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Full Length Research Paper

Analysis of resource use efficiency among small-scale fish farms in Cross River State, Nigeria

Kingsley Okoi Itam[1], Ekanem Abasiekong Etuk[1] and Inibehe George Ukpong[2]*

[1]Department of Agricultural Economics and Extension, University of Calabar, Calabar, Nigeria.
[2]Department of Food Economics and Marketing, School of Agriculture, Policy and Development, University of Reading, RG6 6AR, Reading, United Kingdom.

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The study used the stochastic production frontier model to analyze the resource use efficiency among small scale fish farms in Cross River State, Nigeria. The mean efficiency of 0.89 was obtained indicating room for farm efficiency improvement by 11%. Quantity of feed, farm size (pond size), labour and capital had significant influence on fish production in the study area, with positive coefficients of feed quantity and farm size while that of labour and capital were negative. The return to scale (RTS) was 1.055 indicating increasing returns to scale, which implied that farmers may need to increase the use of productive resources. High cost of feed, unavailable credit, lack of capital and unfavorable price of fish were among the major constraints to fish production in the area. There existed some inefficiency among the sampled farmers. The major contributing factors to efficiency were gender, family size, farming experience and education. This calls for gender mainstreaming when policies that would cause improvement in efficiency are made for implementation.

Key words: Resource use, efficiency, production frontier, fish farming, Cross Rivers, Nigeria.

INTRODUCTION

Fish farming is the art and science of controlled rearing of fish in ponds, farms and in some instances natural water bodies from hatchlings (freshly hatched fishes) to mature size (Amos and Bolorunduro, 2000). It therefore, involves the controlled feeding, fertilization, stocking combination, reproduction and harvesting of fish (Amos and Bolorunduro, 2000).

Fish farming may have started about 50 years ago with the establishment of a small experimental station at Onikan, Lagos State and an industrial farm about 20 ha at Panyan in Plateau State by the Federal Government of Nigeria (Olagunju et al., 2007). Presently, fish culture has spread to all states in the country. Fish culture has been established as the best alternative to bridging the widening gap between the demand for and supply of food fish in the country (Ugwumba and Okoh, 2010). The Food and Agricultural Organization recommends that, an individual should take 35 g/ caput/ day of animal protein for sustainable growth and development (Tanko et al., 2014).

*Corresponding author. E-mail: inibeheukpong@gmail.com, Tel: +447404793722.

However, the animal protein consumption in Nigeria is less than 8 g per person per day, which is far below the FAO minimum recommendation (Niang and Jubrin, 2001). The major animal protein sources in the country include cattle, goats, sheep, poultry and fish. Out of these sources, fish and fish products provide more than 60% of the total protein intake in adults especially in the rural areas (Adekoya and Miller, 2004). Therefore, the importance of the fishing industry to the sustainability of animal protein supply in the country cannot be over-emphasized.

There has been a decline in the supply of fish in Nigeria. This is due to the decline in the country's major source of food fish, the artisanal fisheries (Ugwumba and Chukwuji, 2010), down to 40% in 2006 resulting to about 300,000 metric tons (GAIN, 2007). Osawe (2007) reported domestic fish production at 551,700 metric tons as against the present national demand of about 1.5 million metric tons estimated for 2007. The shortfall is reported to be bridged by the importation of 680,000 metric tons annually consuming about N50 billion in foreign exchange (Odukwe, 2007). Adediran (2002) and Ugwumba (2005) asserted that the only way to boost fish production and thereby move the country towards self-sufficiency in fish production is by embarking on fish farming especially catfish farming. Ugwumba and Chukwuji (2010) noted that this prompted the Federal Government of Nigeria to package the Presidential Initiative on fisheries and aquaculture development in 2003 to provide financial and technical assistance to government programs and projects encouraging fish production.

In Cross River State, fish farming is yet to be fully developed even though the State is highly endowed with rich aquatic resources. A large percentage of production from capture fisheries is mainly contributed by artisanal fisheries whereas production through aquaculture and large trawl fishing is still minimal. Major constraints facing the full industrialization of the sector range from the high cost of feed, low capital to poor enlightenment programs on fish culture techniques. Programs such as the International Fund for Agricultural Development (IFAD)/United Nations Development Programme (UNDP) and Department for International Development (DFID)/ (FAO)/Cross River State (CRS) were put in place to increase fish production to meet a target of 553 metric tons by 2011 in order to attain the FAO minimum protein requirement of 35 g/caput/day for the 2.89 million persons in the State (MANR, 2007).

In spite of these efforts of Government, fish production has remained low in the country vis-à-vis Cross River State. This has been attributed to inadequate supplies from the local fish farmers, which may not be unconnected with low efficiency of fish farming in Nigeria. Onoja and Achike (2011) noted that there are indications that the development of efficiency of fish farming in Nigeria can be a bridge towards solving the problem of inadequate supplies. This can be possible if there is improvement in the use of resources by farmers as it will lead to increase in efficiency and productivity of the fish farms. Increasing productivity and efficiency within the sub-sector of agriculture particularly among small-scale fish producers requires a good knowledge of the current efficiency or inefficiency inherent in the sector as well as factors responsible for this level of efficiency or inefficiency (Agom et al., 2012).

The need to efficiently allocate productive resources for development purposes cannot be over-emphasized. Hence, every factor of production should be efficiently and effectively mobilized to reduce the gap between actual and potential national outputs (Amos, 2007). The efficient allocation of resources at the farm levels will lead to rise in Gross National Product (GNP) and per capita income. Recent studies in estimating resource-use efficiency in Cross River State are centered on crop production, with limited information on fish farming. Related studies on fish farming such as Onoja and Achike (2011) and Ugwumba and Okoh (2010) were conducted in Rivers and Anambra States, respectively. These studies explored the application of the translog model to analyze resource productivity and profitability respectively. While Onoja and Achike estimated technical efficiency of small-scale catfish (*Clarias gariepinus*) farming in Rivers State, Nigeria, Ugwumba and Okoh did a comparative profitability analysis of African crariid catfish farming in concrete and earthen ponds. Such studies are lacking in Cross River State. Therefore, the need for this study is imperative. The main objective of this study is to determine the efficiency of small-scale fish farms in Cross River State. In specific terms, the study estimates the productivity and technical efficiency of the fish farms, identifies the constraints to fish production and analyses the determinants of technical efficiency among fish farmers in the state.

The Stochastic Production Frontier Analysis (SPFA) is an economic model introduced by Aigner et al. (1977) and Meeusen and van den Broek (1977). The frontier is used for estimating technical efficiency where deviation from the frontier is decomposed into random components reflecting measurement error and statistical noise, and a component reflecting inefficiency. The estimation of full frontier could be through a non-parametric approach (Meller, 1976) or a parametric approach where a functional form is imposed on the production function and the elements of the parameter vector describing the function are estimated by programming (Aigner and Chu, 1968) or by statistical techniques (Richmond, 1974; Greene, 1980). A potential advantage of the frontier is that it incorporates the traditional random error of regression in addition to capturing the effect of unexplained variables and errors of measurement in the dependent variable. Thus, its wide acceptance and use in this study.

Small scale fish farmers are defined in this study as fishing households (as opposed to commercial companies) using relatively small amount of capital and energy, relatively small fish ponds (earthen or concrete) or vessels, mainly for local consumption (FAO, 2012). According to FAO's Advisory Committee on Fishery Research (ACFR) working group on small-scale fisheries, small- scale fisheries make an important contribution to nutrition, food security, sustainable livelihood and poverty alleviation, especially in developing countries. Since government cannot provide all the jobs for every citizen, there is need for self-employment to promote economic growth. Engagement in small scale fish farming in Nigeria will rid the country of corruption, and other social vices caused by unemployment. The null hypothesis to be tested in this study is that no inefficiency effects exists among the sampled fish farmers in the study area, while the alternative hypothesis is that there exists some inefficiency effects among the farmers.

Ho: ä = 0

Ha: ä ≠ 0

RESEARCH METHODOLOGY

Cross River State is one of the 36 States of the Federal Republic of Nigeria. It is made up of 18 Local Government Areas and consists of 3 Agricultural Zones namely; Calabar, Ikom and Ogoja agricultural zones. According to the national population census conducted in 2006, the state has a estimated population of about 3 million people. The State is located in the Niger Delta region of Nigeria, and bounded in the North by Benue State, in the South by the Atlantic Ocean, which is responsible for its rich aquatic resources. It is bounded in the East by the Republic of Cameroon and in the West by Akwa Ibom, Abia and Ebonyi States. Cross River lies within latitude 40° 4" South and 60° 30" North, and between longitude 8° and 9° 00" E of the equator. The annual mean rainfall ranges between 1500 and 2000 mm.

The purposive sampling technique was used to select 2 agricultural zones from the 3 zones; Calabar and Ikom zones. Four Local Government Areas (LGAs) namely; Calabar Municipality, Calabar South, Yakurr and Ikom were then randomly selected. This is because of the high concentration of fish farmers in these areas. The second stage was the proportional selection of 3 towns from each of Calabar Municipality and Calabar South, and 2 towns from each of Yakurr and Ikom giving a total of ten towns. Then a simple random selection of 5 fish farmers was carried out from each of the towns making up the total sample size of 50 farmers. Data were collected with the use of a structured questionnaire designed for collecting information on outputs, inputs, farm size (pond size), prices of variables, as well as on the socioeconomic characteristics of the farmers in November - December, 2013. The questionnaires were administered through personal interviews and observation on the selected fish farmers.

Analytical technique

Aigner et al. (1977) independently proposed the stochastic frontier production function which differs from the traditional production function because its disturbance term has two components: one to account for technical inefficiency and the other to permit random events that affects production (Tran et al., 1993). It is specified as:

$$Y_i = f(X_i: \beta)exp(V_i - U_i)i = 1,2,3 \dots N \quad (1)$$

Where, Y= Production of the ith firm, X_i = Vector of input quantities of the ith firm, β = Vectors of unknown parameters, V_i = Random factors such as weather, risk and measurement error beyond the farmers control, U_i = Technical inefficiency effects.

The Cobb-Douglas functional form was assumed for the production technology of the farms and the empirical stochastic frontier production model was specified as:

$$LnY = Ln\beta_0 + \beta_1 LnX_{1i} + \beta_2 LnX_{2i} + \beta_3 LnX_{3i} + \beta_4 LnX_{4i} + \beta_5 LnX_{5i} + V_i - U_i \quad (2)$$

Where: Y = Output of fish (kg), X_1 = Quantity of feed (Kg), X_2 = Farm size (Pond size in square meter), X_3 = Labour (Man days), X_4 = Value of Capital (Naira), X_5 = Value of fingerlings (Naira), V_i = Random factors as earlier stated, U_i = Technical inefficiency effects as earlier stated, Ln = natural logarithm.

The intercept (β_0), and the coefficients of the independent variables which range from β_1 to β_5, are parameters to be estimated. The error factor (Vi) which is assumed to be independently and identically distributed captures random variations due to factors beyond the control of the fish farmers in the study area, while the term (Ui) captures technical inefficiency effects in the production process. The inefficiency effects (Ui) are assumed to be non-negative, half normal distribution N(0, δ^2 u) and specified as follows:

$$Ui = \delta_0 + \delta_1 Z_{1i} + \delta_2 Z_{2i} + \delta_3 Z_{3i} + \delta_4 Z_{4i} + \delta_5 Z_{5i} + \delta_6 Z_{6i} + \delta_7 Z_{7i} \quad (3)$$

Where:U_i = Technical inefficiency of the ith fish farm, Z_1 = Age of fish farmer (years), Z_2 = Gender of fish farmer (Dummy, Female= 0, 1= Male), Z_3 = Marital status (Dummy, Single=0, 1= Married), Z_4 = Pond size (square meter), Z_5 = Family size (Number of persons in farmer's household), Z_6 = Farming experience (years), Z_7 = Education (Years spent in school).

The intercept (δ_0) and the coefficients ($\delta_1, \dots \delta_7$) of the independent variables are parameters to be estimated. The coefficient of the Maximum Likelihood Estimates (MLE) of the parameters (Zs) was estimated using the Frontier 4.1 model by Coelli (1994), while the parameters were tested at 1 and 5% levels of significance.

Likert scale: The use of a 5-point Likert scale was employed to determine the degree of seriousness of the production constraints.

(i) Highly very serious = 5,
(ii) Very serious = 4,
(iii) Serious = 3,
(iv) Moderately serious = 2,
(v) Less serious = 1.

The cut-off point was determined as follows:

$$\overline{X} = \sum f / n \quad (4)$$

Where: X = Critical mean score, f = Total scale score (that is, 5, 4, 3, 2, 1), n = Scale points

Table 1. Estimated maximum likelihood parameters of the stochastic production function for fish production.

Variable	Parameter	Coefficients	Standard error	t-ratio
Constant	β_0	-3.846	0.2903	-1.325
Quantity of feed	β_1	0.823	0.117	6.999***
Farm size (stock size)	β_2	0.340	0.050	6.815***
Labour	β_3	-0.056	0.025	-2.230**
Capital	β_4	-0.125	0.046	-2.724**
Fingerlings	β_5	0.073	0.050	1.474
Diagnostic statistics				
Gamma(Y)	γ	0.120	0.349	0.345
Sigma square	σ^2	0.60	0.031	1.921***
Log likelihood function	L	14.33		
Likelihood ratio (LR) of the One-sided error	ʎ	13.373		

Source: Computed from field survey Data 2013 using Frontier 4.1 Software, ***Significant at 1%, **Significant at 5%.

Hence, 5+4+3+2+1/5 = 3

The mean score was compared with the critical mean, 3. If the calculated mean of a constraint is greater than the standard critical value, that constraint is regarded as very serious. The variable mean score is given as follows:

$$\overline{X_i} = \sum I / n \qquad (5)$$

Where: $\overline{X_i}$ = Variable mean score, I = Variable (e.g., Constraints 1,2,3,4,…13 of fish production), $\sum I$ = Total scores of all the respondents on a variable, n = Number of respondents.

RESULTS AND DISCUSSION

The Maximum likelihood estimate (MLE) of the parameters of the stochastic production frontier model of the fish farmers is presented in Table 1. The table contained the estimates of the parameters of the stochastic production frontier model, the efficiency model and the variance parameters of the model. The variance parameters of the stochastic production function are represented by sigma squared (σ^2) and gamma (γ). From the table, the estimated sigma parameter (σ^2) show that about 60% of the variation in fish production among the farmers was attributed to differences in technical efficiencies of the fish farmers. There was a positive relationship between the level of output of fish and quantity of feed and pond size. This is expected as the level of production depends largely on these inputs, especially the quantity of feed used in the farm. Feeds are necessary resources for fish health and growth. This result agrees with that of Onoja and Achike (2011). On the other hand, there was a negative relationship between the level of output, and labour and capital. This is in contrast with a priori expectation. It implies that these resources were over utilized. Thus, indicating that the contributions of labour and capital resources towards technical efficiency of farms were decreasing.

The existence of technical inefficiency provides a good ground in determining the sources of inefficiencies for fish farmers. Variations in technical efficiency of the farmers may arise from their characteristics and the existing technology (Giroh et al., 2008). Socioeconomic variables were included in the model to determine their influence on technical efficiency. The result of the inefficiency model shows that the signs of the estimated coefficients in the model have important implications on the technical efficiency of fish farmers in the study area. The signs of the coefficients are interpreted in the opposite direction such that a negative sign implies that the variable enhances efficiency and vice versa. From the analysis, gender, family size, experience and education were the significant variables influencing the level of technical efficiency of the model. The coefficients of experience and education had positive signs (Table 2), implying that these variables reduces the efficiency level of the farmers. This is unexpected as farmers usually count on experience and with education, they would be able to read and understand instructions on agricultural innovation and easily adopt them for increased productivity. The negative coefficients of gender and family size imply that these variables enhance efficiency. Farmers usually keep large family members so as to provide labour during production period. Thus, the larger the family size, the more labour is available for farming operations, thus increasing the efficiency of farmers (Amos, 2007).

Furthermore, Table 3 shows that there was presence of technical inefficiency effects among the fish farmers in the study area as confirmed by a test of hypothesis for the presence of inefficiency effects using the generalized likelihood ratio test. Therefore, the null hypothesis of no inefficiency effect in fish production, ä = 0, was rejected

Table 2. Determinants of technical inefficiency in fish production.

Variable	Parameter	Coefficients	Standard errors	t-ratios
Age	d_1	0.378	0.293	1.292
Gender	d_2	-0.028	0.995	-2.814***
Marital Status	d_3	-0.067	0.064	-1.051
Stock size	d_4	0.022	0.035	0.641
Family size	d_5	-0.132	0.029	-6.046***
Farming experience	d_6	1.118	0.507	2.206***
Education	d_7	0.473	0.236	2.0***

Source: Computed from field survey data, 2013 using frontier 4.1 Software, ***Significant at 1%, **Significant at 5%.

Table 3. Hypothesis test of the existence of technical inefficiency among the fish farms.

Efficiency	Likelihood function (L)	Number of restrictions	Likelihood ratio (λ)	Critical at 5%	Conclusion
Technical	14.33	6	13.373	11.9	Reject

Source: Critical value derived from Kodde and Palm (1986).

Table 4. Estimates of frequency distribution of technical efficiency index among fish farms.

Efficiency range	Frequency	Percentage
≤ 0.80	11	22
0.81 – 0.90	5	10
> 0. 90	34	68
Total	50	100
Mean	0.89	
Minimum	0.41	
Maximum	0.98	

Source: Computed from output of Frontier 4.1.

Analysis of technical efficiency of the fish farmers

Table 4 shows that the predicted farm specific technical efficiencies (TE) range of the farmers is between 0.41 and 0.98 with a mean of 0.89. Many of the farmers had efficiency of between 90% and above while a few of them were less than 90% efficient. However, they can increase production by reducing the use of capital and labour inputs. This is because the value of capital and labour were negative decreasing functions to the factors.

Elasticity of production and return to scale

The estimated coefficient for the specified function represents the elasticities of the explanatory variables. The result shows that the value of the returns to scale (RTS) was 1.055 (Table 5). This implies that farmers were experiencing increasing returns to scale in fish production in the study area. Further analysis shows that feed quantity, farm size and fingerlings were positive functions to the factors, indicating that a 10% increase in the inputs will lead to 8.2, 3.4 and 0.73% increase respectively in output. Thus, indicating that variable allocation and use were in the stage of economic relevance of the production function (Stage II). The elasticities of labour and capital were negative functions to the factor implying over utilization of these factors. Hence, caution must be exercised with the use of labour and capital inputs.

Constraints to fish production

Several factors were identified as constraints to fish productivity in the study area and these were ranked

Table 5. Elasticity of production and returns to scale.

Variable	Elasticity
Quantity of feed	0.823
Farm size	0.340
Labour	-0.056
Value of capital	-0.125
Value of fingerlings	0.073
RTS	1.055

Source: Survey Data (2013).

Table 6. Constraints to fish production.

Constraints	Calculated mean	Rank
High cost of feed	3.64	1st
Unavailable credit	3.47	2nd
Unavailable capital	3.12	3rd
Unfavourable price of fish	3.10	4th
Poaching	2.92	5th
Lack of extension agents	2.60	6th
Cost of fingerlings	2.54	7th
Fish mortality	2.44	8th
Lack of skilled workers	2.36	9th
Incidence of disease	2.34	10th
Poor maintenance	2.26	11th
Lack of water supply	2.26	11th
Poor water quality	2.04	12th

Source: Computed from survey Data (2013).

according to their degree of seriousness. Table 6 shows that high cost of feed was top in the rank (3.64). This was closely followed by unavailable credit (3.47), unavailable capital (3.12) and unfavourable price of fish (3.10). These variables were considered as serious constraints of the farmers to fish productivity because their values were above the critical mean of 3. Other constraints were below the critical mean hence, they were less serious.

Conclusion

The study used the stochastic production frontier model to investigate the efficiency of resource use in small scale fish farms in the study area. The results show that fish farmers were not fully technically efficient. The efficiency range of between 0.41 and 0.98 with a mean of 0.89 among the fish farmers was obtained. The mean range of efficiency indicates that there is room for farm efficiency improvement by 11%. Production variables that had significant influence on fish production in the study area are quantity of feed, farm size (stock size), labour and capital, with a positive coefficient of feed quantity and farm size had positive signs, while that of labour and capital were negative. These imply that increasing resource use other than labor and capital would result to increase productivity in fish production among the sampled farms.

Again, gender, family size, level of education and farming experience significantly influenced technical efficiency of fish farmers. Since education and experience had a positive influence, therefore, technical efficiency can be significantly increased as the farmers get more education and experience. The negative coefficients of gender and family size imply that these variables increased the efficiency of the fish farmers.

Also, the fact that the farmers engaged members of their families in farm activities accounted for their increased efficiency. Therefore, farmers are encouraged to continue to engage more of their family members in farm operations so as to reduce labour cost and increase efficiency. The return to scale (RTS) was 1.055 indicating increasing returns to scale. This implied that resource use and allocation were in the stage of economic relevance of the production function (Stage II).

High cost of feed, unavailable credit, lack of capital and unfavourable price of fish were the major constraints of fish production in the study area. Finally, given that gender, family size, education and experience significantly influenced farmers' efficiency, government policy should be directed towards improving these variables.

Conflict of interests

The author(s) have not declared any conflict of interests.

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Full Length Research Paper

Dietary added bamboo charcoal can evoke *Pangasianodon* growth and can reduce ammonia from culture medium

Rawnak Jahan, M. Abdul Quaiyum, Nusrat Jahan, T. Akhter and M. Sadiqul Islam*

Department of Fisheries Biology and Genetics, Faculty of Fisheries, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh.

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Ninety-days feeding trial was conducted to determine the growth performances and reduction of ammonia by adding of dietary bamboo charcoal (BC) of pangasiid catfish, *Pangasianodon hypophthalmus*. Four levels of BC (0, 0.5, 1, and 2% treated as T_0, T_1, T_2 and T_3, respectively) were supplemented to the test diet composition. The growth performance and ammonia elimination were influenced by feed type. The mean value of ammonia were 1.5±0.08 mg/L, 0.67±0.16 mg/L, 0.25±0.06 mg/L and 0.42±0.08 mg/L; mean weight gain (g) of the *P. hypophthalmus* were 51.13±0.87, 68.27±0.88, 77.93±0.88, 68.60±0.58; average daily weight gain (g) were 0.57±0.01, 0.76±0.01, 0.86±0.01, 0.76±0.01; specific growth rate (SGR) (% day^{-1}) were 1.05±0.003, 1.26±0.01, 1.32±0.01, 1.26±0.01; feed conversion ratio (FCR) were 2.59±0.02, 1.87±0.02, 1.83±0.02, 1.88±0.01; survival percentages were 87±0.58, 91±0.58, 94±1.15, and 92±1.15 in treatment T_0, T_1, T_2 and T_3, respectively. Water quality parameters especially ammonia elimination, weight gain, specific growth rate and survival rate of fish fed 1% BC diet (T_2) were significantly ($P< 0.05$) higher than other compositions. Ammonia nitrogen excretion over a subsequent 12 h period decreased with increasing dietary BC. In conclusion, the diet supplemented with 1% BC was found to have a suitable level to fulfill the better growth performance and to decrease the ammonia nitrogen of *P. hypophthalmus*, under the conditions applied in this study.

Key word: Bamboo charcoal powder, ammonia, growth, feed conversion ratio, *Pangasianodon hypophthalmus*.

INTRODUCTION

Aquaculture of the pangasiid catfish, *Pangasianodon hypophthalmus,* is one of the rapidly increasing industries because of its high market demand, and culture using a high stocking density is now common in Bangladesh (Begum et al*.,* 2012). High density and semi-intensive culture of *P. hypophthalmus* in ponds can produce at a rate of as high as 25 to 30 tons/ha/year (BFRI and BARC, 2001). However, serious health problems are affecting the intensive culture of pangus, especially in a pond of high stocking density where high accumulation of

*Corresponding author. E-mail: sadiqul1973@yahoo.com

nitrogenous waste products occurs. Due to high accumulation of nitrogenous waste products that is toxic to fish considered as a limiting factor for growth and survival of fish are affecting the culture of this species (Person-Le et al., 1995). The main source of ammonia in fish ponds is fish excretion. Other main sources of this ammonia are from aquaculture waste feed fed to the fish and diffusion from the sediment. An effective way to reduce the waste load is to modify aqua feeds with the aim of reducing excretion of nitrogen relative to fish growth (Cowey and Cho, 1991; Talbot and Hole, 1994). From the last few years, charcoal has been used in animal feed formulation as an additive because it absorbs ammonia and nitrogen and activates the intestinal function by eliminating the poisons and impurities from the gastrointestinal tract of land animals (Van et al., 2006; Mekbungwan et al., 2004). The term "charcoal" generally refers to the carbonaceous residue of wood, bamboo, cellulose, coconut shells or various industrial wastes left after heating the organic matter. This very fine odorless, tasteless black powder works as an adsorbent for many toxins, gases, and drugs without any specific action. The surface area of charcoal gives it countless bonding sites and its degree of adsorption depends on the dosages of charcoal and the amount of toxins present in the digestive tract (Banner et al., 2000; Bisson et al., 2001).

Several studies have reported about the effect of dietary charcoal supplementation on growth, feed efficiency ratio, specific growth rate, feed intake, nitrogen excretion and digestive functions of terrestrial animals (Banner et al., 2000; Kutlu et al., 2001; Samanya and Yamauchi, 2001; Mekbungwan et al., 2004; Van et al., 2006). Moreover, activated forms of charcoal have been widely used as an adsorbent or detoxicant in modern veterinary and medical science (Hoshi et al., 1991; Jindal and Mahipal, 1999).

Utilization of charcoal from wood or bamboo may provide an economical way to eliminate noxious substances because of their cheaper cost (Prasad et al., 2000). Moreover, bamboo charcoal (BC) is considered to have a higher adsorption capacity than wood charcoal because of the special structure of the micro pores of bamboo stem (Chung et al., 2004). Reports have clarified the ammonia adsorption effect of BC in aqueous solution (Asada et al., 2006), and dietary addition of BC effects on digestion, nitrogen retention, and excretion of growing goats (Van et al., 2006). However, very limited studies about BC in aquatic animal nutrition as a feed ingredient have been conducted. Preliminary study showed the efficacy of dietary BC supplementation on growth performances and nutrient utilization of stomach less tiger puffer, *Takifugu rubripes* (Moe et al., 2009). Accordingly, this study aimed to clarify the effects of BC in other species, such as pangasiid catfish, because the digestive and absorption mechanisms would be different between fish with and without a stomach. This study aimed to clarify the effects of dietary BC supplementation on growth performance, survival of *P. hypophthalmus* and water quality parameters specially ammonia excretion from the medium.

MATERIALS AND METHODS

Study area

The experiment was conducted in twelve experimental ponds located in the fisheries field complex, Bangladesh Agricultural University, Mymensingh. Each experimental pond size was 30 m^2 and the water depth was maintained between of 1.0 and 1.3 m. The ponds were equal in size and similar in shape, depth, basin configuration and pattern type including water supply facilities. Three ponds were used for each treatment.

Pond preparation

For the preparation of the pond, water was drained out and pond bottom was dried in the sun. Aquatic weeds, undesirable fishes, insects and other aquatic organisms were removed manually and the grasses on the pond dykes were also pruned manually into very small size. Lime was applied at a rate of 0.5 kg/40 m^2.

Collection and stocking of fry

The experimental *P. hypophthalmus* fry belonging to the same age group having average length and weight of 5±0.68 cm and 5.4±0.56 g, respectively were collected from the local hatchery (Digarikanda Fish Farm, Mymensingh, Bangladesh) and 100 fish/40 m^2 stocking density were used for each treatment.

Preparation of bamboo charcoal (BC)

Bamboo charcoal is made up of pieces of bamboo, which are taken from plants five years or older. Bamboo was then cut into small pieces and put into a tightly sealed container made of iron and then burned inside an oven at temperatures over 120°C. Once the fire was out, the container left to cool down completely before it opened. The BC then pounded into a fine powder and kept at cool and dry place.

Preparation of diet

Commercial fish feed obtained from commercial feed company (Mega Feed Co. Ltd., Bangladesh) was used as a basal feed supplemented with BC powder at 0, 0.5, 1.0 and 2% in T_0, T_1, T_2, and T_3, respectively. Diets were prepared by mixing the dry ingredients and water (35% of the dry weight of ingredients) and then pellet-type diets were produced through a meat grinder with a diameter disc (size, 1.9 to 2.2 mm). The diets were later oven dried (40°C for 6 h) to approximately 11% moisture. After preparation, the diets were stored at refrigerator until used.

Feeding strategy

Feeding frequency in all treatments were two times a day at a rate of 5% of their body weight till the termination of the experiment. The

Table 1. Water quality parameters in four different treatments during the study period.

Parameter	T_0	T_1	T_2	T_3
Ammonia (mg/L)	1.50±0.08^{c}	0.67±0.16^{b}	0.25±0.06^{a}	0.42±0.08^{ab}
DO (mg/L)	7.12±0.01^{a}	7.40±0.02^{ab}	7.96±0.01^{b}	7.47±0.02^{ab}
pH	8.23±0.14^{b}	7.93±0.04^{b}	7.43±0.04^{a}	7.85±0.05^{b}
Temperature (℃)	29.94 ±0.03^{a}	29.81±0.09^{a}	29.25±0.38^{a}	29.78±0.21^{a}

Values are presented as mean ± SE. Values in the same row having different superscript letters are significantly different (P<0.05).

feed was supplied by spreading method manually and half of the feed was supplied at 9:30 AM and rest of the feed was supplied at about 5:30 PM.

Sampling of fish

The experiment was conducted for three months. Fish sampling was done at fifteen days interval in the morning at around 8:30 AM to 9:30 AM. During each sampling, 10 fish from each pond was caught by cast net. The total length was measured by using ordinary scale graduated to tenth of centimeter and weight was taken by precision weighing balance Digital Scale KD-160 (Tanita Corporation, China) (accuracy up to 1 g).

Water quality parameters

The water quality parameters such as temperature, dissolved oxygen, pH and ammonia were recorded throughout the experimental period. Water samples were collected between 8:30 AM to 9:30 AM at fortnightly interval. The physico-chemical parameters like temperature (℃) was determined by a thermometer, dissolved oxygen (mg/L) was determined by DO meter (YSI Model-58, USA), pH was recorded by a pH meter (Corning pH meter, Model-445, UK) and ammonia (mg/L) was determined by HANNA ammonia test kit at fortnightly interval.

Growth parameters

The following analytical parameters were used to evaluate the growth of fish:

Mean weight gain = mean final weight (g) - mean initial weight (g);

Average daily weight gain (g) = (mean final weight - mean initial weight)/time duration;

% Weight gain = (final body weight – initial body weight) × 100/initial body weight;

Specific growth rate (SGR) = (Log final body weight – Log initial body weight) × 100/ time duration;

Feed conversion ratio (FCR) = feed fed/live weight gain,

Survival rate (%) = No. of fish harvested ×100/No. of fish stocked.

Data analysis

The final data were expressed as mean values ± standard error (SE) and analyzed by one-way analysis of variance (ANOVA). Percentage data were arcsine transformed before analysis of variance. Duncan's multiple range tests were analyzed among different group means. The significant level was set as P<0.05. All statistical analyses were performed using the SPSS11.0.

RESULTS

Physico-chemical parameters of the pond water

As shown in Table 1 during the experiment ammonia (mg/L) concentration was varied from 0.25±0.06 to 1.5±0.08 mg/L. Maximum ammonia content was found in control (T_0) while minimum ammonia content was found in T_2. Ammonia concentrations of different treatments were significantly different from each other. The dissolved oxygen content of the water varied from 7.12±0.01 to 7.96±0.01 mg/L in the experimental ponds. The maximum dissolved oxygen was found in T_2 and minimum dissolved oxygen was found in T_0. Again the range of pH values varied from 7.43±0.04 to 8.23 ±0.14 in the experimental ponds. However, there was no significant variation of temperature values under different treatments.

Growth performance of *P. hypophthalmus*

Weight gain

The mean initial weights of *P. hypophthalmus* in the treatments were 5.40±0.05 g and the final average weight was 74.17±5.58 g. The mean final weights of fish at the end of the experiments were 56.53±0.44 g, 73.67±0.88 g, 83.33±0.88 g and 74.00±0.57 g in T_0, T_1, T_2, and T_3, respectively. Weight gains of *P. hypophthalmus* in different treatments were significantly different to each other (Figure 1).

Average daily weight gain

Average daily weight gains of *P. hypophthalmus* at the end of the experiments were 0.57±0.01 g, 0.76±0.01 g,

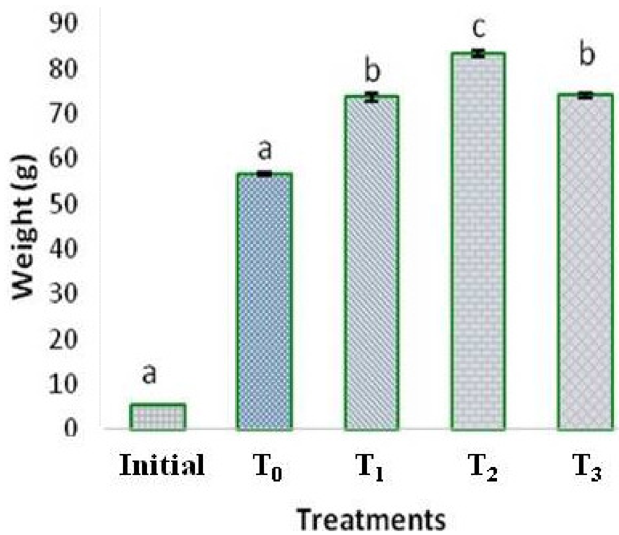

Figure 1. Final weight gains of *P. hypophthalmus* in different treatments. a, b, c means with different superscripts are significantly different from each other (P<0.05).

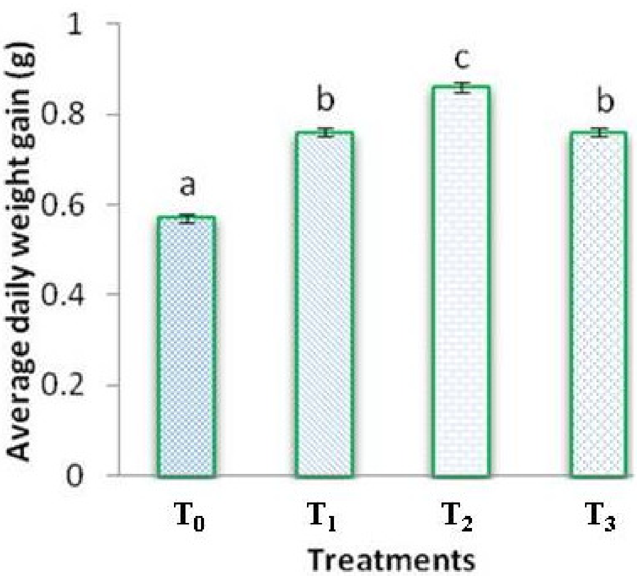

Figure 2. Average daily weight gains of *P. hypophthalmus* in different treatments. Different superscript alphabets in each treatment group are significantly different at P<0.05.

0.86±0.01 g and 0.76±0.01 g in T_0, T_1, T_2, and T_3, respectively. Average daily weight gains of different treatment were also significantly different (Figure 2).

Percent weight gains

The percent weight gains of *P. hypophthalmus* at the end of the experiments were 946.92±8.18, 1264.19±16.35,

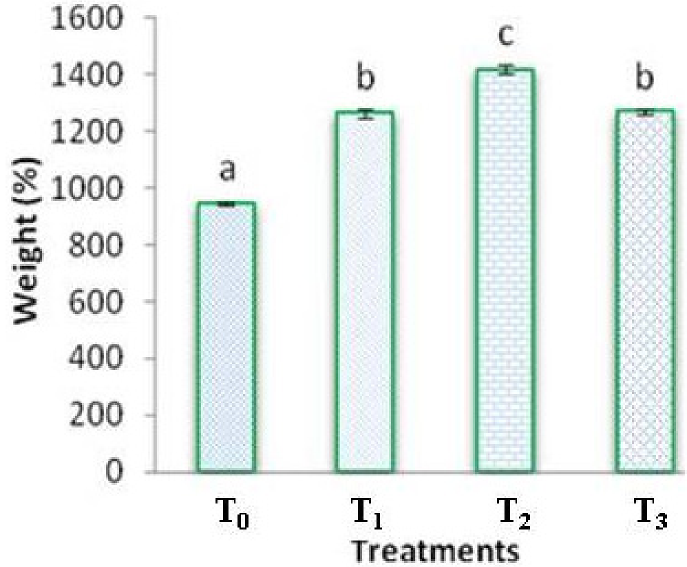

Figure 3. Percent weight gain of *P. hypophthalmus* in different treatments. Bars with different letters are significantly different (P<0.05).

1418.52±16.34 and 1270.37±10.71 in T_0, T_1, T_2, and T_3, respectively. Significantly (P<0.05) highest percent weight gain value was recorded in T_2 (1418.52±16.34) while the lowest was obtained in T_0 (946.92±8.18) (Figure 3).

Specific growth rate

The mean SGR of *P. hypophthalmus* were 1.05, 1.26, 1.32 and 1.26% in T_0, T_1, T_2, and T_3, respectively. Significantly (P<0.05) highest SGR value (1.32) was recorded in T_2 while lowest (1.05) was obtained in T_0 (Figure 4).

Feed conversion ratio (FCR)

Feed conversion ratios of *P. hypophthalmus* were 2.59, 1.87, 1.83 and 1.88 in T_0, T_1, T_2, and T_3, respectively. The highest FCR value (2.59) was recorded in T_0 while lowest (1.83) was obtained in T_2 (Figure 5).

Survival

The survival rates of *P. hypophthalmus* at the end of the experiment were 87±0.58, 91±0.58, 94±1.15 and 92±1.15 in T_0, T_1, T_2, and T_3, respectively. Highest survival was obtained in T_2 (94%) and lowest was recorded in T_0 (87%) where no BC was added (Figure 6).

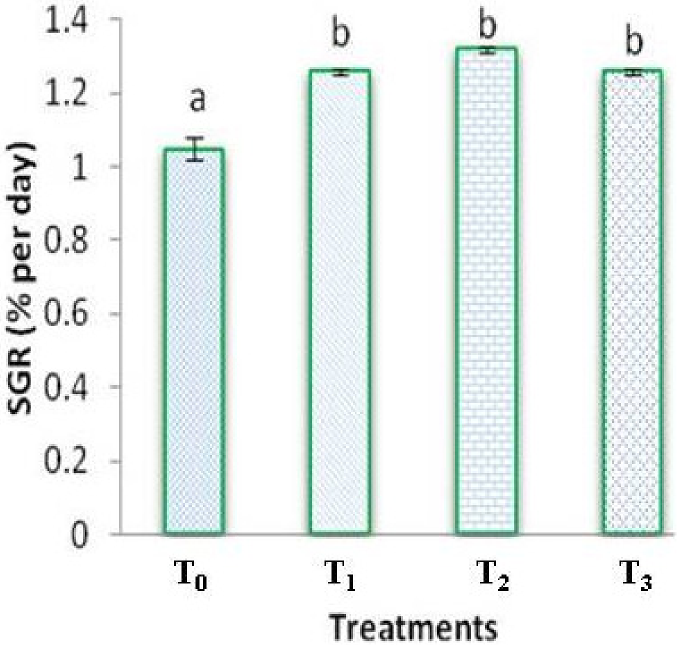

Figure 4. SGR (%/day) of *P. hypophthalmus* in different treatments. a, b means with different superscripts are significantly different from each other (P<0.05).

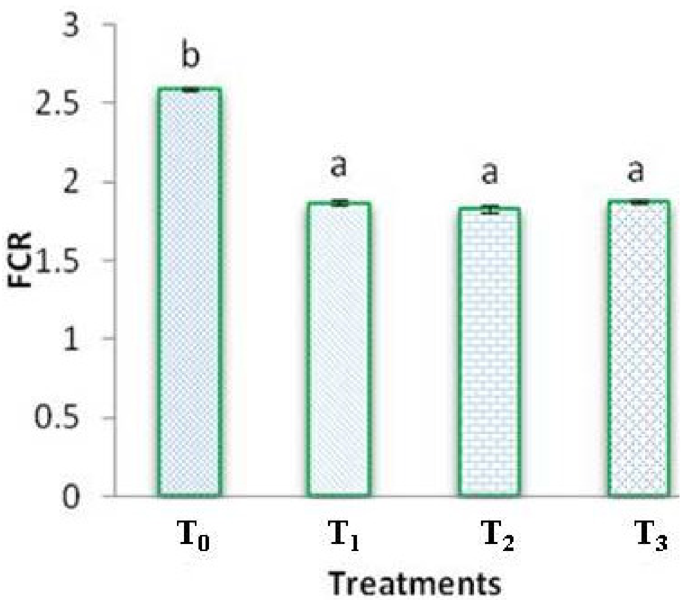

Figure 5. FCR of *P. hypophthalmus* in different treatments. Bars with different letters are significantly different (P<0.05).

DISCUSSION

The present study demonstrated that BC can influence on *Pangasianodon* growth and it can reduce the

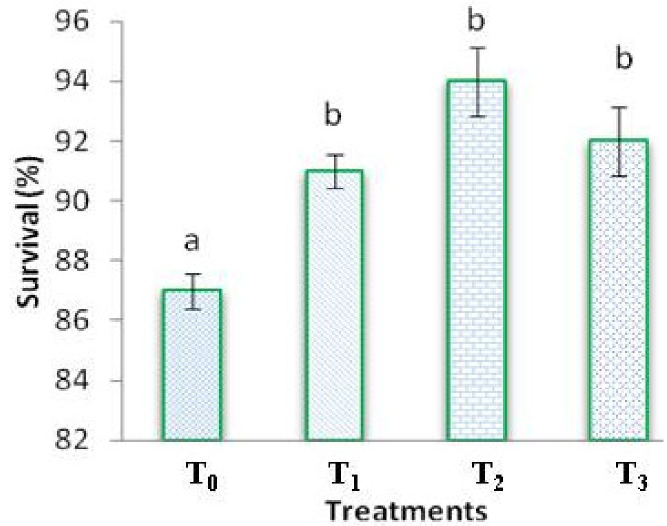

Figure 6. Survival of *P. hypophthalmus* in different treatments. Different superscript alphabets in each treatment group are significantly different at P < 0.05.

ammonia from the aquatic environment. Based on the water quality parameters specially reduction of ammonia and growth, the optimum dietary BC supplementation level for the *P. hypophthalmus* was found 1% of the diet, which was far less than that found in the previous study, where the highest weight gain was obtained at 4% BC supplementation in Tiger puffer fish (Moe et al., 2009). In another study, the dietary BC supplementation level for the juvenile Japanese flounder *Paralichthys olivaceus* was 0.5% (Moe et al., 2010). These results indicated the species-related effect of dietary BC on growth, survival and water quality parameters, and it might be because of the differences in digestion and feeding behaviors of the stomach and stomach less characteristics of these three species.

The maximum growth enhancement was noticed at 1% BC supplementation level and it declined again in supplementation levels above 1%. The minimum ammonia concentration was noticed at 1% BC supplementation level and it increased again in supplementation levels above 1%. This result showed the dose-related effect of dietary BC on ammonia elimination and fish growth. However, fish groups that received dietary BC from 0.5 to 2% level showed higher values of weight gain, SGR, survival, DO and lower FCR, ammonia concentration in this study. These results indicated that the dietary BC supplementation could be a potential feed additive to enhance the ammonia elimination and growth of the *P. hypophthalmus*, and supports research in tiger puffer fish (Moe et al., 2009) and other studies that reported growth in goats (Van et al., 2006) and in broiler chicks (Kutlu et al., 2001). Moreover, similar results were reported by Yoo et al. (2005), who found that the suitable level of CV82 (80% charcoal and 20% vinegar) for optimum growth of juvenile Japanese flounder was within 0.5 to 1% of diet.

In the present experiment, the highest feed conversion ratio was recorded in the control (T_0) group (2.59) while the lowest was obtained in T_2 (1.83). Bamboo charcoal added feed (T_1, T_2, and T_3) showed significantly lower FCR than the control feed (T_0), but no significant differences in FCR were observed among dietary BC treatments. However, the values obtained from fish fed diets containing 0.5 to 2% BC were lower in FCR than those previously reported for pangus (Sayeed et al., 2008). Survival rate of fish fed 1% BC diet were significantly ($P<0.05$) higher than those of fish fed the control diet (without BC). From the result of the experiment, it can be mentioned that BC added feed is more suitable compared to commercial feed.

Higher SGR and lower ammonia concentration in fish fed 1% BC diets may be because of the adsorbent effect of BC, which could be expected to have the potential to condition the intestinal cell membranes, reduce surface tension by eliminating gases and toxins or noxious substances along the intestine, and consequently can improve the utilization and absorption of nutrients across the cell membranes.

Mekbungwan et al. (2004) reported that the wood charcoal and vinegar compounds (WCVC) could activate the intestinal function both at villus and cellular level, and it also increase the feed efficiency of piglets. Moreover, improved feed conversion ratio and activated morphological changes of intestinal villi were observed in chickens fed WCVC supplement diets (Samanya and Yamauchi, 2001). In this study SGR and survival were significantly increased in fish fed all levels of BC diets, but significant enhancements of dry matter digestibility were found at only 4% BC supplementation in puffer fish (Moe et al., 2009). These two results indicated that the effective levels of dietary BC on digestibility vary from species to species.

Another important objective of this study was to determine whether the total ammonia excretion could be reduced by dietary BC. The values obtained from fish fed diets containing 0.5 to 2% BC were lower in ammonia than those previously reported for pangasiid catfish (Ahmed et al., 1996). Similar effects of dietary BC on ammonia nitrogen excretion were found in the study with puffer fish (Moe et al., 2009). Moreover, Van et al. (2006) reported that adding BC at a level of 1 g/kg body weight induced significantly lower urine nitrogen content as compared with the control group in growing goats.

Overall, it is likely that the BC could be used for decreasing ammonia nitrogen by nitrogen retention in the fish body. However, this is the first report for the dietary BC effect on *P. hypophthalmus* and further investigation will be required to clarify the mechanism of dietary BC on nitrogen metabolism.

Conflict of interests

The author(s) have not declared any conflict of interests.

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