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GROWTH PERFORMANCEAND ECONOMIC ANALYSIS OF TILAPIA (OREOCHROMIS NILOTICUS) JUVENILE PRODUCTION IN DIFFERENT EARTHEN POND SIZES

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ABSTRACT-
This study aims to assess the growth performance, and economic and investment analysis of juvenile tilapia production in earthen ponds of different sizes: 800, 1,600, and 3,200 m^2. An on-farm study was conducted in Sakon Nakhon province, Thailand.The tilapia fingerlings were raised to juveniles at a stocking density of 31.29 fish/m^{2}with the average raising time of 76 days. The 800 and 1,600 m^2 ponds provided the better growth performance than the 3,200 m^2 pond. This is due to the survival rate, harvesting weight, weight gain, and yield were higher, while the feed conversion ratio was lower. However, the economic and investment analysis revealed that the net present value, internal rate of return, and benefit-cost ratio of 1,600 m^2 pond were higher, and the payback period was lower than the other pond sizes.Hence, the 1,600 m^2 pond was recommended for tilapia juvenile production.

Keywords: Economic Value, Cost and Return, JuvenileTilapia, Earthen Pond Size, Growth Performance

I. INTRODUCTION

Nile tilapia (*Oreochromis niloticus*) is a freshwater fish,which has some advantages over other culture fish, such as fast growing, utilization of different feeds, tolerance for high stocking densities and different environmental conditions(Celik, 2012). Additionally, tilapia consumption in the global market is increasing. Therefore, tilapia is important to the world economy. In 2016, Thailand produced approximately 209.8 thousand tons of tilapia, which tended to increase continuously from the year 2013 and had an approximate value of 10,842.5 million baht. The amount of tilapia farming accounts for 35.1 percent of the total freshwater fish culture in Thailand, which is 31.0 percent of the total value of Thai freshwater fish culture. Moreover, 79.9 percent of the tilapia culture in Thailand is raised in earthen ponds. The rest are raised in floating baskets, rice fields, and water canals in orchards. (Fishery Statistics Analysis and Research Group, 2018).

In Thailand, the commercial tilapia production consists of production phases raising fry, fingerling, juvenile, and adult fish farming. For tilapia farming in floating baskets,most farmersuse juvenile tilapia for raising adult fish, rather than breeding their own fry.This is because it is easier to manage in a farm, it requires a short raising period, and it providesafast return, resulting in the economic commercial production of juvenile tilapia. In juvenile tilapia production, fingerling is raised until growth up to 10-25 g/fish.Most farmersprefer to producejuvenile tilapia in earthen ponds rather than in floating basketssince they can produce a larger quantity with a greater survival rate and moreweight gain.Generally, 400-1,600 m^2 pond size is used, depending on the size and shape of land used for farming.

The different sizes of pond affect the growth of fish, and the cost and return of investment. The optimal pond sizes for raising hybrid striped bass (striped bass x white bass *Morone chrysops*) were 2.5-10.0acre (approximately 10,000-40,000 m^2) (Gempesaw et al., 1992). While, large ponds (at least 1.6 ha or 16,000 m^2) were recommended for producing striped bass (*Morone saxatilis*) fingerlings in brackish-water ponds, since reducing the cost of construction and maintenance and increasing the efficiency of land and water use (Matlock, 2010). On the other hand, a study by Kapute et al. (2016) conducted in Southern Malawi established that small ponds (200 m^2) and high pond water depth (1.2 m) results in higher tilapia growth performance and yields, thus smaller and deeper ponds were recommended for small-commercial fish farmers. However, medium- and large-commercial fish farmer that requires mass fish product need to use the larger ponds. Nevertheless, very little information is available on the effect of pond size on tilapia juvenile production and economic profitability. This research aims to study the effect of earthen pond sizes on the growth, survival, and economic and investment analysis of tilapia juvenile raising, which provide the guidelines for making business decisions on commercial tilapia production.

II. MATERIALS AND METHODS

Participants

The thirty participants were members of a fish culture farmers' group in Ban Nong Phai, Na Hua Bo sub-district,Phanna Nikhom district,Sakon Nakhon province. They were selected by purposive sampling and they all cultured juvenile tilapia in earthen pond. Three sizes of the earthen pond (800, 1,600, and 3,200 m^2) and thirty ponds of each size were used in this study, which resulted in a total sample of 90 earthen ponds.

Tilapia juvenile production

The tilapia (*Oreochromis niloticus*) fingerlings were purchased from a private nursery. Then, fingerings were batch-weighed before being released into the earthen ponds. The average initial body weight at stocking was 0.25±0.01 g.Different earthen pond sizeof 800, 1,600, and 3,200 m^2were studied, at a stocking density of 31.29±3.75 fingerings/m^2. The water level in pond was kept at 50-80 cm of depth throughout the culture period.

The raising of tilapia juvenile was divided into fourstages. Estimated feeding rates of each stage based on the body weight of fish (Chowdhury et al., 2013; El-Sayed, A.-F.M., 2020). In the first stage (first ten days) of raising, the tilapia fingerlings were fed at 8% body weight per day, four times a day at 7 a.m., 10 a.m., 2 p.m., and 5 p.m. In the second stage (11th to 25th day), the feeding rate was 7% body weight per day, four times a day.In the third stage (26th to 45th day), the feeding rate was 6% body weight per day, three times a day at 7 a.m., 12 a.m., and 5 p.m. In the fourth stage (46th to 76th day), the feeding rate was 5% body weight per day, three times a day. The fish feed was used in the first and the second stages contained at least 40% protein, at least 4% fat, no more than 4% fiber, and no more than 12% moisture. For the third and the fourth stages, the fish feed was changed to at least 30% protein, at least 3% fat, no more than 8% fiber, and no more than 12% moisture.

Growth performance evaluation

To evaluated the growth performance of tilapia, two hundred fish from each pond were randomly selected and weighed every 15 days until the completion of the culture period. At the end of the culture period, the total number of harvested fishes, harvesting weight, and total feed intake were recorded.Average weight gain, survival, product yield, and feed conversion ratio (FCR) were accessed following Mridha et al. (2014) and kunda et al. (2014).

Water quality assessment

The quality of the water used in the three treatments was monitoredbetween 5.00-6.00 a.m. and 3.00-4.00 p.m.,every 15 days until the completion of the 76culture days.Water quality parameters were analyzed according to standard protocols (Rice et al. 2012). Water temperature was measured by using a glass thermometer (SATO No.0110-00, 0-100°C, Sato Keiryoki MFG. Co., Ltd., Japan). The pH of the water was analyzed by using a pH meter (FiveEasy Plus, Mettler Toledo, Switzerland). The hardness of the water was analyzed using the EDTA titrimetric method. The ammonia was analyzed using the distillation-titration method. The dissolved oxygen was analyzed using the azide modification method. The water quality data from5.00-6.00 a.m. and 3.00-4.00 p.m. was totalled and expressed as mean ± standard deviation (S.D.).

Economic and investment analysis

The data of the juvenile tilapia cultured in 2015 were collected by interviewing the respondents using a structured questionnaire. The questionnaire comprised questions concerning the raising method,stocking density, feeding quantity, survival rate, product quantity, raising period, investment cost, and the revenue from the sale of the fish. The economic and investment analyses employed the variable costs (VC), fixed costs (FC), total cost (TC), total revenues (TR), Net profit, break-even price, break-even point, payback period,benefit-cost ratio (B/C ratio), net present value (NPV), and internal rate of return (IRR), (Engle, 2010; Mankiw et al., 2013; Kay et al., 2016; Yuan et al., 2017;Sudirman et al., 2020)as follows.

TC = VC + FC

Net profit = TR – TC

Break-even price = VC/Q

Break-even point= FC/(Price per unit – Variable cost per unit)

Payback period = C/ER

B/C ratio = TR/TC

$$NPV = (P_1/(1+i)^1) + (P_2/(1+i)^2) + \ldots + (P_n/(1+i)^n) - C$$

when P_n is the net cash flow in year n, i is the discount rate, C is the initial cost of the investment, Q is the product quantity, and ER is the expected annual cash revenue.

The equation for findingIRR is the same as for NPV, but the equation is solved for i, the interest rate when NPV = 0 (Engle, 2010; Kay et al., 2016).

$$C = (P_1/(1+i)^1) + (P_2/(1+i)^2) + \ldots + (P_n/(1+i)^n)$$

Statistical analysis

Before performing the statistical analysis, the assumption of normal distribution was tested by using the Kolmogorov–Smirnov test. The homogeneity of variances was checked by using the Bartlett's test.The data of growth perfomance (survival,harvesting weight,weight gain, product yield, and FCR), and water quality (water temperature, pH, hardness, ammonia and dissolved oxygen) were analyzed by one-way ANOVA with the earthen pond sizes as the main factor. When a main effect was significant, the ANOVA analysis was followed by Duncan's multiple range test (DMRT). All data were expressed as mean ± standard deviation (S.D.). The relationship between growth parameters (dependent variables) and pond size variable (independent variable) were analyzed by using the regression analysis (Ahmad and Abdel-Tawwab, 2011). All analyses were performed at 5% level of significanceusing R program (R version 4.0.0, 2020).

III. RESULTS

The growth of the tilapia every 15 days is shown in Figure 1. The average weight of the fish in800 m² pond and 1,600 m²pond were similar and higher than 3,200 m² pond throughout the culture period.

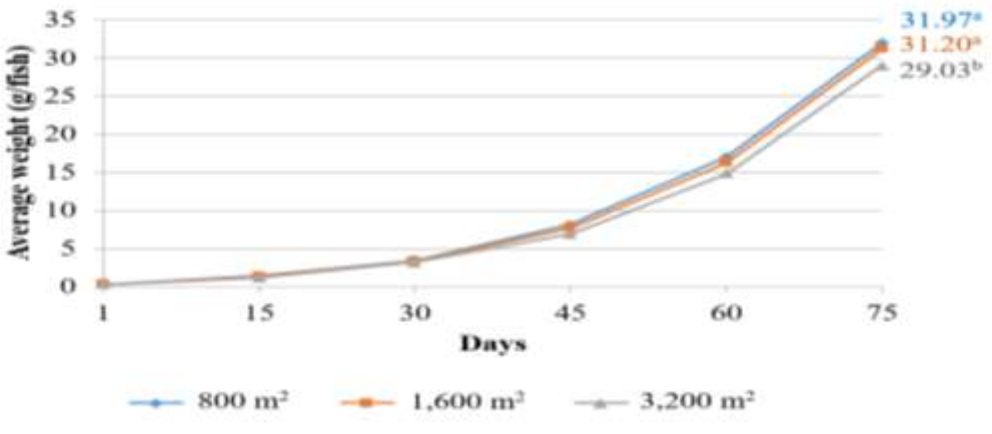

Figure 1 Growth of juvenile tilapia which were raised in different earthen pond sizes.

Mean values (n = 30) on the 75thday of culture with different superscript lettersare significantly different ($p<0.05$).

The information for juvenile tilapia production in the different sizes of earthen pond is shown in Table 1.Survival rate, harvesting weight, weight gain, and yield of 800 m² pond and 1,600 m² pondwere higher than 3,200 m² pond ($p<0.05$). While, the feed conversion ratio was highest in 3,200 m² pond, followed by

1,600 m² pond and 800 m² pond, respectively. Therefore, 3,200 m² pond needed more feed than 1,600 m² pond and 800 m² pondto achieve the same weight gain.

Table 1 Information of juvenile tilapia production in different earthen pond sizes.

Items	Unit	Earthen pond sizes		
		800 m²	**1,600** m²	**3,200** m²
Stocking density^{ns}	Fish/m²	30.83 ± 4.32	31.58 ± 3.36	31.46 ± 3.57
Stocking weight^{ns}	g/fish	0.25 ± 0.01	0.26 ± 0.01	0.25 ± 0.01
Total raising period^{ns}	Days	75.33 ± 11.21	76.67± 10.45	78.50 ± 11.15
Survival	Percentage	81.73^a ± 1.41	80.93^a ± 1.41	72.67^b ± 2.28
Harvesting weight	g/fish	31.97^a ± 2.30	31.20^a ± 1.85	29.03^b ± 1.25
Weight gain	g/fish	31.71^a ± 2.29	30.94^a ± 1.84	28.78^b ± 1.24
Yield	Fish/m²	25.23^a ± 3.68	25.52^a ± 2.35	22.86^b ± 2.61
Feed conversion ratio (FCR)	-	1.42^c ± 0.02	1.44^b ± 0.02	1.57^a ± 0.02

Values expressed as means ± S.D.(n = 30).Different superscript letters in the same row indicate significant differences ($p<0.05$).^{ns}Means in the same row are non-significant differences ($p>0.05$).

The relationship between earthen pond size and growth parameters of juvenile tilapia production are shown in Table 2. It should be noted that the R-square of survival, and FCR are higher than 0.8, which means that their predicted equations provide more confidence in the prediction of the values of the growth parameters. However, the R-square of harvesting weight, weight gain, and yield are very low, so the predicted equation is not appropriate to predict these growth parameters.

Table 2 The relationship between earthen pond size and growth parameters of juvenile tilapia production

growth parameter	Predicted equation	R^2	P-value
Survival (%)	$Y = -(1.736\times10^{-6}) X^2 + 0.003 X + 80.311$	0.85	< 0.001
Harvesting weight (g/fish)	$Y = -0.001X + 33.050$	0.32	< 0.001
Weight gain (g/fish)	$Y = -0.001X + 32.793$	0.32	< 0.001
Yield (Fish/m²)	$Y = -(2.882\times10^{-8}) X^2 + (5.542\times10^{-5}) X + 0.782$	0.28	< 0.001
Feed conversion ratio	$Y = (2.578\times10^{-8}) X^2 - (4.021\times10^{-5}) X + 1.433$	0.93	< 0.001

Y = Growth parameter variable, X = Pond size variable.

The relationships between earthen pond size and either survival or FCR were best expressed by the second-order polynomial regression equations (Figure 2).When the pond is larger, FCR increased. Therefore, the weight gain and harvesting weight of juveniles in the larger pond was lower than the smaller pond. Additionally, When the pond is larger, the survival rate decreased. Resulted in the yield is decreased as well.

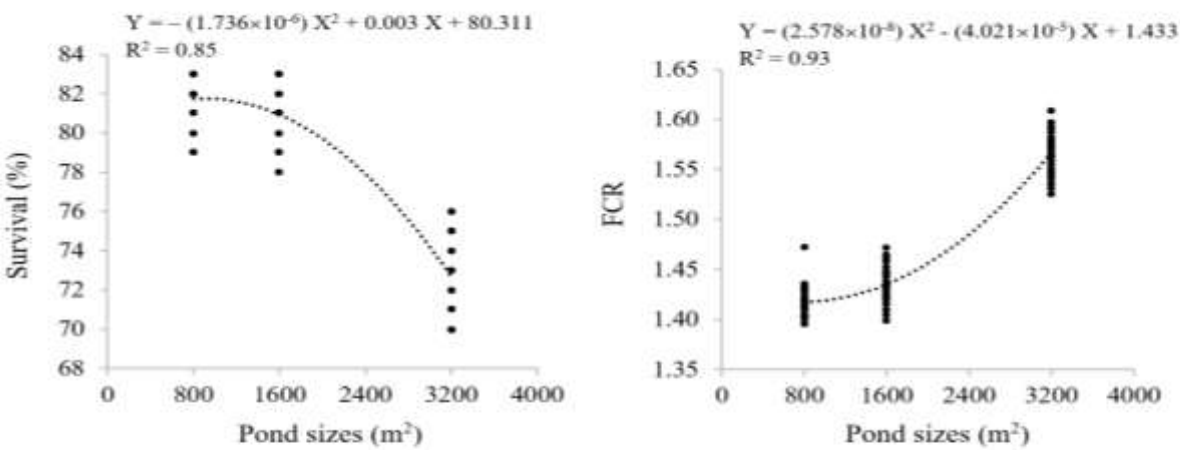

Figure 2 The relationships between earthen pond sizes and either survival or FCR of tilapia juveniles.

Water quality of all treatments was in the normal range for tilapia culture (Table 3).There were no differences in temperature and pH among the treatments ($p>0.05$). Hardness and dissolved oxygen of 3,200 m² pondwere higher than 800 m² pond and1,600 m² pond, respectively. While the amount of ammonia of 800 m² pondwas higher than 1,600 m² pond and 3,200 m² pond, but there was only a slight difference.

Table 3 Water quality in different earthen pond sizes over 75 days of juvenile tilapia raising.

Items	Unit	Earthen pond sizes		
		800m²	**1,600**m²	**3,200**m²
Temperature ^{ns}	°C	30.48±0.62	30.49±0.46	30.56±0.58
pH ^{ns}	-	7.29±0.11	7.28±0.10	7.24±0.09
Hardness	mg/l	80.09^{b}±1.08	80.46^{ab}±1.21	80.96^{a}±1.21
Ammonia	mg/l	0.21^{a}±0.02	0.20^{b}±0.02	0.20^{b}±0.02
Dissolved oxygen	mg/l	6.49^{b}±0.05	6.50^{ab}±0.06	6.52^{a}±0.09

Values expressed as means ± S.D. (n = 30). Different superscript letters in the same row indicate significant differences (p<0.05).^{ns}Means in the same row are non-significant differences (p>0.05).

The totalcosts per square meter of juvenile tilapia production in 800 m² pond was higher than 1,600 m² pond and 3,200 m² pond, respectively (Table 4). The total fixed costs for 800 m² pond, 1,600 m² pond, and 3,200 m² pond were 6.13, 4.83, and 3.64 baht/m², respectively. The fixed costs include depreciation of ponds and equipment, land rental, loan interest, and opportunity cost. Most of the fixed costs are depreciation of ponds and equipment. Smaller ponds have more depreciationcosts, resulting in more fixed costs as well.The variable cost acquired 89.45% (800 m² pond), 91.31% (1,600 m² pond), and 92.80% (3,200 m² pond) of the total cost of production. The variable costs include fingerlings, feed, labor, gasoline, medicines, chemical agents, fertilizer, repair and maintenance, and opportunity cost. Feed and labor cost of smaller pond were higher than the larger pond, while other variable costs were similar.

Table 4 The costs of juvenile tilapia production in three earthen pond sizes.

Items	Units	Earthen pond sizes											
		800 m²				**1,600 m²**				**3,200 m²**			
		Cash	**Non cash**	**Total**	**%**	**Cash**	**Non cash**	**Total**	**%**	**Cash**	**Non cash**	**Total**	**%**
Fixed cost	**Baht /m²**	**0.83**	**5.31**	**6.13**	**10.55**	**0.51**	**4.32**	**4.83**	**8.69**	**0.33**	**3.31**	**3.64**	**7.20**
Depreciation of ponds and equipment	Baht /m²	-	4.06	4.06	6.99	-	3.07	3.07	5.54	-	2.06	2.06	4.08
Land rental	Baht /m²	-	1.19	1.19	2.04	-	1.21	1.21	2.17	-	1.22	1.22	2.41
Loan interest	Baht /m²	0.83	-	0.83	1.42	0.51	-	0.51	0.92	0.33	-	0.33	0.66
Opportunity cost	Baht /m²	-	0.06	0.06	0.10	-	0.04	0.04	0.06	-	0.03	0.03	0.05
Variable cost	**Baht /m²**	**48.47**	**3.52**	**51.99**	**89.45**	**48.04**	**2.64**	**50.68**	**91.31**	**45.23**	**1.76**	**46.98**	**92.80**
Fingerlings	Baht /m²	9.25	-	9.25	15.92	9.48	-	9.48	17.07	9.44	-	9.44	18.64
Feed	Baht /m²	31.18	-	31.18	53.65	31.16	-	31.16	56.13	28.31	-	28.31	55.93
Gasoline	Baht /m²	1.22	-	1.22	2.09	1.22	-	1.22	2.20	1.11	-	1.11	2.20
Medicines and chemical agents	Baht /m²	1.53	-	1.53	2.64	1.15	-	1.15	2.08	1.59	-	1.59	3.13
Fertilizer	Baht /m²	0.52	-	0.52	0.89	0.51	-	0.51	0.91	0.52	-	0.52	1.02
Labor	Baht /m²	0.81	3.52	4.32	7.44	0.80	2.64	3.43	6.19	0.66	1.76	2.42	4.78
Repair and maintenance	Baht /m²	0.80	-	0.80	1.37	0.59	-	0.59	1.06	0.64	-	0.64	1.26

Opportunity cost	Baht /m^2	3.17	-	3.17	5.46	3.14	-	3.14	5.66	2.96	-	2.96	5.84
Total cost	**Baht /m^2**	**49.29**	**8.82**	**58.12**	**100.00**	**48.55**	**6.95**	**55.51**	**100.00**	**45.56**	**5.07**	**50.63**	**100.00**

Land rental valuation based on the cost of the land by Sakon Nakhon Provincial Land Office, Thailand.The loan interest was set at 7% per year according to the loan interest of the Bank for Agriculture and Agricultural cooperatives, Thailand.The opportunity cost of capital was represented by the discount rate, at 7% per year(Whitmarsha et al., 2006).

The results showed that the total costs per square meter of juvenile tilapia production in the 3200 m^2 pond was the lowest (Table 4). However, the total cost per fish of the 1600 m^2 was a little lower than the other pond sizes (Table 5).The average price (Table 5) was calculated based on the local market price of Sakon Nakhon province, Thailand, in 2015.The price of juvenile tilapia depends on the fish's weight.Therefore, the average price, and total revenue of 800 m^2 pond and 1,600 m^2 pond were higher than 3,200 m^2 pond.Since, survival rate and harvesting weight of 800 m^2 pond and 1,600 m^2 pond were higher than 3,200 m^2 pond (Table 1).The average prices of all three pond sizes are more than their break-even price, so a profit is generated. The calculation of net profit from the total cost and total revenue was found that juvenile production in 1,600 m^2 pond provides the highest net profit, followed by 800 m^2 pond and 3,200 m^2 pond, respectively.

The first investment of 800 m^2 pond was highest, follow by 1,600 m^2 pond and 3,200 m^2 pond, respectively(Table 5). Additionally, the break-even point and the payback period of 800 m^2 pond were higher than those of 1,600 m^2 pond and 3,200 m^2 pond. Therefore, raising juvenile tilapia in 800 m^2 pond would require an increased production period to obtain an equal return to raising in 1,600 m^2 pond and 3,200 m^2 pond. Net present value, internal rate of return, and benefit-cost ratio of 1,600 m^2 pond were highest. Consequently, theproduction of juvenile tilapia in the 1,600 m^2 pond is the most interesting investment.

Table 5 Economic analysis of juvenile tilapia production in three earthen pond sizes.

Items	Units	Earthen pond sizes		
		800 m^2	1,600 m^2	3,200 m^2
Total cost	Baht/fish	2.31	2.17	2.22
Average price	Baht/fish	2.95	2.90	2.67
Total revenue	Baht/m^2	74.60	74.12	60.96
Net profit	Baht/m^2	16.48	18.62	10.29
Net profit	Baht/fish	0.64	0.73	0.45
First investment	Baht/m^2	87.08	53.96	32.60
Break-even point	Fish/m^2	7.31	5.47	6.56
Break-even price	Baht/fish	1.80	1.76	1.85
Payback period	year	1.59	0.78	0.95
Net present value (NPV)	Baht	26.80	71.77	37.10
Internal rate of return (IRR)	Percentage	12.39	31.99	28.28
Benefit-cost ratio (B/C ratio)	-	1.28	1.33	1.20

The average price is based on the 2015 local market price in Sakon Nakhon province, Thailand.

IV. DISCUSSION

Water quality was slightly affected by pond size. There were a few differences in hardness, ammonia, and dissolved oxygen among the three pond sizes. While temperature and pH did not show any differences. However, the water quality of the three pond sizes were compared to suitable water quality criteria for raising freshwater animals as reported in the Thai agricultural standard TAS 7417(G)-2013 (National Bureau of Agricultural Commodity and Food Standards, 2014). All parameters of water quality, including water temperature (criteria range: 25-32°C), pH (criteria range: 6.5-8.5), hardness (criteria range: 80-200 mg/l of $CaCO_3$), ammonia (criteria range: no more than 0.5 mg/l), and dissolved oxygen (criteria range: at least 4 mg/l), were in the range of these criteria.

Different pond sizes have provided different growth performance of juvenile tilapia. FCR is an important parameter of growth performance related to production costs (Correa et al., 2017). The pond size increased, FCR increased. The small (800 m^2) and medium (1,600 m^2) pond sizes had a lower FCR than the large (3,200 m^2) ones, which could be explained by the less quantity of feed offered (Figure 2). In other words, juvenile tilapia raising in a small pond has more efficiency used of feed.The survival rate, harvesting weight, weight gain, and yield are the key parameters directly related to the total revenue of farming.The pond size increased, resulting in the survival, harvesting weight, weight gain, and yield decreased (Table 1). In addition, the polynomial regression revealed that the smaller pond size provided higher survival rate and lower FCR than the larger pond size (Figure 2).A reason could be due to the fact that the smaller ponds are easier for farmers to manage. Pond size has an effect on the growth of fish (Gempesaw et al., 1992). Small ponds (200 m^2) were recommended for raising tilapia in Southern Malawi since it provides high growth performance and yield (Kapute et al., 2016). While Large ponds (at least 16,000 m^2) were recommended for raising striped bass fingerings in brackish-water ponds because the land-use efficiency increased and the cost of construction investment reduced (Matlock, 2010). Therefore, considering growth performance only may not be sufficient to make business decisions, the cost and return of investment should be concerned.

A production costs analysis revealed that the cost per square meter of raising juvenile tilapia in the smaller ponds tended to be higher than in the larger ones. However, when taking into account the survival rate, harvesting weight, and the average price, it was found that the 1600 m^2 pond provided the lowest cost per fish, followed by the 800 m^2, and 3200 m^2, respectively.Considering the fixed costs, the smaller pond needs higher investment including the cost of pond construction, and equipment purchase, which agreement with Matlock (2010).The opportunity cost was accounted from the equity capital invested in the fish farm, which would have earned some amount of interest if invested differently (Engle, 2017).As the initial cost in 800 m^2 was higher, loan interest and opportunity costs of capital were higher.Regarding the variable costs,the mean range of feed cost was 53.65-56.13% of the total cost in all three pond sizes.Feed cost was found to be the highest operational cost of tilapia culture, especially when the commercial feed was used, according to the various research (Ferdoushi et al., 2019; Mridha et al., 2017; Omasaki et al., 2017). The important factors affecting the costs of feeding are FCR and feed prices (Barbosa, et al., 2020).Feed quantity was used according to the amount of survival and the feed rate (% body weight) (Chowdhury et al., 2013; El-Sayed, A.-F.M., 2020). In this study, the smaller pond has higher survival rate and weight gain of fish. Therefore, the smaller pond needs more feed, and then, it has a higher feed cost than the large pond.In a production period, farmers who raise fish in the small pond have to change water or pump water into the pond more often than the large pond, to maintain the water quality. Hence, the cost of gasoline, equipment repair, and maintenance were higher.

The average price of juvenile tilapia from 800 m^2 and 1600 m^2 pondswas higher than that from 3200 m^2 pond (Table 5). The reason is that the price of tilapia is based on weight per fish. More fish weight will be sold at a higher price. In addition, the survival and growth performance of juvenile tilapia from 800 m^2 and 1600 m^{2}ponds were higher than that from the 3200 m^2 pond, resulting in product quantityand harvesting weight also being higher.From these reasons, the total revenuein the 800 m^2 and 1600 m^2 ponds were also higher than in the 3200 m^2 pond.

From the point of view of investment analysis, pond size has effects on profitability. Break-even price, break-even point, and payback period of raising juvenile tilapia in the smaller pond tends to be higher than for the larger pond (Table 5). Break-even price is an essential parameter to be considered in any business because they indicate the profitability of the operation (Shoko et al., 2016). In the present study, juvenile tilapia was sold at higher prices than the break-even prices indicate that the production is profitable in all pond sizes.The Break-even point is the point at which total revenue and the total costs are equal (Sajeevan and Rajan, 2019). This parameter helps farmers to decide how many fish have to be sold to cover the cost and for avoiding making a loss.The results showed that break-even point of the 1,600 m^{2}pond is lowest (5.47 fish/ m^2). If the fish can be sold more than the break-even point, the profit will be earned.

Payback period, NPV, and IRR are the most normally used types of investment analyses (Engle, 2010).The payback period is the number of years it would take an investment to return its original cost through the annual net cash revenues it generates (Kay et al., 2016). The shorter payback period, thus, contributes the most to business' liquidity (Engle, 2010).The 1,600 m^2 pond exhibited a shorter payback period, which was preferred for investment.The NPV is a favorite parameter for investment evaluation. Since, it does consider the time value of money as well as the size of the stream of cash flows over the entire life of the investment (Kay et al., 2016).Investments with a positive NPV would be accepted. The NPV of the three pond sizes were positive. However, the highest value of NPV found in the1,600 m^{2}pond. Consequently, the investment in the1,600 m^2 pond trend to be higher profitable than the other pond sizes. The IRR is the actual rate of return on the investment with proper accounting for the time value of money (Engle, 2010). For business investment, a minimum criterion of IRR is often used at 15%, and a higher IRR required because of investment risk and market uncertainty increases (Head and Watanabe, 1995). The present study showed that the IRR of juvenile tilapia raising in the 1,600 and 3,200 m^2 ponds were higher than 15%, but the IRR of the 800 m^2 pond was lower than 15%. Thus, the production of juvenile tilapia in the 800 m^2 pond might be a risk to investment.The B/C ratio is greater than one, an investment is profitable (Oladejo and Ofoezie 2006).Moreover, the greater the value of B/C ratio, the greater the benefit to be derived from such business (Rochaeni and Daulay, 2019). The present study found thatB/C ratio of tilapia juvenile farming was greater than one, so there was profitability investment in all pond sizes. Overall, the NPV, IRR, and B/C ratio were higher in the 1,600 m^2 pond, while the payback period was shorter. Thus, juvenile tilapia farming in the 1,600 m^2 pond is the most profitable for investment, compared with the 1,600 and 3,200 m^2 ponds.

V. CONCLUSION

Earthen pond sizes have effects on growth performance and the economic profitability of juvenile tilapia production, with slight effects on water quality.Smaller ponds tend to have better growth performance because it provided a higher value of survival rate, harvesting weight, weight gain, and yield, while it showed a lower value of feed conversion ratio.

Overall, a pond size of 1,600 $m^2$was theappropriate size for juvenile tilapia production, because it provided the higherpresent net value, internal rate of return, and benefit-cost ratio, while requiring the shorter payback period. However, feed cost is the highest cost of production. Additional research to develop low-cost feed with providing growth efficiency will help to improve the profitability of investment for farmers.

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