similar calculation indicates that if the average fish farmer in the plastic rearing tank was to achieve the TE level of its most efficient counterpart in the sample, then the average farmer could realize a 16% cost savings. Moreover, the most technically inefficient farmer in that farming system could realize a 61% cost savings. Only fish farmers using fibre tanks were 100% technically efficient.

3.4 Factors Explaining Inefficiency

The parameter estimates of the inefficiency effects stochastic production frontier model employed to identify the factors influencing farmers levels of technical inefficiency are listed in the lower panel of Table 4. The results show that, education, age, experience, fish farm management, water and feed management index have a significant impact on technical inefficiency of fish farmers among the rearing techniques while pond area has

Table 5. Frequency distribution of technical efficiency of fish farming under different rearing techniques

Efficiency (%)	Concrete tank		Earthen pond		Plastic tank		Fibre tank	
	Number of farms	%	Number of farms	%	Number of farms	%	Number of farms	%
≤ 0.2	-	-	-	-	-	-	-	-
0.21–0.30	1	0.33	-	-	-	-	-	-
0.31–0.40	2	0.66	3	3.49	2	1.72	-	-
0.41–0.50	3	0.99	-	-	6	5.17	-	-
0.51–0.60	8	2.65	1	1.17	4	3.45	-	-
0.61–0.70	15	4.97	-	-	2	1.72	-	-
0.71–0.80	24	7.95	-	-	12	10.34	-	-
0.81–0.90	182	60.26	1	1.17	51	43.97	-	-
0.91–1.00	67	22.19	81	94.17	39	33.62	23	100
Mean	0.86^b		0.95^a		0.84^b		1.0^a	
Max	0.97		1.00		0.97		1.0	
Min	0.28		0.36		0.36		1.0	

significant impact on the technical inefficiency of the fish farmers using concrete and plastic tanks. In a similar vein, machinery has significant impact on fish farmers using concrete and fibre tanks while primary activity was only significant on the fish farmers using fibre tank. Experience has a positive and highly significant impact on efficiency in concrete, plastic and fibre tanks, while its effect on fish farmers' inefficiencies for earthen pond was negative but significant. While fish farm management, water and feed management index were negative associated with technical inefficiency and significant for fish farmers using fibre tank, the variables were however positive and significant for fish farmers using earthen pond, concrete and plastic tanks. This implies that management varied across the techniques. Hence, fish farmers adopting all the management practices perform significantly better than their peers using fibre tanks, thereby reinforcing the argument that improvement in fish farm, water and feed management practices area crucial factors in increasing productivity. The results of the determinants of technical efficiency are similar. This result is similar to that obtained by [28,30].

4. CONCLUSION AND IMPLICATIONS FOR POLICY

This study used budgetary technique and stochastic production frontier functions to analyze profitability and technical efficiency of fish farmers in Lagos State, Nigeria. Using detailed survey data obtained from 700 farmers in all the 20 Local Government Areas of the State, all the rearing used in fish production shows some level of appreciable profit. However, the operating costs (particularly the feed component) are higher for all rearing techniques. Efforts should be directed in reducing cost of feed by removing tariffs on imported feed or production of locally fish meal which formed the main cost component of fish feed. This study also compares the technical efficiency of four different rearing techniques. The results of analysis indicate variation in the distribution patterns of technical efficiency estimates from the four techniques. The mean levels of technical efficiency are 86%, 95%, 84% and 100% for concrete tanks, earthen pond, plastic and fibre tanks respectively. These results suggest that substantial gains in output and/or decreases in cost can be attained given existing technology. By eliminating technical inefficiency, production may on average be increased without altering the state of technology.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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