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Is tilapia farming financially profitable and efficient? Policy options for sustainable farming

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Abstract

Tilapia *(Oreochromis niloticus)* is known as 'fish for the poor' due to its low market price. However, the question remains about the sustainability of this species because of high production cost and lower market price. Therefore, this study examined the financial profitability, technical efficiency and tried to find out the policy options for increasing the financial benefit of fish farmers. A total of 250 tilapia fish farmers were selected from seven tilapia producing areas of Bangladesh. To fulfill the objectives of this study, profitability, stochastic frontier production function, and sensitivity analysis were employed. Considering all selected farmers, tilapia farming found a profitable business where undiscounted BCR was only1.11. Among all cost items, only feed consists of 70 percent of the total production cost. The mean technical efficiency level of tilapia fish farmers was 85 percent, implies that by operating at full technical efficiency levels, tilapia yield could be increased from the current level of 20.98 to 24.13 tons per hectare and efficient farmers found more productive than inefficient farmers. Farmer's financial benefit can be increased by reducing the feed price, decreasing FCR or increasing the output price. Feed price reduction or enhance the quality of feed could be effective policy options for sustaining the tilapia farming.

Introduction

The contribution of aquaculture is remarkable for the impressive growth in the supply of fish for human consumption as well as the fastest growing sectors of food production in the world (FAO, 2018). In terms of overall fish production, Bangladesh stood fifth all over the world and this sector is playing an increasingly important role in the economic upliftment of Bangladesh (FAO, 2018). Presently, the fisheries sub-sector contributes about 4.43 percent to national GDP, 22.21 percent to agricultural GDP and 2.75 percent to the foreign exchange earnings (BBS, 2016). Out of total fish production, aquaculture contributes 52.92 percent and has expanded rapidly all over the country (DoF, 2017). Production trend of aquaculture has also considerably increased over the last one and half a decade (DoF, 2017).

Among the aquaculture species, tilapia is one of the major species which has expanded tremendously all over the country. Tilapia as hardy, fast-growing, short term, suits in freshwater to brackish, smaller to larger water bodies, cope with different culture patterns, taste with no muscular bone becoming popular day by day (Alam *et al.*, 2012). Consequently, overall as well as per capita production of tilapia has increased sharply from 2006 to 2016 (DoF, 2017) (Fig. 1). In the vision 2020-21, it is expected that tilapia will play an important role in producing 4.552 million MT fish (Rahman *et al.*, 2015). In the vision, the government of Bangladesh (GoB) targeted to reduce 65 million hardcore poor people to 22 million where fisheries sector, especially tilapia, will contribute significantly (Rahman *et al.*, 2015).

In recent years, tilapia farming is facing the problems of decreasing market prices, increasing feed cost with quality degradation. As a result, the production cost became high enough compared to the market price of the tilapia and the farmers are being discouraged to tilapia farming. Furthermore, the exponential increase of population creates pressure on silently decreasing cultivable land which necessitates thinking about efficient use of existing resources. So, it is being envisaged that if rising demand is not met by equally fast supply growth, shortages of fish will cause lower fish consumption, especially among the poor, and threaten food security (World Fish Centre, 2007). Therefore, tilapia production needs to be increased which can be achieved by increasing the efficiency of tilapia farmers using existing technology and encouraging them through profiting. New technology and scientific management practices that promise higher returns or lower costs are constantly being introduced. Improvements in these technology and production systems are all interlinked where research can complement traditional knowledge to improve the

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efficiency and productivity of aquaculture. Moreover, the available evidence suggests that farmers in the developing countries fail to exploit the full potential of a technology and/or make allocative errors (Ali and Flinn, 1989; Kalirajan and Shand, 1989; Bravo Ureta and Evenson, 1994; Shanmugam and Palanisami, 1994; Sharma and Datta, 1997; and Thomas and Sundaresan, 2000). Thus, the measurement of financial profitability and the technical efficiency of tilapia is an important issue from the standpoint of aquaculture development exercises in developing countries like Bangladesh. It will give pertinent use and useful information for making sound management decisions on resource allocations and for formulating aquaculture policies. Few studies on profitability and technical efficiency in different aquaculture farms had been conducted (Aktar *et al.*, 2018; Khan *et al.* 2018; Sarker *et al.*, 2016; Iliyasu *et al.*, 2014; Alam *et al.*, 2012; Alam, 2011; Khan, 2012; Khan and Alam, 2003; Sharma and Leng, 2000; Dey *et al.*, 2010) but research work related to financial profitability and technical efficiency of tilapia farming in Bangladesh is very few. Therefore, this study was conducted to know, how the financial benefit can be increased through new policy intervention in developing countries for sustaining the tilapia farming.

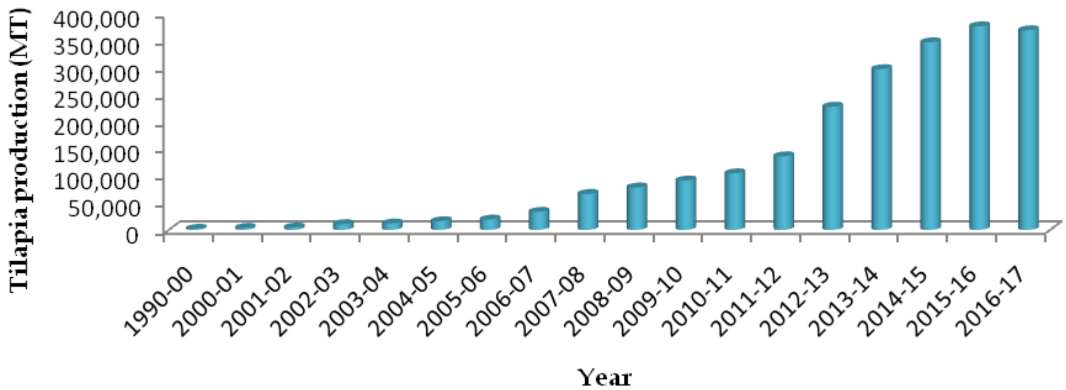

Fig. 1. Tilapia Production Trend from 1990 to 2017
Source: DoF, (1990-00 to 2016-17)

Materials and Methods

Study area and sample size

Considering the intensity of tilapia fish production, seven (7) districts were purposively selected for this study, which are Mymensingh, Cumilla, Bogura, Jashore, Bhola, Khulna, and Chattogram Afterward, 18 upazilas were selected as per production volume (on the basis of DoF statistics) from these seven districts. Finally, a total of 250 tilapia farmer were selected following the simple random sampling technique from this 18 upazilas. Data were collected through direct interviews of the respondents using a prescribed survey schedule during the months of March to June in 2016 considering the production year 2015. Each survey schedule was checked and verified to eliminate possible errors and inconsistency after the interview.

Analytical technique

Per hectare financial profitability of tilapia production from the viewpoint of individual farmers was measured in terms of net return, the benefit-cost ratio (undiscounted), gross profit margin, net profit margin, and break-even price. In addition, sensitivity analyses were performed to assess how farmers can earn financial benefit in different situations (reducing feed price and increasing output price). If the production process is not technically efficient, then resources become wasted. Therefore, it is important to know the level of technical efficiency and an optimal input combination of a farm. The Stochastic Frontier Analysis (SFA) and Data Envelopment Analysis (DEA) are the two principal methods to measure farm efficiency. In this study, SFA was used to estimate the technical efficiency of tilapia fish farmers. Two types of functions, namely Cobb-Douglas and Translog dominate the technical efficiency literature. Both functional forms were tested where Cobb-Douglas found suitable for the data set.

The empirical stochastic production function for the tilapia farmers was specified as

$$\ln Y_i = \beta_0 + \beta_1 \ln(X_1) + \beta_2 \ln(X_2) + \beta_3 \ln(X_3) + \beta_4 \ln(X_4) + \beta_5 \ln(X_5) + V_i - U_i$$

Where, *Ln* = natural logarithm; *Y* = observed farm output (kg / hectare); X_1 = quantity of labor (man-days/hectare); X_2 = fingerlings (no./hectare); X_a = feed (kg / hectare); X_4 = salt (kg / hectare); X_5 = lime (kg/hectare).

Inefficiency model was used to determine the contribution of the socioeconomic variables to the observed technical inefficiency (TI) of the fish farmers. The empirical technical inefficiency effects, U_i is as follows:

$$U_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + \delta_5 Z_5 + \delta_6 Z_6 + \omega_i$$

Where, Z_1 = age of the respondents (years); Z_2 = family size (number); Z_3 = dependency ratio; Z_4 = education (year of schooling); Z_5 = farming experience (years); Z_6 = training (days).

Furthermore, polynomial regression model was used to estimate the relationship between efficiency and productivity of tilapia farm. This model is normally used in those situations where the relationship between dependent and explanatory variables is curvilinear and it can be expressed as:

$$Y_i = m(X_i) + \delta(X_i)\varepsilon_i$$

For some unknown mean and variance functions m (·) and δ^2 (·), and symmetric errors with E () = 0 and Var ( ) = 1. The goal is to estimate $m(x_0) = E[Y|X=X_0]$, making no assumption about the functional form of m(·).

Results and Discussion

Financial Profitability of Tilapia Farming

Human labor, fingerlings, feed, fertilizer, water cleaning cost, medicine, insecticide, lease value of land and depreciation of equipment were identified as cost items in the tilapia production process. All input costs were taken into account for one production year to calculate the per hectare cost of tilapia production. Here, it is important to mention that, tilapia is being cultured twice in a year and each culture period takes 4 to 5 months. All cost and return data have been collected for the whole year i.e. two culture periods. In the study areas, both family and hired labor were used for different activities and valued at the prevailing wage rate. Human labor was used for pond preparation, feeding, fertilizing, manuring, application of lime and harvesting of fish. Considering all locations, it was observed that about 280 labors were used for tilapia culture which cost was Tk 103600 per hectare and shared 6.04 percent of the total cost. Normally, farmers purchased fingerlings from the fry collectors and/or hatcheries and the cost was calculated on the basis of farm gate price. On an average, per hectare stocking density of fingerlings was 66227 pieces and costing was Tk 137951 consisting of 8.04 percent in total cost (Table 1).

Table 1. Per hectare cost-return and profitability of tilapia fish farming

Heads	Quantity	Price per unit	Value (in Tk.)	% of total cost
Family labor (man-days)	115		42550	
Hired labor (man-days)	165		61050	
Total labor	280	370	**103600**	6.04
Fingerlings (no.)	66227	2	137951	8.04
Feed (kg)	34307	35	1200745	70.00
Water cleaning cost (salt, lime and water exchange) (Tk.)	-		75212	4.38
Medicine cost	-		16717	0.97
Fertilizer (kg) (Urea and TSP)	126	20	2594	0.15
Others cost (Tk.)	-		95794	5.48
A. Total variable cost	-		**1632613**	**95.17**
Fixed cost				
Land lease	-		74100	4.42
Equipment, boat and nets	-		7671	0.51
B. Total fixed cost	-		**82771**	**4.83**
Total cost (A+B)	-		**1715384**	
Total return (Kg)	20976	91	**1908816**	
Gross margin (Tk.)	-		276203	
Net return (Tk.)	-		193432	
Benefit-cost ratio (BCR)			1.11	
Gross profit margin (GPM) (%)			14.47	
Net profit margin (NPM) (9%)			10.13	
FCR (Feed conversion ratio)			1.64	

Feed is the most important input for aquaculture production and farmer uses industrial pellet feed in the study area. Considering all locations, the average cost of feed was estimated at Tk 1200745 per hectare and among all cost items, it constitutes 70 percent in total cost (Table 1). The finding of this current study is consistent with Prodhan and Khan (2018), Khan (2012) and Bureau *et al.*, (2009), where they observed that feed was the major operational cost for most fish farms, accounting for 60-75 percent of the variable cost depending on farming intensity. This is mainly because of the rising price of commercial fish feed in Bangladesh. Rising feed costs squeeze not only fish farmers, but also feed producers, driving them to search for alternatives to conventional feed ingredients to minimize their costs (Bureau *et al.*, 2009). Furthermore, Feed Conversion Ratio (FCR) was found 1.64 implies that about 1.64 kg of feed was needed to produce 1 kg tilapia fish. In recent years, poor-quality feed with low nutritional value is the main cause of low productivity (Bureau *et al.*, 2009). Again, countries like Bangladesh, commercial feed is simply beyond the reach the most small-scale farmers, limiting their ability to intensify aquaculture production. Therefore, relatively high fish feed prices favor large, vertically integrated fish farms; small-scale farms are becoming increasingly vulnerable to rising feed costs and highly competitive market. To make tilapia farming more flexible and input efficient, reducing feed cost is the most concerning part to look at.

Water cleaning is one of the main important operational activities in fish farming. Pond water becomes unhealthy due to regular use of industrial feed and lack of proper water exchange facilities. Therefore, farmers take different actions to maintain water quality such as application of lime, salt, aqua clean, gerolux, potash, timsen, bleaching powder, and zeolite etc. In addition, farm those have water exchange facility uses shallow tube well for exchanging water. On average, water cleaning cost per hectare was estimated at Tk 75212 and it was 4.38 percent of the total cost. Tilapia farms also incurred some other costs such as harvesting, electricity, torchlight, rope, umbrella, commission for the caretaker, mobile bill, and repair of guard shed etc. and it was estimated at Tk 95794 thus shared 5.48 percent of the total cost. The average total variable cost of tilapia cultivation was estimated at Tk 1632613. On the other hand, land lease value and depreciation cost of different capital items were considered as the fixed cost which was estimated at Tk. 82771 consists of 4.83 percent of total production costs.

The total return of tilapia farm was calculated by multiplying the total amount (sold and consumed) of production by their respective market prices. On average, productivity was found 20976 kg per hectare and the average market price of per kg tilapia was estimated at Tk.91. Profit from per hectare of pond was estimated at Tk 193432 with BCR only 1.11 which is lower than other fish species (Alam *et al.*, 2006; Faruque *et al.*, 2005). Furthermore, gross profit margin (GPM) and net profit margin (NPM) was 14.47% and 10.13%, respectively which was significantly lower than shrimp farming in Bangladesh (Shawon *et al.* 2018).

Technical Efficiency Analysis

The maximum-likelihood estimates of the parameters for the stochastic production frontier model and those for the technical inefficiency model for tilapia production are presented in Table 2. Cobb-Douglas production function and a single linear functional form were used in the frontier production function and inefficiency function, respectively. Several variables such as human labor, number of fingerlings, quantity of feed, salt, and lime were used in the tilapia production process. Most of the coefficient of the stochastic frontier or output elasticities of input had expected sign. The coefficient of labor, feed, salt, and lime had positive signs and were statistically significant at the 1 percent level, implying that increasing the amount of these inputs helps the farmers increase their output. On the other hand, the fingerlings quantity was found insignificant. It clearly indicates that the fingerlings had no significant effects on tilapia production. The reason was that farmers did not use the appropriate numbers of fingerlings in the pond that was recommended by fisheries scientist. Output elasticity of input was the highest for feed (0.558) followed by labor (0.204), salt (0.142), lime (0.126) and fingerling (0.098).

Table 2. Maximum likelihood estimates of stochastic production function and inefficiency function

Variables	Coefficient	t-value
Production function		
Labor (man-days)	0.204***	3.971
Fingerling (number)	0.098	1.076
Feed (kg)	0.558***	14.278
Salt (kg)	0.142***	2.821
Lime (kg)	0.126***	3.497
Constant	0.224	0.225
Gamma	0.909***	43.739
Inefficiency function		
Age	-1.024***	-2.387
Family size	-0.961***	-2.737
Dependency ratio	-0.766	-0.282
Education	-0.057	-0.537
Farming experience	-0.072***	-6.426
Training	-0.675***	-2.815
Constant	5.884***	2.847
Mean Efficiency	0.847	

*** indicates statistically significant at 1% level

** indicates at 5% level and * indicates at 10* level

Technical efficiency of any farmer is determined by socio-economic and demographic factors (Kalirajan and Shand, 1989; Bhende and Kalirajan, 2007). Therefore, the contribution of socioeconomic variables to the technical inefficiency (TI) of tilapia fish farmers was determined by using the inefficiency model. Age of farmers, family size, dependency ratio, education, farming experience, and training were taken into account to estimate the inefficiency effects. Since the dependent variable of the inefficiency model was defined in terms of technical inefficiency, a farm-specific variable associated with the negative (positive) coefficient will have a positive (negative) impact on technical efficiency. Age, family size, farming experience, and training were significant at the 1 percent level and had a positive impact on technical efficiency (negative impact on technical inefficiency) (Table 2). As old farmers have normally more experience than younger farmers and this experience along with better training services make them able to reduce the production inefficiencies and losses by gaining more information. Education and dependency ratio did not seem to have any effect on technical efficiency individually as they were all statistically insignificant. The γ-parameter was found to be 0.91 which was estimated to be close to 1 and highly significant. Although the γ-parameter cannot be interpreted as the proportion of the total variance explained by the technical inefficiency effects, the result indicates that inefficiency factors had a significant impact on tilapia production. The mean technical efficiency of tilapia fish farmers of Bangladesh was found 85 percent varying from 26 to 99 percent and surprisingly, not a single farm appears as fully technically efficient (Table 2). The findings imply that farmers were operating 15 percent lower than the production frontier given the level of technology which was similar to another finding on the efficiency of cage fish farming in Peninsular Malaysia resulting an estimated mean technical efficiency score of 79 percent (Iliyasu *et al*., 2014). This finding was also consistent with Islam *et al*., (2004); Khan *et al*., (2010); Islam *et al*., (2012). By operating at full technical efficiency levels, tilapia yield could be increased from the current level of 20.98 to 24.13 tons per hectare.

The result also reveals that about 54.4 percent of tilapia farmers have technical efficiency scores ranging from ≥ 0.80 to ≤ 0.90 and 28.8 percent operate above 0.90 level (Fig. 2) which implies that most of the farmers operate above 80 percent efficiency level. Furthermore, only 3.6 percent of farmers operate at less than 60% level of technical efficiency (Fig. 2). This technical efficiency level of tilapia farmers appears to be higher than the previous study of Bangladesh by Alam *et al.,* (2012) were found mean technical efficiency score 78% and 32% farmers have technical efficiency scores ranging between 70 and 80% while 28% operate between 90 and 99% level.

Farm productivity mainly depends on the scientific and efficient use of different inputs. To examine whether efficient farmers are productive or not, polynomial regression was used. Fig. 3 shows that productivity increases with the increase of the efficiency of the farmers which means if the farmer uses different inputs efficiently then the productivity will also increase. Therefore, knowledge of scientific management practices is essential for getting higher productivity and financial benefit.

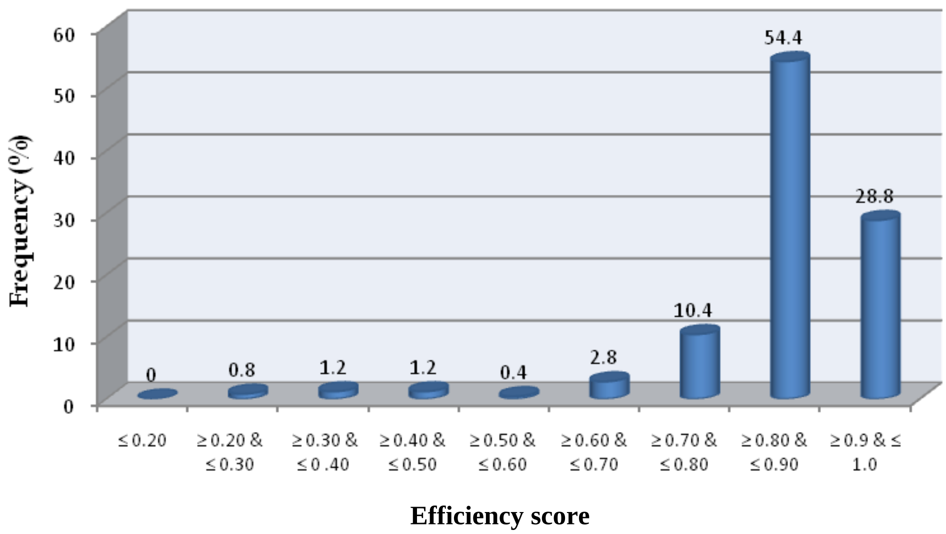

Fig. 2. Frequency distribution of technical efficiency scores

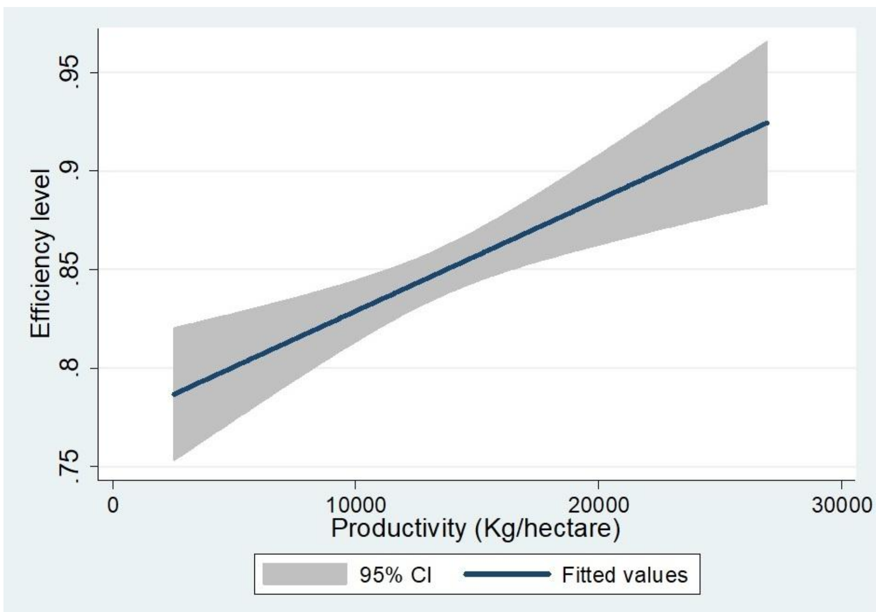

Fig. 3. Relationship between efficiency and productivity

Sensitivity Analysis

Due to low market price and high input cost, farmers are being discouraged to culture tilapia and it was also observed from the field level that farmers were switching from tilapia to other indigenous fish species to get the higher financial benefit. Therefore, the government, as well as relevant organizations, need to take some policy for sustainable tilapia farming. This study found that only feed cost consists of about 70 percent of total production cost, and output price was low compared to other fish species. Therefore, there are rooms to introduce some policies. To generate new policy, this study tried to show the effects of changes in feed and output price on financial benefit. Five scenarios were evaluated with the business as usual (Table 3). Other things remaining the same, if the feed price is reduced by only 10 percent, then BCR becomes 1.2 and farmers can earn profit about Tk.15 from per kg of fish which was Tk. 9 in the business as usual situation and the variable cost of per kg fish can be reduced from Tl.78 to Tk.72. In the same way, if the output price is increased by only 10 percent with other things remain the same, BCR becomes 1.22 and NPM reached 18.3 percent from 10.13 percent of business as usual. In this situation, the benefit from per kg of fish reached Tk. 18.32 which is higher than the reduction of 10 percent feed price implies that the farmer gets more benefit from the increase in output price compared to feed price reduction (Table 3). In addition, another two situations were analyzed as only “5 percent reduction in feed price and 5 percent increase in output price”, and “10 percent reduction in feed price and 10 percent increase in output price" (Table 3). Results reveal that Tilapia farmers can be financially benefited through implementing both policies, where by reducing 10 percent feed cost and 10 percent increase of output price, BCR become 1.32 and net profit margin reached to 24.02 percent. Finally, another option has been analyzed where FCR was reduced by 10 percent meaning feed use reduction by 10 percent for producing per kilogram fish. It is only possible when feed quality can be increased with other things remain the same. From the above results, it can be concluded that the reduction of feed price, enhance the quality of feed or an increase of output price may be an effective policy for sustainable tilapia farming.

Table 3. Sensitivity analysis of feed and output price changes and its effects on financial benefit

Scenario	BCR	GPM	NPM	BEP	VCK	BKF
Business as usual	1.11	14.47	10.13	81.78	77.83	9.22
Feed price reduced by 10%	1.20	20.76	16.42	76.05	72.11	14.95
Feed price reduced by 20%	1.29	27.05	22.71	70.33	66.38	20.67
Output price increased by 10%	1.22	22.25	18.30	81.79	77.83	18.32
Feed price reduced by 5% and output price increased by 5%	1.21	21.54	17.41	78.92	74.97	16.63
Feed price reduced by 10% and output price increased by 10%	1.32	27.96	24.02	76.05	72.11	24.05
FCR reduced by 10%	1.19	20.25	16.12	76.33	72.39	14.67

BCR: Benefit-cost ratio; GPM: Gross profit margin; NPM: Net profit margin; BEP: Break-even price; VCK: Variable cost per kg fish; BKF: Benefits from per kg fish

Conclusions and Policy Recommendation

Tilapia farming has expanded tremendously in Bangladesh over the last two decades. Throughout the country, commercial tilapia farms follow semi-intensive farming practices where the industrial feed is the main input of production and has become very expensive to the producer. Furthermore, the market price of tilapia is very low compared to other fish species which leads to less financial benefit from tilapia farming. In this study, tilapia farming found a financially profitable business where BCR was low compared to other fish species. Among all cost items, only feed cost was about 70% of the total production cost. Labor use, number of fingerlings per hectare, amount of feed, salt, and lime were contributed significantly to the production of tilapia. Age of farm operators, education, training, and experience were significant determinants of technical inefficiency. Per hectare yield could be increased by 15 percent with the existing technology if farmers could run at the frontier. Thus, given the levels of existing technologies and resource use, the sample farms could increase their average yield from the existing 20.98 to 24.13 tons/ha by using their existing resources more efficiently. Department of Fisheries and other relevant organization can play a vital role in improving the technical efficiency of tilapia farmers through better training on stocking, feeding and fertilizing ponds. In this case, leaflet distribution on scientific tilapia farming may be one of the best ways, which may help to improve fish production practices. Farmers in the study areas are not able to use inputs, especially feed at optimum level because of the higher price and also output price was very low as their expectation. Reduction of feed price, FCR reduction though increasing feed quality and the increase of tilapia price found effective ways for enhancing the financial benefit of tilapia farmers. But increases in output price depends on several factors such as demand, supply, and consumer preferences. In addition, increases in output prices hamper the consumer's welfare. Therefore, the reduction of feed price or enhance the quality of feed could be an effective policy for sustainable tilapia industry. Government can provide subsidy on fish feed or can introduce tax rebate policy in imported feed ingredient for reducing the feed price. Furthermore, the feed market is mainly controlled by very few companies and earn the supernormal profit that leads to increase the feed price. Therefore, the government's monitoring system in the feed industry is to be strengthened and new regulatory policy needs to be introduced for sustaining the industry.

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