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Preliminary Study on Construction of Three-in-one Fishpond and Its Effect on Aquaculture in Ethiopia

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Abstract

Sandy nature of soil in Ethiopian rift valley challenged use of earthen ponds for fish culture. This trial was conducted at Algae Agricultural Technical and Vocational Educational Training (ATVET) College in Ethiopian central rift valley to investigate feasibility of fishpond constructed from mixture of local materials named “Three-in-one” and to assess its suitability and capacity for aquaculture. Fishponds were excavated, walls built with three layers; plastic membrane, "Three-in-one" soil and cement pavement. "Three-in-one" is a mixture of clay soil, termite soil and teff straw. Fish growth in the ponds was evaluated under supplement of different sorts of agricultural residues or agricultural by-products. The "Three-in-one" fishpond technology was found to be low cost, simple to construct, able to retain water effectively and has long service life. The fishpond also supported fish growth with good farming performances as 9,250 kg/ha. Use of agricultural residues or agricultural by-products as feed for fish culture in the fishponds effectively reduced the cost of fish farming with feed coefficient 2.4~2.6. The "Three-in-one" fishpond technology and matching feed has to be evaluated and popularized for extension in appropriate sites of Ethiopia.

Keywords: Ethiopia; Fish culture; Local feed; “Three-in-one” fishpond

Introduction

Many countries of the world faced major challenges in combating food deficit, in introducing and sustaining ways of increasing availability of safe and nutritious food, especially protein sources. Production of aquatic products, especially fish become an important agricultural sector as a main source of dietary protein for most people in the world [1,2]. Though landlocked country, fish production is possible in Ethiopia using the inland water resources. Estimated fish production potential of the country from natural stock was 51,481 tonnes [3] while the actual production from the natural stock was reported increasing and became 38,370 tonnes in 2013/14 [4]. However, a natural fish stock in some major lakes of Ethiopia has shown sign of overfishing [5].

National fish demand in Ethiopia was somewhat seasonal, as religious observances exert strong influence on fish consumption patterns [3]. Demand for fish products is however increasing in Ethiopia especially during lent season of Christians of the Coptic Orthodox Church, who refrain from eating meat, milk and eggs, resort to fish as a substitute [6,7]. The current fish supply is by far not enough to meet need of over 100 million people of the county and thus there is an urgent need to develop the fish industry [4].

In some parts of Africa like Uganda, Nigeria, Tanzania and Egypt, fish production has been exercised significantly to contribute in the world fish production [8]. However, in some other countries like Ethiopia, fish production especially aquaculture is still a new industry in which fishpond construction has just been started, and the aquaculture technology is still in the groping [9]. Ethiopia is located in northeast Africa, known as the East African water tower, where the unique plateau and inland conditions provide suitable natural conditions for aquaculture development [10,11]. Aquaculture production has not been well practiced in Ethiopia where the total annual production from the sector was reported only 38 tonnes in 2012, of which 87% was Nile tilapia and 13% was carp [3]. Urgent need for aquaculture development is therefore not only a guarantee for sustainable fish supply replacing production from natural stock but also an option to relieve malnutrition of indigenes in Ethiopia and even Africa in general [12-14].

The base to develop aquaculture industry in artificial ponds is the construction of fishponds. In addition to considering sustainable water source, the water retention capacity of soil is one of the most important factors in fishpond construction [15]. Central rift valley of Ethiopia is generally a sandy soil with poor water retention capacity [16,17], and the fishponds previously built by several fishery resources and fish research centers in Ethiopia were composed of concrete, with long construction time, high cost and maintain frequently due to crack [18], and difficult for poor farmers to afford. This study was proposed with the idea of constructing fishponds from "triad" local materials and conducting fish farming experiments in the ponds at Algae Agricultural Technical and Vocational Education and Training College in Ethiopia. The objectives of the study were to evaluate efficiency of fishponds constructed with "Three-in-one" local materials for aquaculture use and to evaluate fish farming technologies in the" Three-in-one" fishponds.

Materials and Methods

Study area

This study was conducted at Algae Agricultural Technical and Vocational Education and Training (Algae ATVET) College in the federal state of Ethiopia. It is located at a distance of 220 km south of Addis Ababa, the capital of Ethiopia, at a longitude of 38°42ʹ E, latitude of 7°60ʹ, and the altitude of 1581 mas. Nursery fishpond and spawning fish ponds were constructed from locally available materials. Fish growth and yield experiments were evaluated within the nursery ponds and spawning ponds by supplying different feeds prepared from local ingredients.

Construction of nursery fishpond

Fishponds were constructed from locally available materials. The construction materials used in this experiment included plastic films, cements, gravels, "Three-in-one" soil (common clay, termite soil and teff straw), as well as steel bars, bricks, and water gates (Figure 1A and 1B). The teff is a cereal crop of grass family endemic to Ethiopia. Since the main objective of the trial was to evaluate the use of the locally available materials in construction of fishponds, mixture of clay soil, termite soil and teff straw was used as a technology and thus termed as "Three-in-one" soil.

The cross-section of "Three-in-one" fishpond had three layers, plastic film bottom layer, "Three-in-one" soil middle layer and cement plaster concrete outer layer (Figure 1A). The plastic film layer mainly acted as the water retention membrane to prevent water leakage. The "Three-in-one" soil layer protects the plastic film against mechanical damage, degradation by ultraviolet radiation, extending the service life of the film. It also provides water-retaining function as the second layer in the fishpond. Concrete layer is the cement plastered outer layer which reinforces and protects the "Three-in-one" soil layer from wind and water erosion and also from fish digging nests for reproduction and to prolong the service life of the entire layer of the fishpond.

The ponds were built on a desolate/uncultivated land, and the construction of these small ponds included the process of site clearing, pond excavation by manual digging, forming the required slope of the pond, levelling, paving the plastic film, preparing "Three-in-one" soil mixture, plastering the entire bottom and wall of the fishpond with the "Three-in-one" soil and paving cement to make the outer layer concrete, followed by construction of water inlets and outlets, stretching pipe lines and construction of pond ladders to ease pond management.

Fish growth evaluation in the nursery fishpond

Water quality: After the nursery fishponds were built and filled with water, it was fertilized by using chicken manure and green grass [19] till the water forms light green colour and reaches the transparency of about 45 cm. The water pH ranged between 7.0 to 8.5, temperature has ranged between 20°C to 22°C in the morning (9 AM to 10 AM) and 24°C to 28°C, sometimes up to 32°C in the afternoon (3 PM to 4 PM). Water refreshment was done within every two weeks by filling the fishpond with fresh water.

Fish stocking: Nile tilapia (*Oreochromis niloticus*) was used for the growth performance evaluation in the nursery fishpond in this experiment. Four hundred fish seeds were obtained from Batu Fishery and other Aquatic Life Research Center on March 22, 2015. The fish seeds were transported to Algae ATVET College in oxygen-filled polyethylene bags (made in China) the same day with a survival rate of 100%. After the fish arrived at Algae, the oxygen bags were opened and a small amount of pond water was added to the bags to acclimatize the fish with the new environment, and then the oxygen bags were put into the water surface of the fish pond so that the fish seedlings slowly swim into the water.

The average size of the fish seeds at stocking was 8 cm to 12 cm total length and 15 g average weight, making 6 kg total weight of fish in the pond. Culture period was 2 years, from March, 2015 to March 2017. Conventional pond management measures were made by checking water quality parameters every seven days and maintaining the transparency between 30 cm and 60 cm and pH value of pond water between 6.5 and 8.5.

Feed preparation and feeding: A powder feed was prepared from mixture of ingredients at Algae ATVET College. The feed ingredients include maize flour, noug seed cake, wheat bran, soybean and a small amount of salts, bone meal. The protein content of feed was 28.6%. Feeding was adjusted according to fish total weight at a rate of 3% of the fish weight in fishpond and was increased during the spring season, and before the fish breeding period. During the whole experiment, the growth rate of fish was monitored by sampling fish using narrow mesh net to estimate quantity of feed to be delivered. Predatory birds were controlled by protective net over the ponds. Eggs and tadpoles of frogs and toads were timely removed from ponds when they appeared.

Construction of spawning fishponds

Similar with nursery pond construction, nine spawning fishponds were constructed by using the Three-in-one soil as a main layer. The shape of the ponds was rectangular and had dimensions of 7 m length × 5 m width × 1.4 m depth and the wall slope of 1:1 (Figure 2). The ponds were also used for fish growth evaluation.

Fish growth evaluation in the spawning ponds under different feeds

Water quality and pond management: Water source for all experimental ponds was one common reservoir tank. The pond water was clarified by adding 0.5 g/L of gypsum powder for 3 days. Water transparency was maintained as deep as 60 cm and the pH value about 7.5. Acute toxicology test of fish was carried out by point before commencing the experiment. If the fish remained active 24 hours in the pond, the water was qualified for fish culture and could be piped into fish ponds for cultivation. The pond water temperature was also monitored by measuring at 9 AM to 10 AM in the morning and 3 PM to 4 PM in the afternoon every day. The temperature varied between 20°C to 24°C.

Experimental fish: Nile tilapias (*Oreochromis niloticus*) were used in the spawning trial. The fish were obtained from Batu Fishery and other Aquatic Life Research Center on June 2, 2016. Totally 400 fry at sizes of 7.0 cm ± 0.4 cm total length and 7.4 g ± 0.2 g average weight were transported from Batu to fish farm at Algae. The transportation was made within the oxygen-filled bags with survival rate of 100% at stocking.

Feed treatments: Different feeds were formulated and provided for fish as treatments in order to compare fish growth. This trial consisted four treatments T1=15% soybean meal + bone and meat mealT2=15% fish offal meal + wheat flourT3=15% poultry litter + maize flour and

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T4=5% soybean meal + wheat bran + noug seed cake. The soybean was roasted for 5 minutes in order to decrease anti nutritional factor trypsin. Each treatment was made in two replicate ponds and each fishpond was stocked with 50 fishes of similar size at a density of two fish per square meter.

The feeding rate of each of the treatment was adjusted at 3% of the fish weight and provided three times a day. Feed adjustment was done every 15 days following fish weight measurement. The duration of the experiment was 90 days.

Data collection from the fish was done every 15 days. Total length and weight of fish were measured by using measuring board to 0.1 cm and sensitive balance to 0.1 gm respectively. Birds were kept away from the pond area in time. Eggs and tadpoles of frogs and toads were timely removed from ponds when they appeared.

Results and Discussion

Construction of nursery fishpond

One nursery fishpond was constructed. The fishpond was rectangle in shape with dimensions of 20 m length × 10 m width and × 1.5 m depth. Slope of pond bottom was 3% and that of the pond wall was 2:1 (Figure 1A).

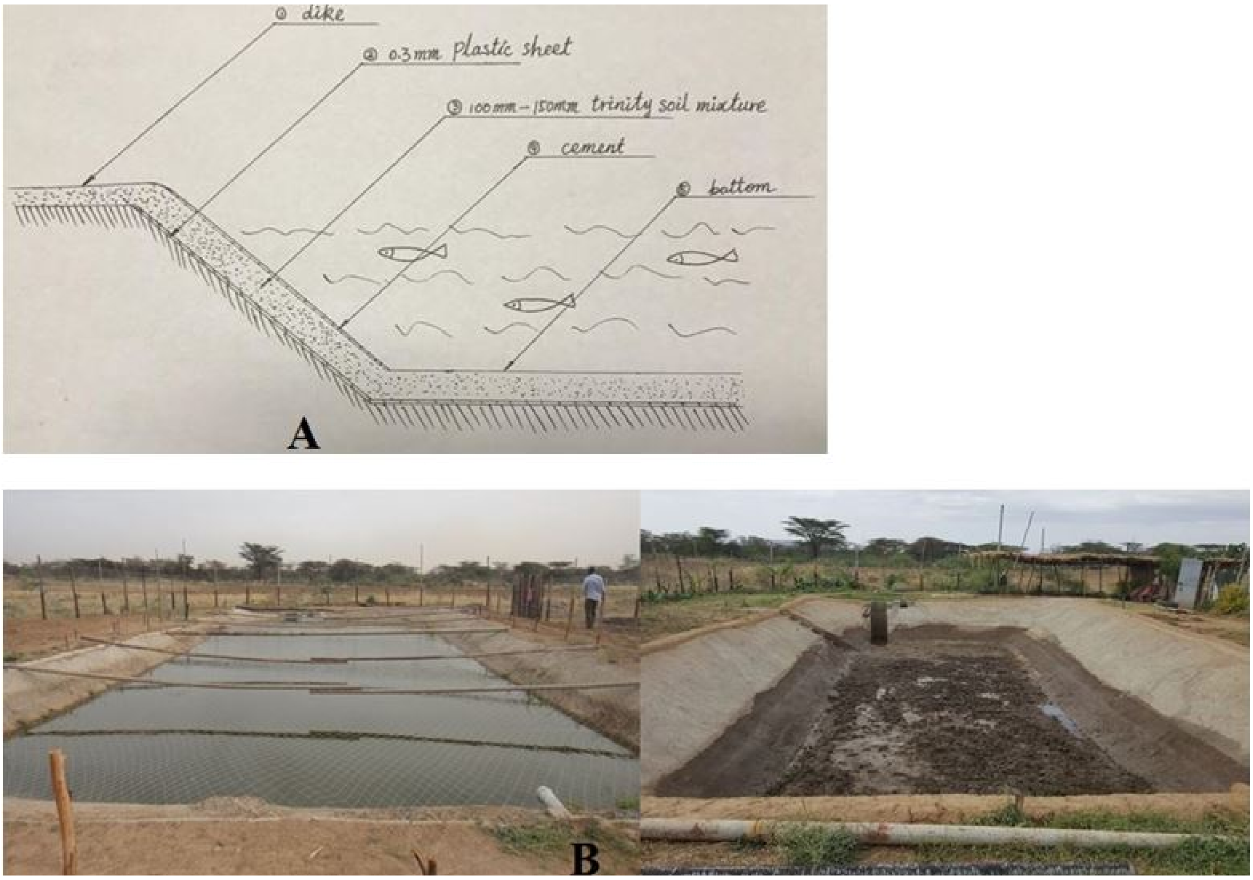

Figure 1: A) Wall and bottom schematic diagram of "Three-in-one" nursery fishpond structure. B) Nursery pond, with water (left) and drained (right).

Building the nursery fishpond was started in February 2014 by manual excavation and completed nearly after four months. The fish pond included structures such as inlet, outlet and pond ladder. A sedimentation pond of 10 m × 1.2 m × 1 m was designed on the inlet line to prevent muddy water from entering the pond during the rainy season. For the production safety of the fish pond, spillway diverting flood and protective fence around the fishpond area and bird net over the pond were subsequently added.

The nursery fishpond, built from a layer consisting "Three-in-one" soil, can mainly be used for large-scale production of fish seed and also be used as a transit pond for fish ponds. The pond has been rendering fish culture service for over 36 months since March 2015. The water retention capacity was very good and no leakage occurred during the service period of over 36 months. The fish grew fast with good economic efficiency. During total harvest, the water collects near the outlet in fish collection site and eventually dries up.

Fish growth in the nursery pond

Fish harvesting from the nursery pond was made two times during the growth period of two years from March 2, 2015 to March 12, 2017. The first harvesting was done by screening the larger fish in March 2016, one year after stocking; while the second harvesting was complete harvesting done in March 2017, two years after stocking. Fish growth parameter data and the yield data collected at the two harvestings were summarized (Table 1).

Parameter	Partial harvest using net March 15, 2016	Complete harvest by drying pond March 12, 2017
Fish length range (cm)	22-26	5-30
Fish weight range (g)	180-400	2-520
Fish yield (kg)	60	185 (9,250 kg/ha)

Table 1: Length, weight and yield of tilapia harvested from the nursery pond.

The results showed that the fish were able to grow to maximum sizes of 26 cm and 400 g after one year, and 30 cm and 520 g after two years. The total yield of the two harvests was 245 kg fish. Recalling the total fish weight at stocking was 6 kg, the net weight gain of the fish was 239 kg during the culture period the culture period of two years in the nursery pond. It should be noted that, the size of the tilapias during harvest was non-uniform due to the early maturing of Nile tilapia within 20 g ~ 30 g to spawn, hatch and produce fish seeds in ponds [20].

Cost benefit analysis of fish culture in Three-in-one fishpond

Estimating the service life of the Three-in-one fish pond is 15 years, the depreciation cost over the 2 years' service was about 419.4 ETB (fixed cost). The price of 400 fish seeds (6 kg) was estimated to 600 ETB and the feed cost over the two years was estimated to 11,460 ETB while the labour cost during this culture period was 10,000 ETB. The sum of all the costs made a total production cost of 22479.4 ETB.

The revenue from total fish harvest was estimated to ETB 23,900 (239 kg fish) during the two years of culture period. Hence by deducting total cost from total revenue (ETB 23,900.0- 22,479.4), the net profit was estimated to ETB 1,420.6 per pond which was equivalent to ETB 71,030 ha^{-1} during the two years. The value was higher than the income obtained from fish in other places of Ethiopia [14]. However, the feed coefficient of this trial was as high as 2.4 to 2.6, and this level of aquaculture belonged to moderate level thus the technology of aquaculture should be improved. In China, the highest production level of tilapia is 23,628 kg/ha, and the feed coefficient is only 1.48 [21]. Introduction of tilapia culture technology to Africa from China might be an effective way to reduce the cost and increase the economic yield [22].

Construction of spawning fishponds

Nine spawning fishponds were constructed. The ponds were also used for fish growth evaluation. The ponds were rectangle in shape and have dimensions of 7 m length × 5 m width × 1.4 m depth and the wall slope of 1:1 (Figure 2).

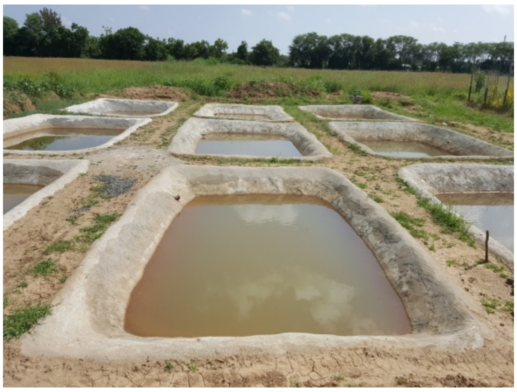

Figure 2: Shape and arrangement of the nine spawning fishponds.

The fishponds can be used for spawning of different fish such as tilapia, catfish and carp, and also be used for other experiment in fish culture technology. The nursery fishponds served for 18 months with very good water retention capacity and without any crack. Based on this experience, Plant Sciences Department, and Irrigation Department of Algae ATVET College have used the Three-in-one technology and built reservoirs for irrigation purpose. If built in sufficient quantity, the pond can be used for large scale fish production and also enable running wide research activities in aquaculture at the college.

The "Three-in-one" fishpond had the advantages of low construction cost and short time period. Comparison (Table 2) was made between construction of three different ponds; the "Three-in-one" fishpond, cement brick pond and concrete fish pond (without including cost of pond excavation).

Fishpond type	Fish pond (5 m × 5 m × 1.5 m)	Main construction material	Material cost (ETB)	Construction time (days)
Three-in-one	Gradient 1:1	"Three-in-one" soil, plastic sheet 7 m × 6 m, cement 300 kg, sand, and gravel	3145.5	6
Stone brickwork	Gradient 0.7:1	Large stone 8 square, cement 500 kg, gravels and sand	3982.5	15

Concrete	Gradient 1:1	Steel bar 14.54 kg (2.89 kg/m^3), mixed soil (calculated by 25 MPa) 5.03 m^3 (including cement 1,509 kg, gravels and sand 6,036 kg)	7028.1	25

Table 2: Comparison of "Three-in-one", stone brickwork and concrete fishponds.

The results showed that the cost of raw materials for the "Three-in-one" fishpond was the lowest and the construction time was the shortest under the same size of construction. However, in the fishpond construction, we also noticed that the surface layer, middle layer and inner layer of the pond wall all might crack under some conditions. The potential reasons of cracking might include the long exposure of surface of the thin cement layer to the sun's ultraviolet rays, digging habit of tilapia fish breeding, use of less and immature teff straw mixed in the "triad" soil, and use of old and broken thin plastic sheet at the bottom. We therefore recommend many improvements to the design of the "Three-in-one" fishpond. It is suggested to increase the thickness of each layer, the cement layer to >5 mm, the "Three-in-one" soil layer >100 mm, and the plastic film >0.3 mm. The outer cement layer could be replaced with a plastic sheet of 0.5 cm to 1 cm thick in the future in order to shorten the constructing period.

To strengthen construction quality, focus should be made on consolidating the pond dike, walls and bottom surface. Sticking plastic membrane should cover pond surface tightly without interspaces and avoiding hard materials between the plastic sheets and the pond surface. Thorough mixing and maturing of the “triad” soil is important before use. In building the “triad” layer, concave and convex surface, or holes surface should be prepared for the good sticking by cement layer. Filter screen of the inlet, outlet and overflow gate important during the rainy season are vulnerable to aging and can easily be damaged; and should therefore be collected during dry season and repaired when necessary. The nylon net protecting ponds against birds are also liable to be weathered and have to be replaced with hemp rope.

Fish growth in spawning ponds under different feed supplement

In this feed experiment, four different mixtures of local ingredients were provided to tilapias in order to evaluate the growth response of fish for 90 days; from June to September 2016. Fish samples were taken and weighed after 90 days from each of the replicate ponds of the four treatments. Summary of the fish weight and feed delivered to the fish is shown in the following table (Table 3).

Treatment	T1	T2	T3	T4
Average initial fish weight (g/fish)	7.2	7.6	7.6	6.8
Average final fish weight (g/fish)	55.1	50	51.5	60.2
Average weight gain (g/fish)	47.9	42.4	43.9	53.4
Feed intake (g/fish)	119.8	101.8	109.8	138.8
Feed coefficient	2.5	2.4	2.5	2.6
N.b. T1=15% soya bean meal + bone and meat meal; T2=15%fish offal meal + wheat flour; T3=poultry litters (more than 60 days) + maize flour; T4=5% soya bean meal + wheat bran + noug seed cake.				

Table 3: Weight of tilapia under different feed treatments in nursery ponds.

The initial average length and weight of the experimental fish was 7.4 cm and 7.3 g respectively. The average final fish weight after 90 days was 50.0 g, 51.5 g, 55.1 g and 60.2 g in T2, T3, T1 and T4 respectively (Table 3). The weight gain during this period was at least 42.4 g/fish (T2) and at most 53.4 g/fish (T4) at a daily growth rate (DGR) of 0.47 g.day^{-1} and 0.59 g.day^{-1} respectively. The current DGR results attained by the supplement of local feeds was lower than the tilapia growth attained in earthen ponds integrated with poultry farm (0.75 g.day^{-1}) but better than the growth attained in pond fertilized with goat manure alone (0.25 g.day^{-1}) [23] and also better than the growth rate attained by feeding maize flour + noug cake (0.15 g.d^{-1}) and wheat flour + noug cake (0.35 g.d^{-1}) [24].

Feed coefficient refers to the ratio of the amount of feed given (g) to the fish weight increased (g). It is often used to measure quality of feed used in aquaculture. The feed coefficient of the treatments ranged from 2.6 to 2.4 indicating that the culture level was moderately below average. Considering that feed materials were basically agricultural by-products and cheap, the expenses of production could still be greatly reduced in extensive culture in the rural areas.

Conclusions and Recommendations

The construction cost of the "Three-in-one" fishpond was low, the time of construction was short, the raw materials are abundant in Ethiopia especially in the rift valley, the process was quantitative (>5 mm cement layer, >100 mm "Three-in-one" soil layer, and >0.3 mm plastic film layer), and the water retention capacity was strong. Hence, the pond can be used for aquaculture industry and also as water reservoir for crop irrigation and animal husbandry.

The "Three-in-one" fishpond technology has been expanded in three departments at Algae ATVET College, and we recommend the technology to be evaluated and demonstrated in other parts of Ethiopia where fish culture in pond is a challenge because of water retention problem.

In order to reduce production cost of aquaculture, agricultural residues or agricultural by-products such as soybean, oil seed cake, wheat or rice bran, maize flour, bone and blood meal, fish offal meal, and poultry dung can be mixed and used as fish feed. The ingredients were abundant in the area and relatively of cheap prices and efficient to promote fish growth.

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