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EFFECT OF FEED QUALITY ON GROWTH PERFORMANCE AND WATER QUALITY IN CAGE CULTURE SYSTEM FOR PRODUCTION OF NILE TILAPIA [*Oreochromis niloticus*, (L., 1758)] IN LAKE BABOGAYA, ETHIOPIA.

BY

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Abstract: This research was conducted in Lake Babogaya, Ethiopia, to investigate the effect of feed quality on growth performance and water quality in cage culture system for production of Nile tilapia (*Oreochromis niloticus*). All the treatments had the same stocking density of 100 fish per m^3 cage. Seven different types of test diets (M=T1, D=T2, O=T3, MD=T4, MO=T5, DO=T6, and MDO=T7) were formulated from three locally available diets (M=Mill sweeping, D=Chicken dung, and O=Oil seed cake). The test diets were formulated in a proportion of 100, 50, and 33.3%, respectively. One control group (C) without supplementary diet was used. All treatments including the control group were in duplicate. Mixed sex juveniles with an average weight of 33.62±0.21 g were stocked in all treatments. The fish were fed the test diets at a rate of 3% of their body weight twice per day using feeding trays for 170 days in powder form. The results showed that the growth of Nile tilapia was affected by the quality of the test diets. The final mean weight of *O. niloticus* ranged from 166.90±1.61 to 242.87±1.97 g and the mean weight gain ranged from 0.79±0.06 to 1.23±0.03 g day^{-1}. The mean feed intake per fish ranged from 2.57 to 3.52 g day^{-1} while the feed conversion ratio (FCR) ranged from 2.76 to 3.33. Greater FCR for caged tilapia was obtained from T4 and T7 diets with insignificant difference ($P > 0.05$), while the poorest FCR was obtained from the test diet containing 100% oil seed cake (T3, $P < 0.05$). There was significant effect of feed quality and culturing periods on condition factor ($P < 0.05$). Water quality parameters were similar ($P > 0.05$) among the test diets and sampling sites. In conclusion, T4 and T7 treatments were the best diets preferred by Nile tilapia in terms of all the growth parameters in the study and produced the highest growth performance. So chicken dung and mill sweeping should not be used separately to get the maximum fish growth as revealed in T1 (100%), T2 (100%), T4 (50%), and T7 (33.3%). Moreover, oil seed cake can only partially be used as a source of protein in locally formulated diet, at a limited amount of not more than 33.3% as demonstrated in T3 (100%), T5 (50%), T6 (50%) and T7 (33.3%).

Key words/phrases: cage culture, chicken dung, feed quality, growth performance, mill sweeping, oil seed cake, *Oreochromis niloticus*, Lake Babogaya, water quality.

1. Introduction

Since 1992 Ethiopia has become a land locked country depending only on the inland water resources for the supply of fish as a cheap source of protein (Tesfaye Wudneh, 1998). It has a number of lakes and rivers with important fish resources. These water bodies cover only 0.7% of the total surface area of the country (Greboval *et al*., 1994) and comprise 10 lakes located in the Central Highlands, mostly in the Rift Valley, with a total surface area of 7,500 km^2 (Mebrat Alem, 1993) . The largest lake is Lake Tana, located outside of the Rift Valley on the North-western plateau, with a surface area of 3,600 km^2. Minor water bodies such as crater lakes and dam reservoirs occupy a total area of about 400 km^2 (Wood and Talling, 1988). The main rivers stretch together for a total of approximately 7000 km (Mebrat Alem, 1993). During the periods of good rainfall, these rivers and their numerous tributaries create floodplains (ONAR, 2004).

From these water bodies, Ethiopia has an estimated annual total exploitable potential of 51,000 tons fish production distributed as 28,000 tons in the lakes and reservoirs, and 23,000 tons in the rivers (LFDP, 1996). Out of this potential, about 15,000 tons were realized in 2003, representing about 30% of the potential fish production. Most of the fishing so far takes place in the lakes (85 %) with only 15 % in the rivers (ONAR, 2004).

Fish production in most water bodies is far below the estimated yield and the exploitation of them is very uneven. In 1996/1997, the total number of fishermen in Ethiopia was believed to be more than 3000, and their total landings was estimated to 10,400 tons from Lakes Abaya, Awassa, Chamo, Langano, Tana, Ziway and Koka reservoir (Reyntjens and Tesfaye Wudneh, 1998). Those located near the capital, Addis Ababa, and having good road connections, like Lakes Ziway and Awassa, have been heavily exploited to the extent of overfishing (Tesfaye Wudneh, 1998; Felegeselam Yohannes, 2003). Lake Tana which is located 565 km from Addis Ababa is among the least exploited lakes, in spite of its large size and fish resources. One of the largest Rift Valley lakes, Chamo, contains Nile perch, *Lates niloticus.* Although it is as far from Addis like Lake Tana, the fishing activity is high due to the high price for this fish, being more expensive than beef (Tesfaye Wudneh, 1998; Hailu Anja and Seyoum Mengistou, 2001).

There is a switch in catch composition from highly commercially important fish species (Tilapia) to Catfish and Carp in Lake Ziway (LFDP, 1996). A sharp decrease in abundance by about 75 % of the migratory riverine spawning *Labeobarbus* species were also seen in the sub littoral and pelagic zones of Lake Tana, areas where no fishing takes place and the collapse of the juvenile *Labeobarbus* (between 5 and 18 cm FL; by 90 %) was observed during the 1990s which suggests recruitment overfishing (de Graaf *et al*., 2006).

The estimated average national per capita fish consumption, in spite of an increase by 20% in the last 4 years, is still low (FAO, 1997). Ethiopia is the least in fish consumption compared to other countries in Africa and worldwide. The equivalent consumption is only 175 g per person per annum, which is very low compared to the fish consumption of world and Africa about 14 Kg and 8 Kg per annum per person, respectively (FAO, 2003).

Furthermore, the national average per capita fish supply is less than 240 g/person/annum (FAO, 2003), but if population as a factor is taken the total annual fish demand will be more than 65,344 tons which was approximately 1 kg/person/annum (FAO, 2003). The national demand for fish is continuously increasing. If population grows at the present rate, it is estimated to be 85,000 tons, and would increase to 100,000 tons and 120,000 tons by the years 2010 and 2015, respectively (ONAR, 2004). In view of this the supply from these water bodies can no more meet this demand. In addition if other positive factors that trigger the demand such as low fish price, increased distribution networks and improved product quality are considered, the demand will be much higher.

Ethiopia is a developing country with sparse industrial and other major human activities demanding a big scale usage of the water resources (Zinabu Gebremariam *et al*., 2002). In the country water resources have so far been developed to a marginal extent (Abate Zewdie, 1994), and the development of this sector will become of major importance as the country develops. Although expansion of water use for various purposes including hydroelectric power will be most significant in its social and economic effects, emphasis should be given to resource conservation and the rational use of water (Tesfaye Wudneh, 1998).

Contrary to the increasing demand the supply from the currently exploited natural stocks has already shown signs of stock decline due to overfishing (Reyntjens and Tesfaye Wudneh, 1998). Furthermore, the growing hydroelectric projects together with the irrigation projects will potentially aggravate the threat on the riverine stocks (Abebe Getahun and Stiassny,

1998). This therefore calls for an increasing attention to be given for aquaculture development in Ethiopia from the point of view that it can contribute to the conservation of biodiversity. According to FAO (2003) report in 2001, 54,187 tons (107,918 US$) fishery product was exported while; 35,575 tons (78,056 US$) was imported verifying that for the first time export exceeded import of fishery products. Hence the fishery sector in Ethiopia is contributing to the national economy, despite its small quantity.

Many researchers have suggested small-scale commercial aquaculture, for Ethiopia faced with deficit in animal proteins, in particular to supply during fasting periods (Balarin, 1986; Alemu Kebede, 2003; Abebe Tedesse, 2007; Ashagrie Gibtan *et al*., 2008). However, Aquaculture in Ethiopia is still non-existent inspite of the fact that the country's physical and socio-economic conditions favor its development. The high central Plateau above 2500 m (11% of total area) could be appropriate for all year round farming of cold-water species (FAO, 1997; ONAR, 2004).

The surrounding and central highlands are believed to have temperature characteristics favorable to the breeding of a large number of species, from cold water to warm water (Tekalign Mamo *et al*., 1993). In addition, the temperature conditions are remarkably stable as compared to European temperate climates and give a great scope for cultivating a wide range of species in very good conditions. The lowlands (33 % of total area) offer ideal temperature conditions for warm water species such as tilapia, but are unfortunately water-deficient zones, with a long dry season susceptible to drought. Soils are also generally sandy and not germane for pond construction. Water storage microdams could however be employed for fish breeding (FAO, 1997; ONAR, 2004).

However, such developments require significant technical support in terms of provision of fingerlings, demonstration and extension services, which are lacking. Taking this into account the Sebeta Fish Culture Station (SFCS) now known as the National Fisheries and Other Living Aquatic Resource Center of the FRDD (Fisheries Resource Development Department) is attempting aquaculture activity for culture-based stock enhancement operation into natural water bodies and manmade reservoirs since 1973 (Breuil, 1995). The station, built in 1975, has research, training and extension vocation programs. The SFCS has maintained and propagated brood stocks of common carp (*Cyprinus carpio*), crucian carp (*Carassius carassius*), tilapia (*Tilapia zillii and Oreochromis niloticus)* (collected from natural water bodies) and goldfish (*Carassius auratus*) (FAO, 1997; ONAR, 2004).

In addition to this, a great effort is needed not only to maximize fish production but also to tackle the problem associated with poverty, since fish culture activities increase job opportunity for some people (Ashagrie Gibtan *et al*., 2008). Consequently, there is a need to look for less expensive technology which requires simple methodology. With this respect, cage culture system is relatively cheap, easy to construct and use existing water bodies (Beveridge, 1984). Even, it is a simple methodology that could be applied by the fishermen themselves. It is commonly practiced worldwide in fresh water and marine environments including the open ocean, estuarine, lakes, reservoirs, ponds and rivers (Beveridge, 1987).

As a result, exploitation of the aquatic ecosystem, particularly fishery by the use of cage culture, is a well-developed activity in several parts of the world. On the basis of this, in countries such as Ethiopia, where drought is one of the major factors reducing agricultural production, the aquatic ecosystem needs full exploitation so that the problem of food shortage can be alleviated.

On this aspect, Ethiopia has high potential for development of aquaculture sector, although much of that potential is still unexploited. However, lack of tradition, competition from capture fisheries and small purchasing power of local people, are the major constraints to the development of fish farming activities. But, with a population of 75 million people the potential market for the fish and fish products is enormous and such activity can be used to economic development. Furthermore, the development of aquaculture sub sector is of great significance to the government to meet the food security requirement of the country. Having many lakes and rivers containing different fish stocks, the development of such technology will reduce risk of the natural stock and promote diversification. As a result, it is critical to use such alternative means particularly in countries like Ethiopia where the diversity of freshwater biota is poorly known and the rate of degradation of the environment is very high (Abebe Getahun and Stiassny, 1998).

There are six commercially important fish species in Ethiopia and they belong to the following families: Cichlidae (*Oreochromis niloticus*), Claridae (*Clarias gariepinus and Bagrus dockmak*), Centropomidae (*Lates niloticus*), and Cyprinidae (*Labeobarbus sp*. and *Labeo sp*.) (ONAR, 2004; JERBE, 2006). Of these, *O. niloticus* is the most exploited species and represents about 80 % of the total fish capture in Ethiopia (Breuil, 1995; ONAR, 2004). It is one of the most important species in the ecology and fisheries of almost all Ethiopian inland

waters (Shibru Tedla, 1973). Moreover, among local species found in the country, this species has a good breeding potential (FAO, 1997).

O. niloticus (Linnaeus, 1758) is currently considered to be the most important and commonly cultured tilapia species around the world, and constitutes over 70 % of the cultured tilapia (Fitzsimmons, 2004). This is because of different attributes / reasons which can be biological (fast growth, short food chain, high food conversion ratio, readily accepting artificial feeds, ease of breeding in captivity, disease resistant, high fecundity), social (good table food quality, good market price), and physical reasons (tolerant to wide range of environmental conditions).

So far, there is no research or adaptation concerning prospects on utilizing cage culture in the country except that studied by Ashagrie Gibtan *et al*. (2008) and Abebe Tadesse (2007). They evaluated to what extent supplementary feeding and stocking density affect growth performance, survival and yield of *O. niloticus* reared in cages in Lakes Kuriftu and Elen. They recommended that 2% and 5% body weight feed treatment for a density of 200 and 100 fish per cage ($1m^3$), respectively is suitable for cage culture of *O. niloticus* while they confirmed that there is no effect on the survival rate and environment (water quality).

However, there is no any study on the effect of feed quality on the growth performance, survival and yield of *O. niloticus* reared in cages. Therefore, the present study has been conducted to evaluate the effect of feed quality at a rate of 3% body weight on growth performance and water quality in cage culture system for production of *O. niloticus* for a density of 100 fish per cage ($1m^3$), in Lake Babogaya. Moreover, another study by Solomon Hailu (2008) has been conducted to evaluate the effect of feed quantity at rates of 1, 2, 3, 4 and 5% body weight on growth performance and water quality in cage culture system for production of *O. niloticus*, for a density of 100 fish per cage ($1m^3$) in the same area. Thus, these studies are continuation of studies conducted by Abebe Tadesse (2007) and Ashagrie Gibtan *et al*. (2008).

General objective

The general objective of this study is to generate base line data on cage culture fisheries in order to improve food security, reduce poverty and maximize the economy of the country.

Specific objectives

- To assess the effect of quality of the different feed types (feed/body weight) on growth performance and yield of *O. niloticus* in cages.
- To compare growth performance of fishes fed naturally and with different supplementary feed types.
- To examine effect of cage culture on water quality.
- To determine the optimum inclusion level (100, 50, and 33.3%) of three diets (Mill sweeping, Chicken dung, and Oil seed cake) consistent with good growth performance without compromising the feed utilization efficiency and health of *O. niloticus*.

Results obtained, hopefully, will provide valuable scientific information which would be used for proper exploitation of *O. niloticus* in Lake Babogaya. Moreover, this study will provide base-line data for future aquaculture development in Ethiopia since the best option for significantly improving fish supply in the country lies in aquaculture or fish farming.

2. Literature Review

Tilapia have a good characteristic for farming, and they have been referred to as “the aquatic chicken” by many aquaculturalists (Nandlal and Pickering, 2004). Tilapia belong to a group of fish called cichlids and are endemic to Africa. The group consists of three important genera, *Oreochromis*, *Sarotherodon* and *Tilapia*. All Tilapia species are nest builders (fertilized eggs are guarded in the nest by a brood parent) while species of both *Sarotherodon* and *Oreochromis* are mouth brooders (eggs fertilized in nests are picked up immediately by the parent’s mouth and hold during incubation for several days after hatching).

They are fast growing, able to survive in poor water conditions, eat a wide range of food types, and breed easily with no need for special hatchery technology. As a result, they are one of the best researched species for aquaculture, and there is a wealth of experience in their husbandry (FAO, 1997). Moreover, they are tough and tolerant to a wide range of environmental conditions; little environmental modification is needed. So, aquaculture systems can be low technology. Due to these fact earthen ponds, concrete tanks, raceways, and cages can be used for growing tilapia (Nandlal and Pickering, 2004).

Tilapia represent a major fish protein source in many countries of the world, and has been transplanted to and stocked in waters of nearly every country of the world (Nandlal and Pickering, 2004). Tilapia is ranked second only to carps in global production (El-Sayed, 2002) and is likely to be the most important cultured fish in the 21st century (Fitzsimmons, 2000). In 2003, the global production of tilapia reached 1.5 million metric tons (Fitzsimmons, 2004). From the tilapia species, *O. niloticus*, is currently considered to be the most important and commonly cultured tilapia species around the world, and constitutes over 70% of the cultured tilapia (Fitzsimmons, 2004).

Cage culture involves the rearing of animals in a structure enclosed on all but the top side by wooden, mesh or net screens, whilst maintaining a free movement of water (Beveridge, 1996). The production of fishes in cages has been practiced for many years in various countries worldwide. The use of cages for rearing fish and other aquatic animals is thought to have begun in China nearly one thousand years ago (Hu, 1994), and to have become locally widespread in China, Cambodia and Indonesia during the closing years of the last century and

early decades of the present century (Beveridge and Stewart, 1998). It is likely that cages were first used by fishermen to hold capture fishes until they could be sold to market.

Today, one of the most advanced aquaculture development programs in Africa can be found in Egypt which has the highest output of farm-raised fish of any African country (Louise, 2006). Aquaculture in eastern Africa is developing, small scale production being found in Kenya, Uganda, Burundi, Tanzania, Rwanda (Dadzie, 1992) but overall, it does so at a slow rate. Culture of fish in cages was attempted in Africa in Lake Victoria (Tanzania) and in Lake Kainji (Nigeria) (Dabbadie and Jerome, 1992; Agbebi and Fagberno, 2006). In tilapia monoculture, the percentage of pond spawned tilapia in the total yields has been reported to exceed 70 % in the Congo (Bardach *et al*., 1972). According to Ouattara *et al*. (2003) successful culture of *O. niloticus* in cages was demonstrated in Lake Kossou (Ivory Coast) in recent years, with average production of up to 17 kg/m^3 of cage per month, with stocking densities up to 7 kg/m^3 and feeding with locally prepared diets (FAO, 1997). Commercial-size tilapia of 200-250 g weight could be produced in four to five months' time (FAO, 1997).

Under good growth conditions, O. *niloticus* will reach sexual maturity in farm ponds at an age of 3 to 6 months (150 to 200 g) while 10 to 12 months (350 to 500 g) in several east African lakes (Dadzie, 1992). When growth is slow, sexual maturity in *O. niloticus* is delayed a month or two and stunted fish may spawn at a weight of less than 20 g.

Cage aquaculture in lakes and reservoirs is often viewed as desirable as it can generate employment, income and food, support or complement capture fisheries or other activities, capitalizing on previously under-exploited resources such as agricultural and industrial waste materials (Beveridge, 1996; Eng and Tech, 2002). Some of its advantages are: inexpensive method to construct and manage, easier to monitor, simpler harvesting, lower production costs per kilogram, higher yield per hectare, compliments with agriculture for land and water use rather than competing, allows farmers to supply customers with desired size of fish, and produce quality fish.

However, cage culture has disadvantages too. Some of its disadvantages are: water quality problems, disease outbreaks, escape of fish during cage damaging, fish are easier to poach or vandalize, require daily access or follow up, and lower production rates (Beveridge, 1996; Eng and Tech, 2002).

The design of fish cages is determined by the behavior of the culture species (Rakocy and Mc Ginty, 2005). For *O. niloticus*, which is less active and sometimes territorial in habitat, the shape of the cage does not affect its mobility. In this case, one has to design rectangular cages for easy assemblage and management (Fitzsimmons, 2004). Cage size depends on the size of the pond, the availability of aeration, and the method of harvest. Consequently, cage size may vary from 1 to more than 1,000 m^3. As cage size increases, costs per unit volume as well as production per unit volume decrease and results a reduction in the rate of water exchange (Eng and Tech, 2002).

Cage components consist of a frame, mesh or netting, feeding ring, lid, and flotation. The frame of the cage can be constructed from wood, iron, steel, aluminum, fiberglass, or Polyvinyl chloride (PVC). Frames of wood, iron, and steel (unless galvanized) should be coated with a water-resistant substance like epoxy, or asphalt based or swimming pool paint to avoid corrosion effect (Fitzsimmons, 2004). Similarly, bolts or other fasteners used to construct the cage should be of rust-resistant materials. Mesh or netting materials that can be used include plastic coated welded wire, solid plastic mesh, and nylon netting (knotted or knotless).

Mesh size should be no smaller than 12.5 mm to assure good water circulation through the cage to renew the oxygen supply and remove waste while holding relatively small fingerlings (100 to 130 mm) at the start of the production cycle (Dikel *et al.*, 2005). A larger mesh size can be used if large fingerlings are stocked. Moreover, the use of large mesh size requires a larger fingerling size to prevent gill entanglement or escape. For example, a 20 mm plastic mesh will retain 9 g tilapia fingerlings while a 25 mm mesh requires a fingerling weighing at least 25 g with plastic netting and 50 to 70 g with nylon netting (Silva *et al.*, 2000). On the other hand, larger mesh size facilitates the entry of wild fish into the cage. These fish will grow too large to swim out of the cage, but they do not grow large enough to reach marketable size, thereby representing a waste of feed. This indicates that mesh size has a significant impact on production. The mesh sizes for tilapia cages should be at least 12.5 mm, but 20 mm are preferred (Bocek, 1996).

Further, cages should be equipped with covers to prevent fish losses from jumping or bird predation. However, these covers are often eliminated on large nylon cages if the top edges of the cage walls are supported 30 cm to 60 cm above the water surface (Mc Ginty, 1991).

The other most important factor that affects cage culture is the placement of the cage. It is very important in that faecal and urinary wastes from the fish and uneaten fish feed fall through the cage and away from the immediate area of the cage. Therefore, the fish cage should be placed in an area where there is at least 60 cm of water between the bottom of the cage and the pond or lake bottom. It is undesirable for wastes to accumulate near the fish cage. Due to this fact the fish cages should also be placed where the water can move freely through and around the cage. Since wind action is the primary contributor to water movement, the cage should be placed in open water where the prevailing winds can create water movement. Even the slightest breeze helps to flush water through and around the cage, remove waste products, and provide fresh, oxygenated water. However, disturbances near the cage, such as swimming, boating, and fishing activities are not desirable.

Major water parameters measured by Boyd (1990) remained in the favorable range for tilapia suggesting that tilapia growth performance was not limited by any of the water quality parameters. In addition, Coche (1982) stated that water exchange through the cage is critical to the growth of caged fish. This is because water current circulation throughout the area gives a continuous flushing of water inside the cages, making dissolved oxygen highly available to fish and wash out metabolites.

Moreover, a suitable concentration of dissolved oxygen (DO) is vital to successful fish culture. The ideal range of dissolved oxygen concentration on the water must be at least 3 ppm (parts per million) (Lin and Diana, 1995) while optimal fish growth occurs when oxygen levels are maintained above 6 ppm for coldwater species and above 5 ppm for warm water species (Dikel *et al.*, 2005). However, the amount of oxygen that can be dissolved in water is dependent on water temperature, altitude, and salinity. Moreover, the symptoms of low DO are fish not feeding and fish gasping near the surface. Low DO levels can be expected to occur during the early morning hours and during or after extended periods of cloudy weather (Eng and Tech, 2002) due to limited photosynthesis.

On the other hand, the suggested temperature range for tilapia growth is from 20°C to 30°C. The lethal temperature levels are ≤ 12°C and ≥ 42°C (Cherviniski, 1982; Avella *et al.*, 1992; Popma and Masser, 1999). To enhance a better growth, the acceptable pH range for fish culture is from 6.8 to 8.0 (Coche, 1982). The pH will increase during the day as photosynthesis removes free carbon dioxide (decreasing carbon dioxide levels result in decreasing levels of carbonic acid). At night, photosynthesis ceases and carbon dioxide

produced by respiration decreases the pH. Fish will grow over a wide range of alkalinities but values from 120-400 ppm are considered optimum (Coche, 1982).

O. niloticus feed on large variety of natural food organisms found in fertilized ponds (Binh *et al.*, 2004). Physical, chemical and biological parameters did not differ among cages or between cages and open water indicating that the tilapia had similar culture environment and equal access to the natural feeds (Yi *et al.*, 1996). But, addition of artificial feeds has an important role especially under conditions of heavy stocking, when natural food supply has declined or completely disappeared (Ahmad *et al.*, 2005). This is because compared to the non-feeding cages, the addition of supplementary feed resulted in higher yields and growth rates (Dikel *et al.*, 2005). For a complete balanced diet, these feeds should be rich in protein/amino acids, carbohydrate, fats, vitamins, minerals and growth promoting substances (Khattabetal *et al.*, 2004).

In cage culture, feed selection is extremely important because fish are not able to forage for insects and other food items that are available in the pond or the water body. As a result the feed selected should be nutritionally complete. Moreover, since fish cannot feed on the bottom, the feed used should float. In countries that have well developed aquaculture, there are processed feeds made for cage culture, which meet these two requirements. According to Yi *et al.* (1996) feeding rings are usually used in smaller cages to retain floating feed and prevent wastage. The rings consist of small-mesh (3 mm or less) screens suspended to a depth of 450 mm or more. Feeding rings should enclose only a portion of the surface area because rings surrounding the entire cage perimeter may reduce water movement through the cage. However, it should be noted that any high quality feed that floats could be used in cage culture (Khattabetal *et al.*, 2004). Supplementary feeding in Tilapia culture employed in Asia and Africa are rice bran, broken rice, oil cakes, flour, corn meal, kitchen refuse, rotten fruit, coffee pulp, and a variety of aquatic and terrestrial plants (Diana *et al.*, 2004).

Balarin and Haller (1982) have reviewed various studies on tilapia and concluded that fish of less than 1 g require 35-50% protein, 1-5 g fish require 30-40% protein, 5-25 g fish require 25-30% protein; tilapias weighing more than 25 g require 20-25% protein. However, for larger fish, recommended dietary levels vary from 25% protein for fish raised in ponds, 28-32% when reared in cages, to 35-40% when fish are grown in tanks. Moreover, the total lipid requirement for tilapia smaller than 2g should be about 10% of the diet, decreasing to 6-8% as fish grow from 2g to harvest (Alceste and Jory, 2000).

In addition to this, feed allowance (feeding rate) for young fish (<25 g) is usually 6-15% of their body weight per day, and older fish (>25 g), 1-3% of their body weight. Tilapia growth rates also increase with multiple daily feedings (feeding frequency) (3-8 times a day depending on fish size). Tilapia from 25 to 100 g should be fed three times per day and tilapia from 100 g to market size two times a day (Schmittou *et al*., 1998).

There is a need for research in tilapia nutrition, not only to determine what feeds are best but also what rate of feeding are most effective. The study of tilapia feeding rate was carried out on Java tilapia and *O. niloticus* at Auburn University, using a mixture of 35 % peanut meal, 35 % soybean meal, 20 % ground beef liver, 15% fish meal with feeding rates of 1, 2, 3 and 4 % of body weight per day (Chapman, 2000). Java tilapia grew best at 3% but nearly as well at 2%. Feed conversion rate were best at 2% and 1%, respectively (Bardach *et al.*, 1972). The feeding rate relative to the body weight decreases as fish increases however, the rate of food consumed increases per individual. Solomon Hailu (2008) also recommended that 3% body weight feed treatment for a density of 100 fish per cage ($1m^3$) is suitable for cage culture of *O. niloticus.* The correct amount of feed must be weighed daily. Feeding rate tables or programs are required to make periodic increments in the daily ration. Feeding adjustments can be made daily, weekly or every 2 weeks (Cruz, 1997). The fish should be sampled every 2 to 6 weeks to determine their average weight and the correct feeding rate for calculating adjustments in the daily ration.

In fish farming practices, stocking density is considered to be one of the important factors that affect fish growth, feed utilization and the gross fish yield (Liu and Chang, 1992; Diana *et al*., 2004). In many cultivated fish species, growth is inversely related to stocking density and this is mainly attributed to social interactions (Holm *et al*., 1990; Haylor, 1991; Silva *et al*., 2000). Silva *et al*. (2000) studied the effect of stocking density (2, 3 and 4 Kg/m^3) on the growth of tetra hybrid red tilapia, and found that final body weight gain was significantly higher at a density of 2 and 3 Kg/m^3, while the biggest biomass and feed consumption were observed at a density of 4 Kg/m^3. The results of this and other studies generally demonstrated an inverse relationship between stocking density and growth rate. Coche (1982) suggested that about 90 Kg as being the maximum carrying capacity for 250–350 g *O. niloticus* fed a complete diet and reared in $1m^3$ cages.

On the other hand, Ridha (2006) expressed that FCR (food conversion ratio) was significantly affected by stocking density ($fish/m^3$). At the higher density (200 fish/ m^3), FCR was 10.7%

higher than at the lower density. This difference in FCR could be attributed to the lower growth rate at the higher stocking density. Similar results were reported for *O. niloticus* stocked in re-circulating tanks and in cages (Yi *et al*., 1996). Similarly, in ponds, Diana *et al.* (2004) found the most efficient FCR to be at the lower density. Moreover, similar results were reported by Ashagrie Gibtan *et al*. (2008) and Abebe Tadesse (2007) from their study of the effect of supplementary feeding and stocking density on growth performance, survival and yield of *O. niloticus* reared in cages in Lake Kuriftu and Elen respectively. A FCR of 8.5 would be considered as very good for feedlot cattle, 2.5 for pigs and 1.8 for broiler chickens. However, the best FCRs are found in fish. Feed conversion rates of up to 1.05 have been observed experimentally in *Clarias gariepinus*. Hence, the FCR of fish is also dependent on the nutritional value (feed quality) of the specific dry feed consumed (Fourie, 2006).

These results indicated that fish culture study on stocking density and supplementary feed is important in an effort to increase fish yield. Therefore, studies on the effect of supplementary feed quality and quantity on the growth performance, survival and yield of *O. niloticus* reared in cages, are still important areas of research especially in countries like Ethiopia where there is no cage culture practice. Thus a research was conducted in Lake Babogaya to see the effect of feed quality at a rate of 3% body weight on growth performance and water quality in cage culture system for production of *O. niloticus* for a density of 100 fish per cage ($1m^3$).

3. Description of the study area

Lake Babogaya (Bishoftu Guda) (Fig. 1) is one of the volcanic crater lakes found in and around Bishoftu town (Debre Zeit) about 47 Km East of Addis Ababa. The lake is small, roughly circular and fairly deep, and is found at an altitude of 1870 m and about 9^0N latitude and 39^0 E longitudes (Prosser *et al.,* 1968; Wood *et al.,* 1984). Like all the other volcanic crater lakes in this area, it is a closed system surrounded by very steep and rocky hills. The vertical distance from the lake's surface to the crater rim is 20 m, and this affords moderate protection from wind (Baxter, 2002). The catchment of the lake is formed from volcanic rocks of basalt, rhyolite and tuff (Mohr, 1961). It is substantially sheltered from wind by its deep well-preserved crater (Wood *et al.,* 1976) and is primarily fed by precipitation falling directly on its surface and run-off from its small catchment area (Prosser *et al.,* 1968).

The climatic condition in Lake Babogaya area is characterized by a moderate rainfall, varying around 850 mm per annum (Rippey and Wood, 1985) and maximum heat content in September. Baxter and Wood (1965) reported that Lake Babogaya has two rainy periods, the minor one extending roughly from February to April and the major one between June and September.

Lake Babogaya was found to be stratified from March to November and mixing takes place from November to February. The temperature of its surface water was reported to be mostly between 22^0C and 24.5^0C while the bottom temperature was almost constant (19.2^0C-19.4^0C) (Wood, *et al.,* 1976; 1984).

Previous limnological studies made on the Lake described its bathymetry (Prosser *et al.,* 1968), water chemistry (Prosser *et al.,* 1968; Wood *et al.,* 1984; Rippey and Wood, 1985; Zinabu Gebre-Mariam, 1994; Baxter, 2002; Zinabu Gebre-Mariam *et al.,* 2002), thermal stratification and mixing (Baxter and Wood, 1965; Baxter *et al.,* 1965; Wood *et al.,* 1976; 1984), chlorophyll a and phytoplankton (Wood and Talling, 1988; Zinabu Gebre-Mariam, 1994; Zinabu Gebre-Mariam and Taylor, 1997), bacterial abundance and zooplankton associations (Green, 1986) temporal and seasonal variation of phytoplankton, (Yeshimebet Major, 2006), studies on reproduction, food, length-weight relationship and condition factor of African catfish (*Clarias gariepinus*) (Lemma Abera, 2007) and temporal and spatial dynamics of zooplankton in relation to phytoplankton variation (Denbere Belay, 2007).

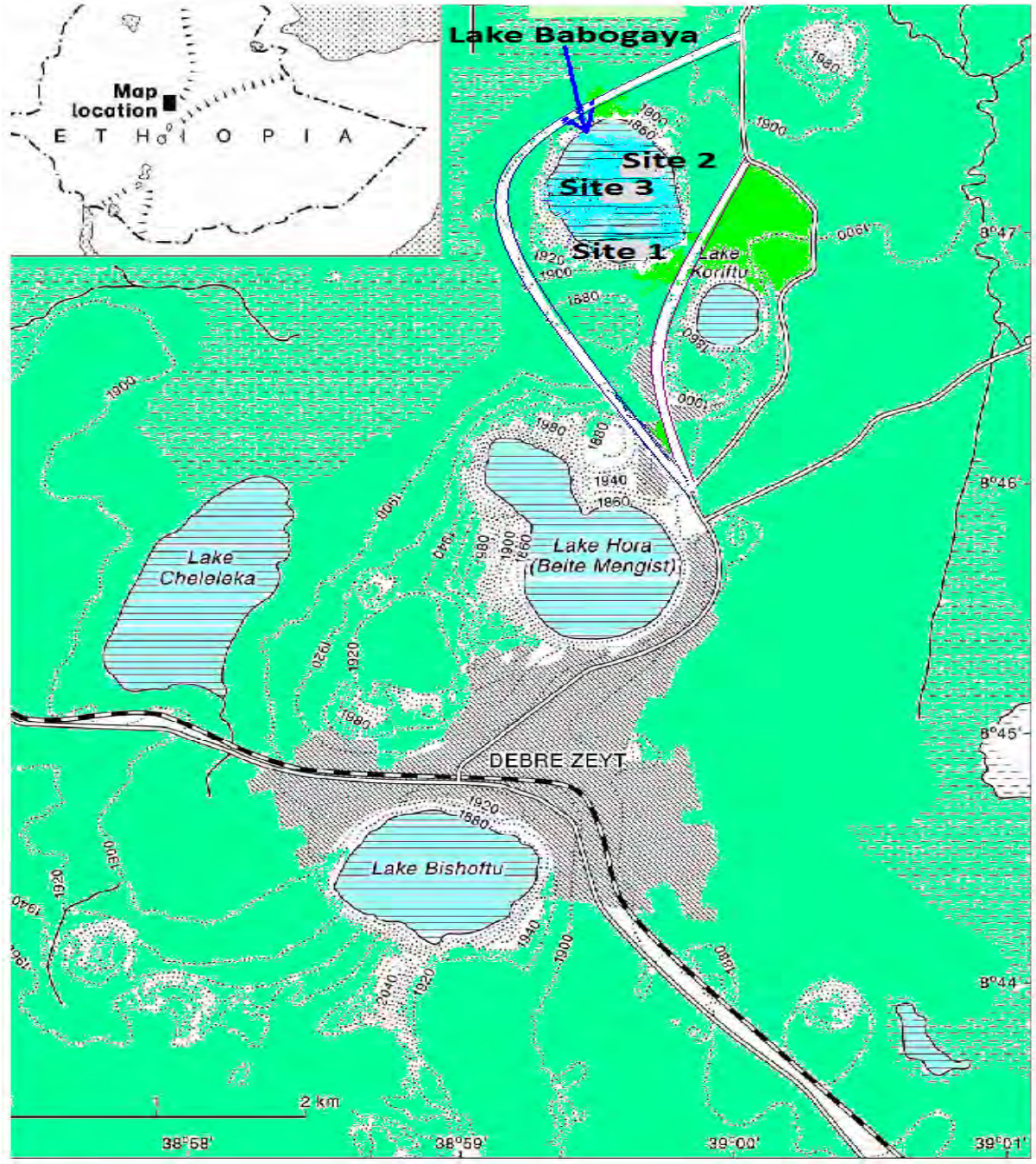

Fig.1. Location of the study Lake Babogaya (sampling sites: 1, 2 and 3) in relation to other Bishoftu Crater Lakes (Lamb, 2001).

It is alkaline lake with Na^+ as the dominant cation and carbonate-bicarbonate as the dominant anion (Table 1). The erosion of basaltic and hyperalkaline rocks surrounding the lake has an important role in increasing the alkalinity of the water (Wood and Talling, 1988).

Drier slopes around the lake support various tree species such as *Acacia* spp. where disturbance and grazing are minimal. Severely eroded areas are either bare or carry highly drought-tolerant shrubs, scramblers and succulents, the most conspicuous of which are *Carissa edulis*, *Euphorbia tirucalli*, *Pterolobium stellatum*, *Caesalpina spinosa* and *Opuntia ficus-indica* (Prosser *et al.*, 1968; Wood *et al.*, 1984).

Table 1. Some morphological and chemical features of Lake Babogaya (Bishoftu Guda) ([a] Prosser *et al.*, 1968; [b] Tudorancea and Taylor, 2002).

Parameters	**Values**
Latitude (m)	9^{o}N and 39^{o}E[a]
Altitude (m)	1870[a]
Surface area (Km^2)	0.58[a]
Volume (Km^3)	0.022[a]
Maximum depth (m)	71[a]
Mean depth (m)	38[a]
Conductivity, K_{25} (μscm^{-1})	900[b]
Alkalinity ($meql^{-1}$)	10.2[b]
pH	9.2[b]
Salinity (gl^{-1})	0.9[b]
SiO_2 ($meql^{-1}$)	<0.1[b]
Na^+ ($meql^{-1}$)	5.5[b]
Cl^- ($meql^{-1}$)	0.9[b]
Sum of cations ($meql^{-1}$)	11.7[b]
Sum of anions ($meql^{-1}$)	11.4[b]

The phytoplankton is dominated by blue green algae, green algae, eugleniods, Cryptomonas and particularly diatoms and dinoflagellates, (Wood and Talling, 1988; Yeshimebet Major, 2006) while the zooplankton is dominated by Copepods (*Afrocyclops gibsoni*, *Lovenula africana*), Rotifers (*Asplancha sieboldi*, *Brachionus calyciflorus* and *Hexarthra jenkinae*) (Green, 1986), and Cladocerans (*Diaphanosoma excisum*) (Yeshimebet Major, 2006; Denbere Belay, 2007). The fish community found in the lake is mainly composed of *O. niloticus*, *C. gariepinus* and T. *zilli*. From these, *C. gariepinus* is the most dominant species

next to *O. niloticus* (Lemma Abera, 2007). Lemma Abera (2007) reported that there is an intensive fishing activity on the lake though it was mainly used for recreation and domestic water-use purposes.

Denbere Belay (2007) reported that mean monthly maximum and minimum air temperature of the lake ranged from 8.4^{0}C in November to 13.8^{0}C in August, 2006 and from 23.6^{0}C in September to 29.3 ^{0}C in March, 2007 respectively while monthly total rainfall varied from 5.2 mm in November to 329 mm in July, 2006. On the other hand, Lemma Abera (2007) reported that mean monthly maximum and minimum air temperature of the lake ranged from 11.2 to 13.5^{0}C and from 21.6 to 31.5 ^{0}C, respectively while monthly total rainfall varied from 2.1 mm (January 2006) to 239.5 mm (July 2006) (Fig. 2).

Although Baxter and Wood (1965) reported that the region has two rainy periods, appreciable quantities of rainfall were recorded from February through to October peaking in July, 2006 (Denbere Belay, 2007; Lemma Abera, 2007). Moreover, Rippey and Wood (1985) documented that the area has moderate rainfall, varying around 850 mm per annum while Denbere Belay (2007) and Lemma Abera (2007) reported an annual mean rainfall of about 877.2 mm. Yeshemebet Major (2006) reported that the water temperature and dissolved oxygen of the lake ranged from 23^{0}C to 27^{0}C and 7 mg l^{-1} to 14 mgl^{-1}, respectively.

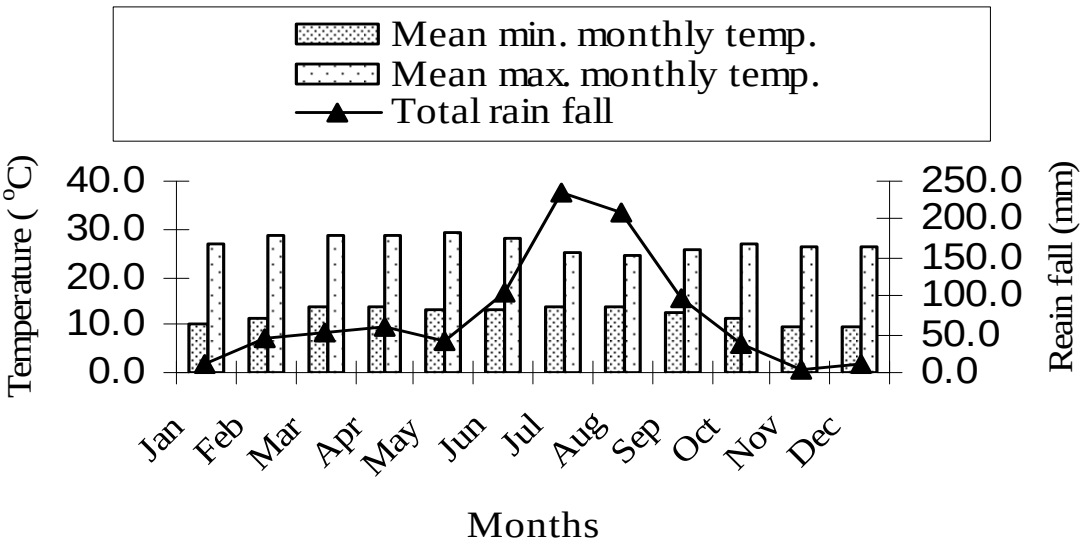

Fig. 2. Average monthly minimum and maximum temperature and total rain fall of the Lake region from 1998-2007 (Source: NMSE).

4. Materials and Methods

4.1. Site Selection

The more appropriate and secured trial site for cage placement was selected in Lake Babogaya. Before the beginning of the experiment new landing structure (jetty) for cage placement was constructed by using eucalyptus wood. It had a T shape with a 9.4 m length; 4.5 m depth and about 3 m distance from the shore. This would enable sufficient water circulation for waste removal and enough oxygen circulation (Coche, 1982). Moreover, three sites, one in the cage area (site 1) the second on the other side of the shore (site 2), and the third around the center of the lake (site 3) were chosen for limnological sampling (Fig. 1).

4.2. Construction of experimental cage

The cages were constructed as mentioned in Beverage and Stewart (2002) in fishery laboratory of the Department of Biology of Addis Ababa University in addition to those used by previous researchers. The size of each cage was $1m^3$ (1m x 1m x 1m). PVC (polyvinyl chloride) was used to make the frames of the cages and enclosure nylon material was used to make the mesh or netting material (4 cm stretched mesh size) of the cages. The PVC was type 50 with a tube of 50 mm by 1 mm polyethylene material (Fig.3).

Fig. 3. Experimental cage Construction.

First, the PVC was cut into pieces each with 1m length and then fixed together by using jointer and gum to make it like a square. Further, the joints were fastened by scotch-tape to give them extra strength. The meshes were then cut according to the desired specification to

enclose the cages. Then, every mesh of the four corners was double-laced using nylon twine (210D/24). Moreover, the upper part of the lower square frame of each cage was perforated so that each cage distends and weights down due to the entrance of water. Finally, the cages were placed side by side at a distance of 1m difference on the constructed jetty so that all have equal access to natural food and water circulation.

4.3. Juvenile collection method

O. niloticus juveniles of mixed sex were collected from the wild population for two weeks from September 22/ 2007 to October 06/ 2007. They were collected by using beach seine of 50 m x 2.5 m with 20 mm stretched mesh size from Lake Babogaya. During collection and transportation juveniles were kept in large plastic containers (80 L) that were supplied with oxygen using oxygen cylinder. Then, they were acclimated about seven days before launching on the feeding experiment (October 13/2007).

After acclimatization, total length (to nearest 1mm using measuring board) and body weight (to nearest 0.1g using Ohaus balance) were measured to select those juveniles suitable for the proposed mesh size of the net. Then, juveniles of 120–130 mm length and 25-35 g weight were selected from the wild as experimental group.

4.4. Supplementary feeding

Three kinds of locally available feed and their combinations were used. These were Mill sweeping (M), Chicken dung (D) and Oil seed cake (O). Equal proportion (50% and 33.3%) of each feed type was used to make the combined MD, MO, DO and MDO feed types, respectively from M, D and O feed types. Feed was given two times per day early morning at 7:30 AM and late afternoon at 4:00 PM following Cruz (1997) and Chapman (2000) by hand at a rate of 3% per body weight per day for 170 days. Feeding rates were adjusted every two weeks based on the average weight of fish in each feed treatment stock in each sampling period. The study was carried out from October 13/2007 to March 30/2008 under pilot scale cage culture conditions. Proximate nutritional composition analysis was done for only oil seed cake diet by Ethiopian Health and Nutrition Research Institute (EHNRI) for which no literature was found. The proximate nutritional compositions of diets used in this study are presented in Table 2.

4.5. Stocking of juveniles

Equal number of mixed sex juveniles (100 per m^3 of cage) with 25-35 g weight and 120–130 mm total length were stocked as proposed by Abebe Tadesse (2007) and Ashagrie Gibtan *et al*. (2008) for about 6 months. Hence, replicates of seven feeding treatments (T1, T2, T3, T4, T5, T6 and T7) with the same stocking density (100 per m^3 of cage) were used to evaluate the effect of feed quality on growth performance (Where T1=M, T2=D, T3=O, T4=MD, T5=MO, T6=DO and T7= MDO). Further, replicates of control groups (C1 and C2) with equal stocking density (100 per m^3 of cage) but without feeding were used to evaluate the difference in growth performance between natural and supplementary feed types.

4.6. Data collection

4.6.1 Growth parameters

Initial weight, length and number of the stocks were recorded. Dead fishes were removed and recorded daily. 30% of fish in each treatment were sampled randomly by use of scoop net every 2 weeks to monitor growth and make feeding adjustments. Furthermore, the growth changes in length and weight were recorded and evaluated twice per month. On the other hand, water samples were taken once per month to evaluate the effect of cage culture on water quality. At the end of the experiment all fishes were harvested and they were counted, weighed, measured and sexed.

Table 2. Feed type used and their nutrient proximate composition.

	Nutrient composition						
Feed type	Moisture (%)	Fat (%)	Protein (%)	Ash (%)	Crude Fiber (%)	Carbohydrate (%)	Source
Mill sweeping*	-	14.00	12.50	-	7.50	58.00	Bardach, Ryther and Mc Larney (1972)
Chicken dung‡ (poultry manure)	-	-	23.00	30.00	-	-	Kebede Alemu (2003)
Oil seed cake† (for Flax)	6.20	12.39	36.38	7.15	7.86	30.02	Determined in the present study (by EHNRI)

* A mixture of flours of Teff (*Eragrostis teff*), Wheat (*Triticum vulgare*), Maize (*Zea mays*), Horse Beans (*Vica faba*), Field Peas (*Pisum sativum*), etc which are swept from local mills.

‡Composed of 69% Organic matter and 85.3% Dry matter (Kebede Alemu, 2003).

† A byproduct of local oil production system either from Niger seed (*Guizotia abyssinica*) or Flax (linseed) (*Linum usitatissimum*).

4.6.2. Water quality analysis

Concentration of dissolved oxygen (DO) was determined in the laboratory using Winkler method and water temperature was measured with thermometer *in situ* monthly at 25 cm below the surface of water at the experiment (cages area) and control sites. Visibility was measured monthly at 12:00 AM using Secchi disk. Visibility was calculated as the average depth at which the Secchi disk disappeared when lowered, and the depth at which it reappeared when raised (Boyd and Tucker, 1992). The secchi disk depth was used to estimate the euphotic depth of the lake. pH was measured with pH meter. Within a few hours of sample collection, carbonate-bicarbonate alkalinity was determined by titration.

4.6.3. Estimation of Zooplankton abundance

Zooplankton samples were collected monthly with a net mesh size of 64 μm plankton net and with mouth diameter of 30 cm at 2 m depth of the three sites (in cage area and control sites) of the lake. Immediately after sampling, zooplankton samples were preserved with 5% formaldehyde in 200 ml plastic bottles.

To estimate abundance, 20-25 ml of sub sample was taken using pipette with wider mouth and poured into a grided petridish (15 grids). Three grids were counted for each sample after allowing the sample to settle and the average value was taken and then extrapolation is made to the sample and the filtered volume. Counting was done with stereoscope microscope (magnification of 50x).

Zooplankton species were identified using standard methods and references (Vogit and Koste, 1978; Van de Velde, 1984; Defaye, 1988; Fernando, 2002). Abundance of zooplankton population was estimated as individual per m^3 by using the formula ($V = 3.14 r^2h$) where, V is the volume of water filtered, r is the radius of the net and h is the depth from which the sample is taken (Edmondson and Winberg, 1971). Based on this, the number of organisms per m^3 of the lake was calculated and then the abundance of each category of zooplankton of the lake was expressed as number per m^3.

4.6.4. Estimation of phytoplankton abundance

Samples for the identification of phytoplankton taxa and estimation of the relative abundance were collected from 2m depth of the open water using a mesh size of 25 μm phytoplankton net. Then samples were preserved in a few drops of Lugol's solution (Wetzel and Likens, 2000) and placed in a refrigerator. The samples were examined with inverted microscope and the identification of phytoplankton to the lowest taxa possible was made using the literature (Whitford and Schumacher, 1973; Jeeji-Bai, 1977; Durand and Leverque, 1980; Gasse, 1980; Talling, 1987; Willen, 1991; Rot and Lenzenwger, 1994; Hindak, 2000; John *et al.*, 2002; Komarek and Cenberg, 2001; Komarek and Komarokova, 2002).

After sedimentation, aliquots of the preserved samples were used for the estimation of relative abundance of the major algal groups with Sedgwick-rafter cell under an inverted microscope (40x and 100x) following the procedures outlined in Hotzel and Croome (1999). The number of cells per ml was calculated using the following formula:-

$$Co = \frac{N\ x\ 1000\ M^{3} x\ 1}{A\ x\ D\ x\ F\ x10}$$

Where:

C_o = Number of cells per ml

N= Number of cells or units counted

A= Area of field (mm^2)

D= Depth of a field (Sedgwick-Rafter chamber depth) (mm)

F= number of Fields counted and 1/10 is the concentration factor.

4.7. Data analysis

Growth performances of fishes were determined and feed utilizations and survival were calculated in terms of Weight Gain, Daily Growth Rate (DGR), Specific Growth Rate (SGR), Feed Conversion Ratio (FCR), Survival Rate and Net yield as described by Sveier *et al.* (2000) as follows:

- Weight gain =*Final weight –Initial Weight = W2 –W1*
- Daily growth rate (DGR, g/day) =*Total weight per fish per culture days*

$$= \frac{W_2 - W_1}{T}$$

- Specific growth rate (SGR, % /day) =*lnWf -lnWi/ no. of culture days (%)*

$$= \frac{W_2 - W_1}{T} x100$$

Where W_1 and W_2 are initial and final weight (g), respectively and T is culture days.

- Survival rate (%) $= \frac{N_2}{N_1} x100$

Where N_2– number of fish harvested and N_1 number of fish stocked.

- Net yield (Kg year $^{-1}$) =Biomass gain (kg) x 365
  Time (days).
- Food conversion ratio (FCR) = *total weight of dry feed given per total weight gain*
  = Dry food given
  Weight fish gained

Sex ratio (male: female) was calculated for fish at harvest. Chi-square test was employed to test sex composition from the total sample.

The well being of fishes was studied by calculating the Fulton condition factor (FCF) (Bagenal and Tesch, 1978). FCF (%) was calculated as

$$FCF = \frac{TW}{TL^3} \text{ X } 100$$

Where, TW = total weight (g) and TL = total length (cm).

ANOVA (SPSS version 15.0) was used to test differences in growth parameters. Duncan's New Multiple Range Test (1955) was subsequently used to identify the significance differences between treatment mean values for selected parameters. The significance of the relationship was statistically tested using ANOVA. Moreover, simple t-test was used to check if the variation in grazing in zooplankton and phytoplankton rate and water quality between the three sites was statistically significant (at $p < 0.05$).

5. Results

5.1. Physico-chemical parameters

Water quality parameters which were measured during the study period (Temperature, pH, and dissolved oxygen) are given in Table 3. Water temperature ranged from 17.60 to 25.60°C and the lowest water temperature occurred in December 2007 during the study period while the highest temperature recorded in March 2008. Mean water temperature decreased from October 2007 to December 2007 and then increased up to the end of the study period, March 2008 (Table 3). Despite the variations in the measurement value at different sampling periods, all the values of physical parameters were not significantly different at the three sites ($P > 0.05$, Table 4).

5.2 Growth Performance

The highest growth occurred in February 2008 when the water temperature increased from 17.60°C in December 2007 to 23.63°C in February 2008. In contrast, the lowest growth occurred in December 2007 when the temperature decreased to 17.60°C (Table 7). Initial and final body weights and lengths, and growth performances for caged *O. niloticus* fed the seven diets in terms of growth parameters are summarized in Table 5. There were no significant differences in weight and length between experimental groups at the beginning of the study and no significant differences were found between replicates of the groups over the course of the experiment. Hence, data from replicates were pooled for each treatment prior to analysis. Statistically significant differences were found between treatments in terms of final growth parameters ($P < 0.05$). For instance, the final mean weight were calculated after 170 days of culturing period and were found to be significantly lower at T3, T5 and T6 than at the other treatments ($P < 0.05$). The highest and lowest growth parameters were observed in T4 and T3, respectively, among the feeding treatment (Table 5). The highest and the lowest FCR were obtained in T3 and T4, respectively (Table 5). Survival rate of caged *O. niloticus* ranged from 87.5 % in C to 94 % in T4 (Table 5).

Table 3. Water quality parameters in three sites during the experimental period in Lake Babogaya.

		Physical parameters				
Sampling dates	Site	Water Temperature (^oC)	pH	Secchi depth (cm)	Euphotic depth (cm)	Dissolved oxygen (mg/l)
	1	20.50	9.30	2.80	11.20	9.90
	2	20.00	9.31	2.20	8.80	10.30
Oct-07	3	20.50	9.36	2.05	8.20	11.00
	1	20.20	9.22	2.35	9.40	7.60
	2	20.40	9.14	1.70	6.80	7.60
Nov-07	3	20.30	9.20	1.55	6.20	7.80
	1	17.80	9.02	1.82	7.28	7.70
	2	17.60	9.10	1.91	7.20	9.70
Dec-21	3	17.70	9.21	1.86	7.44	11.90
	1	22.30	9.12	1.82	7.28	8.30
	2	22.40	9.20	1.80	7.20	8.90
Jan-08	3	22.30	9.20	1.86	7.44	9.00
	1	23.60	9.12	1.72	6.88	8.40
	2	23.70	9.31	1.68	6.72	9.00
Feb-08	3	23.60	9.36	1.66	6.64	8.70
	1	25.60	9.01	1.68	6.72	9.55
	2	25.50	9.30	1.54	6.16	10.45
Mar-08	3	25.40	9.31	1.56	6.24	11.90

Table 4. Mean Values of water quality parameters in three sites during the experimental period in Lake Babogaya. Mean values with the same superscript letters in the same column were not significantly different at P = 0.05 (using simple t-test).

	Physical parameters				
Site	Temperature	pH	Secchi	Euphotic	Oxygen
1	21.67±1.13^a	9.13±0.05^a	2.03±0.18^a	8.13±0.73^a	8.58±0.39^a
2	21.60±1.16^a	9.23±0.04^{ab}	1.81±0.09^a	7.15±0.37^a	9.33±0.43^a
3	21.63±1.11^a	9.27±0.03^b	1.76±0.08^a	7.03±0.33^a	10.05±0.72^a
Average	21.63±0.61^a	9.21±0.03^a	1.86±0.08^a	7.43±0.30^a	9.32±0.33^a

Table 5. Initial and final body weights and lengths, and growth performances of *O. niloticus* in terms of growth parameters for each treatment and the control in a 170-day culture period (Biomass, net yield and total net yield are expressed in Kg/cage, g/fish/cage and Kg /year). Mean values with the same superscript letters in the same row were not significantly different at P = 0.05 (using ANOVA, and Duncan's multiple test, 1955).

	Treatments and control							
Parameters	T1	T2	T3	T4	T5	T6	T7	C
n_i	100	100	100	100	100	100	100	100
n_f	89	88	91	94	90	92	89	88
Sample size (n)	30	30	30	30	30	30	30	30
Initial weight (g)	33.70 ± 0.59^{a}	33.47 ± 0.47^{a}	32.97 ± 0.66^{a}	34.20 ± 0.76^{a}	33.27 ± 0.46^{a}	32.93 ± 0.46^{a}	34.80 ± 0.85^{a}	33.60 ± 0.44^{a}
Final weight (g)	207.43 ± 2.75^{e}	194.60 ± 2.49^{d}	166.90 ± 1.61^{b}	242.87 ± 1.97^{g}	182.77 ± 2.52^{c}	178.30 ± 1.57^{c}	221.63 ± 2.42^{f}	113.07 ± 1.48^{a}
Initial length (mm)	121.67 ± 1.15^{a}	121.07 ± 0.46^{a}	121.67 ± 1.00^{a}	122.27 ± 0.61^{a}	122.20 ± 0.54^{a}	122.17 ± 0.45^{a}	124.17 ± 0.83^{a}	122.80 ± 0.49^{a}
Final length (mm)	183.67 ± 0.83^{e}	182.33 ± 0.86^{d}	174.33 ± 0.71^{b}	192.03 ± 0.57^{g}	177.23 ± 0.83^{c}	185.33 ± 0.72^{c}	187.27 ± 0.72^{f}	167.43 ± 0.94^{a}
DGR (g/day)	1.02 ± 0.04^{e}	0.95 ± 0.03^{d}	0.79 ± 0.06^{b}	1.23 ± 0.03^{g}	0.88 ± 0.08^{c}	0.86 ± 0.06^{c}	1.10 ± 0.06^{f}	0.47 ± 0.04^{a}
SGR (%/day)	1.07 ± 0.29^{e}	1.04 ± 0.11^{d}	0.96 ± 0.05^{b}	1.15 ± 0.24^{g}	1.00 ± 0.11^{c}	0.99 ± 0.20^{c}	1.09 ± 0.43^{f}	0.71 ± 0.23^{a}
Survival rate (%)	88.50	88.00	90.50	94.00	90.00	92.00	88.50	87.50
FCR	2.85	2.92	3.33	2.76	3.06	3.01	2.85	-
Initial FCF (%)	1.88 ± 0.03^{a}	1.88 ± 0.02^{a}	1.83 ± 0.02^{a}	1.87 ± 0.03^{a}	1.82 ± 0.02^{a}	1.80 ± 0.01^{a}	1.81 ± 0.02^{a}	1.81 ± 0.01^{a}
Final FCF (%)	3.34 ± 0.02^{f}	3.21 ± 0.01^{d}	3.15 ± 0.02^{c}	3.43 ± 0.01^{g}	3.28 ± 0.01^{e}	2.80 ± 0.01^{b}	3.37 ± 0.01^{f}	2.41 ± 0.02^{a}
Initial fish Biomass	3.37	3.35	3.30	3.42	3.33	3.29	3.48	3.36
Final fish Biomass	18.36	17.12	15.10	22.83	16.45	16.40	19.61	9.89
Fish Biomass gain	14.99	13.78	11.81	19.41	13.12	13.11	16.13	6.53
Net yield	173.73	161.13	133.93	208.67	149.50	145.37	186.83	79.47
Total net yield	32.40	29.58	25.53	41.67	28.17	28.15	34.88	14.15

5.2.1. Mean Weight Gain

Growth was significantly affected by supplementary feeding ($p<0.05$). The highest mean final body weight of *O. niloticus* was in T4 (242.87 g) followed by T7 (221.63 g), T1 (207.43 g), T2 (194.60 g), T5 (182.77 g), T6 (178.30 g) and T3 (166.90 g) (Table 6 and Fig. 4). The lowest value (113.07 g) was obtained in the control cage (C). Fish fed on mixed mill sweeping and chicken dung (T4) produced better sized caged tilapia (220-255g, 185-196 mm) while those fish fed on three mixed fed (T7) produced 198-240 g of caged *O. niloticus* (180-192 mm) which is close to 200-250 g commercial-sized tilapia (Table 9).

Eventhough both treatments were not significantly different at the first sampling period ($p>0.05$), the control group (C) was significantly lower ($p < 0.05$) than other treatments after the first sampling period. T1 and T2 were significantly different ($p < 0.05$) only after the eighth sampling period (February 02/2008) while T5 and T6 exhibited slight differences ($p > 0.05$) throughout the sampling period. T3 became significantly different from T5 and T6 only after the tenth (March 01/2008) sampling period. T4 and T7 which produced table sized caged tilapia were significantly different from each other and with the other treatments throughout the sampling periods (Fig. 4).

There was a significant difference ($P< 0.05$) on the total weight gain amongst the fish fed each of the experimental diets. Fish in the mixed mill sweeping-chicken dung (T4) treatment showed significantly higher ($P<0.05$) weight gain (208.67 g), followed by those fish given three mixed fed (T7) (186.83 g), mill sweeping only (T1) (173.73 g), chicken dung only (T2) (161.13 g), mill sweeping-oil seed cake (T5) (149.50 g), chicken dung-oil seed cake (T6) (145.37 g), and oil seed cake only (T3) (133.93 g). But mill sweeping-oil seed cake and chicken dung-oil seed cake did not differ significantly ($P < 0.05$) from each other (Table 6).

Table 6. Mean weight (g) of caged tilapia in different treatments and a control group over a 170-day experimental period (Mean±SE). Values with the same superscript letters in the same row were not significantly different at P = 0.05.

	Treatments and control							
Sampling periods	T1	T2	T3	T4	T5	T6	T7	C
13-Oct	33.70 ± .59^{a}	33.47 ± 0.47^{a}	32.97 ± 0.66^{a}	34.20 ± 0.76^{a}	33.27 ± 0.46^{a}	32.93 ± 0.46^{a}	34.80 ± 0.85^{a}	33.60 ± 0.44^{a}
27-Oct	42.27 ± 1.14^{ac}	40.13 ± 1.32^{ab}	37.83 ± 1.31^{a}	45.93 ± 1.43^{c}	39.43 ± 1.24^{ab}	38.80 ± 1.34^{ab}	45.03 ± 1.37^{c}	37.50 ± 1.21^{a}
10-Nov	52.17 ± 1.69^{c}	49.57 ± 1.31^{bc}	46.70 ± 1.70^{b}	59.03 ± 1.53^{d}	48.53 ± 1.28^{bc}	47.00 ± 1.51^{b}	56.53 ± 0.99^{d}	41.60 ± 1.00^{a}
24-Nov	64.33 ± 1.39^{d}	61.07 ± 0.90^{cd}	57.07 ± 1.48^{b}	73.90 ± 1.38^{e}	59.50 ± 1.70^{bc}	57.00 ± 1.34^{b}	69.87 ± 0.91^{f}	45.40 ± 1.39^{a}
08-Dec	73.87 ± 1.49^{d}	69.97 ± 1.05^{cd}	63.60 ± 2.22^{b}	85.90 ± 1.03^{f}	67.10 ± 0.90^{bc}	64.30 ± 1.14^{b}	80.93 ± 1.85^{e}	48.30 ± 2.23^{a}
22-Dec	82.30 ± 1.73^{d}	77.57 ± 0.96^{c}	69.90 ± 1.58^{b}	96.90 ± 1.67^{f}	73.60 ± 0.94^{bc}	70.80 ± 0.80^{b}	91.37 ± 1.84^{e}	50.90 ± 1.98^{a}
05-Jan	97.10 ± 1.25^{d}	91.20 ± 1.72^{cd}	81.80 ± 1.87^{b}	114.53 ± 2.48^{f}	86.67 ± 2.02^{bc}	84.20 ± 2.39^{b}	107.60 ± 2.86^{e}	58.40 ± 2.13^{a}
19-Jan	113.13 ± 0.97^{d}	106.37 ± 1.90^{cd}	96.40 ± 1.83^{b}	132.47 ± 2.58^{f}	100.87 ± 2.82^{bc}	98.30 ± 4.04^{bc}	124.47 ± 4.45^{e}	66.40 ± 2.28^{a}
02-Feb	132.40 ± 1.74^{d}	124.67 ± 2.68^{c}	112.80 ± 2.63^{b}	156.53 ± 1.97^{f}	116.90 ± 0.49^{b}	113.20 ± 4.67^{b}	144.40 ± 1.47^{e}	76.50 ± 2.38^{a}
16-Feb	152.90 ± 0.80^{d}	143.80 ± 2.50^{c}	129.37 ± 1.57^{b}	181.10 ± 1.95^{f}	135.10 ± 4.75^{b}	130.27 ± 2.06^{b}	165.53 ± 2.36^{e}	87.50 ± 2.75^{a}
01-Mar	171.80 ± 2.02^{e}	161.67 ± 1.65^{d}	143.40 ± 4.54^{b}	202.97 ± 2.55^{g}	154.1 ± 2.71^{c}	147.00 ± 1.11^{b}	184.70 ± 2.92^{f}	96.40 ± 0.73^{a}
16-Mar	190.53 ± 2.89^{e}	178.93 ± 1.65^{d}	156.70 ± 3.90^{b}	224.43 ± 2.03^{g}	168.30 ± 3.91^{c}	163.40 ± 1.97^{bc}	204.27 ± 2.55^{f}	104.90 ± 1.73^{a}
30-Mar	207.43 ± 2.75^{e}	194.60 ± 2.49^{d}	166.90 ± 1.61^{b}	242.87 ± 1.97^{g}	182.77 ± 2.52^{c}	178.30 ± 1.57^{c}	221.63 ± 2.42^{f}	113.07 ± 1.48^{a}

5.2.2. Daily Growth Rate (DGR)

The mean daily growth rate (DGR) was computed for 170 days between each sampling periods for all treatments and the variation is presented in Table 7, and Fig. 5 and 6.

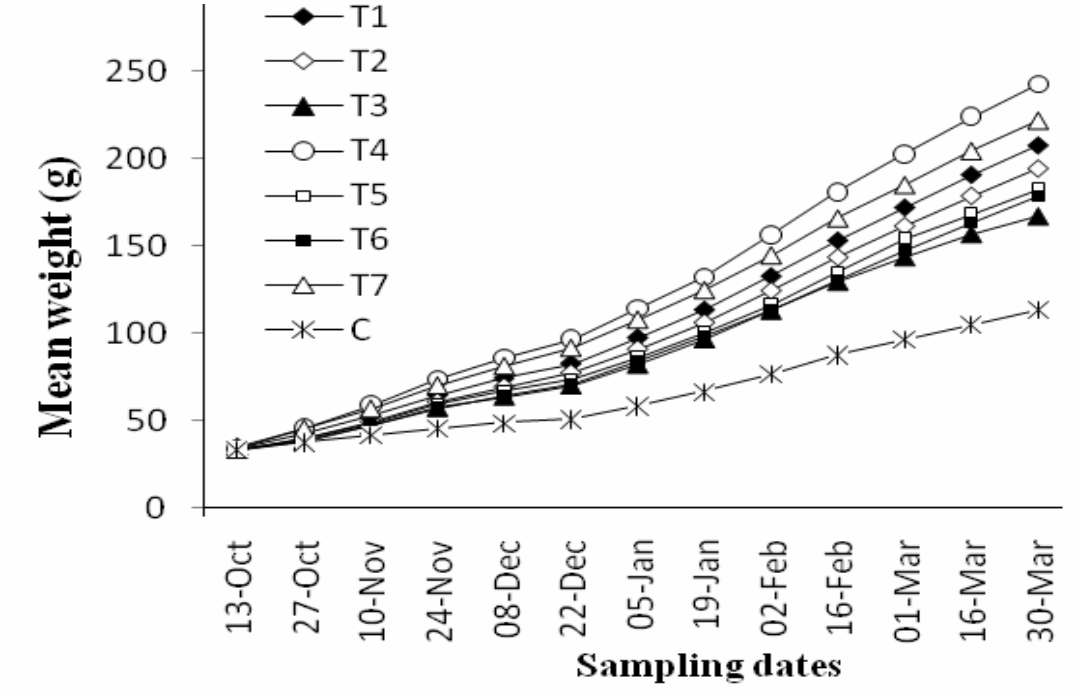

Fig. 4. The relationship between average weight (g) and culturing time (weeks) of *O. niloticus* fed the seven test diets.

Among the feeding treatments the maximum and minimum average DGR were 1.23 and 0.79 g/individual/day in T4 and T3, respectively while the control group (C) attained significantly lower DGR ($p < 0.05$) than all other treatments (0.47 g/individual/day) throughout the sampling periods (Table 7). The DGR of T1 and T2 became significantly different ($p < 0.05$) only after the eighth (February 02/2008) sampling period while T5 and T6 exhibited slight differences ($p > 0.05$) throughout the sampling periods. T3 became significantly different from T5 and T6 only after the tenth (March 01/2008) sampling period. T4 and T7 were significantly different in DGR ($p < 0.05$) from each other and with the other treatments throughout the sampling periods. Progressive decreases in the DGR were observed in all treatments (November 24 to December 22/2007) during which 162 fish died between the fifth and the sixth sampling periods (14-20/12/2007). However, mean daily growth rate was significantly different in all treatments and found to be significantly affected by supplementary feeding (Tables 5 and 7) ($p < 0.05$).

Table 7. Mean Daily Growth Rate (DGR) of caged tilapia in different treatments and a control group over a 170-day experimental period (Mean±SE). Mean values with the same superscript letters in the same row were not significantly different at P = 0.05

	Treatments and control							
Sampling periods	T1	T2	T3	T4	T5	T6	T7	C
27-Oct	0.57 ± 0.09^{ac}	0.44 ± 0.09^{ab}	0.32 ± 0.11^{a}	0.78 ± 0.10^{c}	0.41 ± 0.09^{ab}	0.39 ± 0.10^{ab}	0.68 ± 0.10^{c}	0.26 ± 0.09^{a}
10-Nov	0.71 ± 0.17^{c}	0.67 ± 0.14^{bc}	0.63 ± 0.16^{b}	0.94 ± 0.13^{d}	0.65 ± 0.12^{bc}	0.59 ± 0.12^{b}	0.82 ± 0.10^{d}	0.29 ± 0.13^{a}
24-Nov	0.87 ± 0.16^{b}	0.82 ± 0.11^{b}	0.74 ± 0.13^{b}	1.06 ± 0.14^{b}	0.78 ± 0.12^{bc}	0.71 ± 0.16^{b}	0.95 ± 0.11^{b}	0.27 ± 0.12^{a}
08-Dec	0.68 ± 0.10^{d}	0.61 ± 0.11^{cd}	0.47 ± 0.15^{b}	0.86 ± 0.11^{f}	0.54 ± 0.13^{bc}	0.52 ± 0.11^{b}	0.79 ± 0.15^{e}	0.21 ± 0.13^{a}
22-Dec	0.60 ± 0.12^{d}	0.56 ± 0.07^{c}	0.45 ± 0.14^{b}	0.79 ± 0.09^{f}	0.46 ± 0.11^{bc}	0.46 ± 0.10^{b}	0.75 ± 0.14^{e}	0.19 ± 0.26^{a}
05-Jan	1.06 ± 0.12^{d}	0.97 ± 0.11^{cd}	0.85 ± 0.16^{b}	1.26 ± 0.13^{f}	0.93 ± 0.14^{bc}	0.96 ± 0.18^{b}	1.16 ± 0.19^{e}	0.54 ± 0.26^{a}
19-Jan	1.15 ± 0.12^{d}	1.08 ± 0.16^{cd}	1.04 ± 0.18^{b}	1.28 ± 0.12^{f}	1.01 ± 0.19^{bc}	1.01 ± 0.26^{bc}	1.20 ± 0.39^{e}	0.57 ± 0.20^{a}
02-Feb	1.38 ± 0.13^{d}	1.31 ± 0.16^{c}	1.17 ± 0.22^{b}	1.72 ± 0.13^{f}	1.15 ± 0.19^{b}	1.06 ± 0.22^{b}	1.42 ± 0.39^{e}	0.72 ± 0.20^{a}
16-Feb	1.46 ± 0.15^{d}	1.37 ± 0.18^{c}	1.18 ± 0.22^{b}	1.75 ± 0.25^{f}	1.29 ± 0.34^{b}	1.22 ± 0.35^{b}	1.51 ± 0.20^{e}	0.79 ± 0.11^{a}
01-Mar	1.35 ± 0.18^{e}	1.28 ± 0.23^{d}	1.00 ± 0.39^{b}	1.56 ± 0.15^{g}	1.17 ± 0.26^{c}	1.20 ± 0.15^{b}	1.37 ± 0.27^{f}	0.64 ± 0.23^{a}
16-Mar	1.25 ± 0.26^{e}	1.15 ± 0.01^{d}	0.89 ± 0.27^{b}	1.43 ± 0.23^{g}	1.12 ± 0.34^{c}	1.09 ± 0.15^{bc}	1.30 ± 0.29^{f}	0.57 ± 0.12^{a}
30-Mar	1.21 ± 0.29^{e}	1.12 ± 0.22^{d}	0.73 ± 0.28^{b}	1.32 ± 0.20^{g}	1.03 ± 0.32^{c}	1.06 ± 0.15^{c}	1.24 ± 0.29^{f}	0.58 ± 0.15^{a}
Average	1.02 ± 0.16^{e}	0.95 ± 0.13^{d}	0.79 ± 0.20^{b}	1.23 ± 0.15^{g}	0.88 ± 0.20^{c}	0.86 ± 0.17^{c}	1.10 ± 0.22^{f}	0.47 ± 0.17^{a}

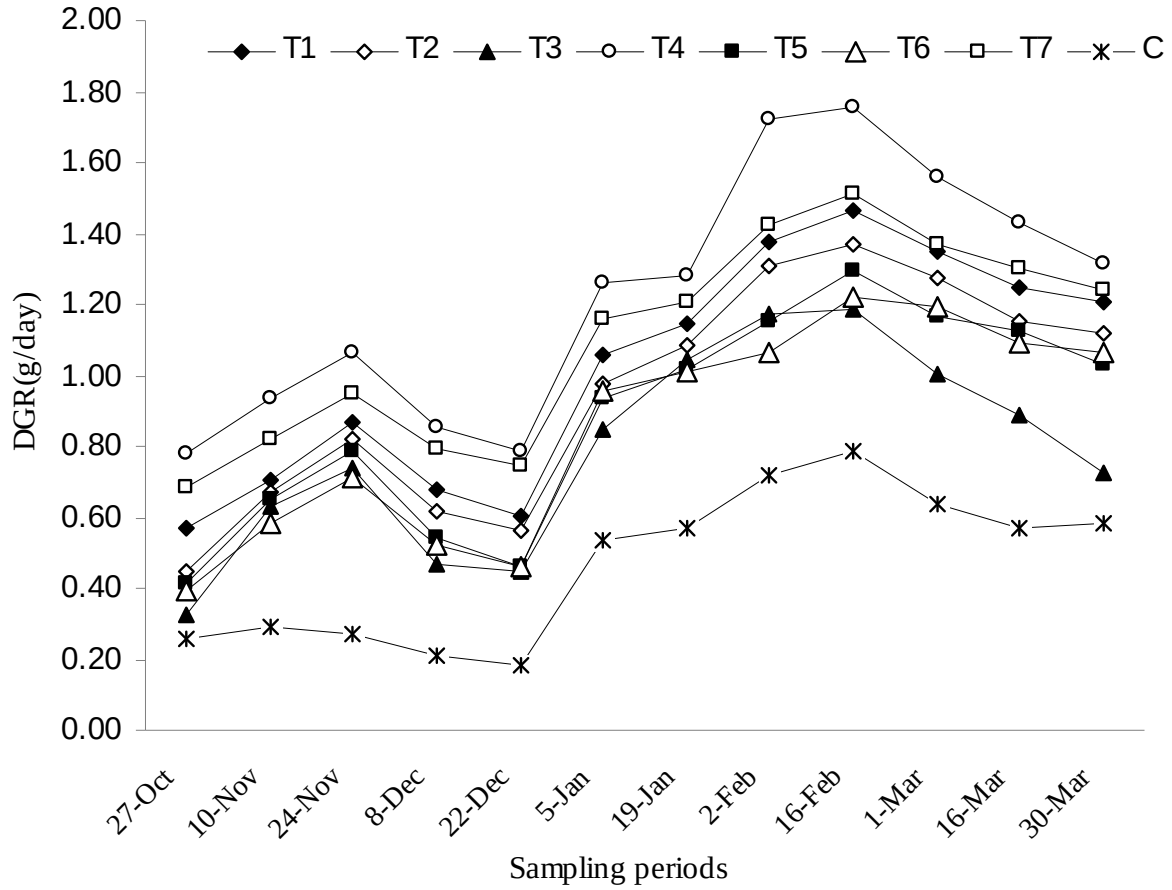

Fig. 5. Variation in mean Daily Growth Rate of caged tilapia in all treatments and a control group by compiling data of 170-days culture period.

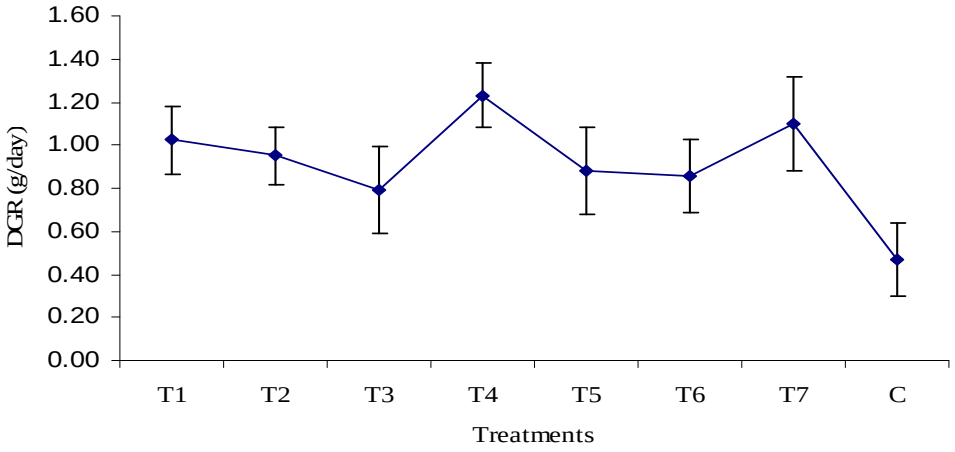

Fig. 6. Average Daily Growth Rate for caged tilapia in all treatments and a control group by compiling data of 170-days culture period (Mean±SE).

5.2.3. Specific Growth Rate (SGR)

The variations of specific growth rate with treatments during the sampling periods are presented in Tables 5 and Fig. 7 and 8. T4 (1.15 %/day) and T3 (0.96 %/day) attained the maximum and minimum average SGR, respectively among the feeding treatment while C attained the lowest average SGR (0.72 %/day). Fish in the control had significantly low specific growth rate than those in the feeding treatments ($p < 0.05$). The highest mean SGR was observed in the first growth period (October 13/2007) in all treatments and the lowest was at the last growth period (March 30/2008). Progressive decreases in the SGR were also observed in all treatments (November 24 to December 22/2007) during which 162 fish died between the fifth and the sixth sampling periods (14-20/12/2007). All treatments except T5 and T6 were statistically different in their specific growth rate, and SGR was found to be significantly affected by supplementary feeding ($p < 0.05$).

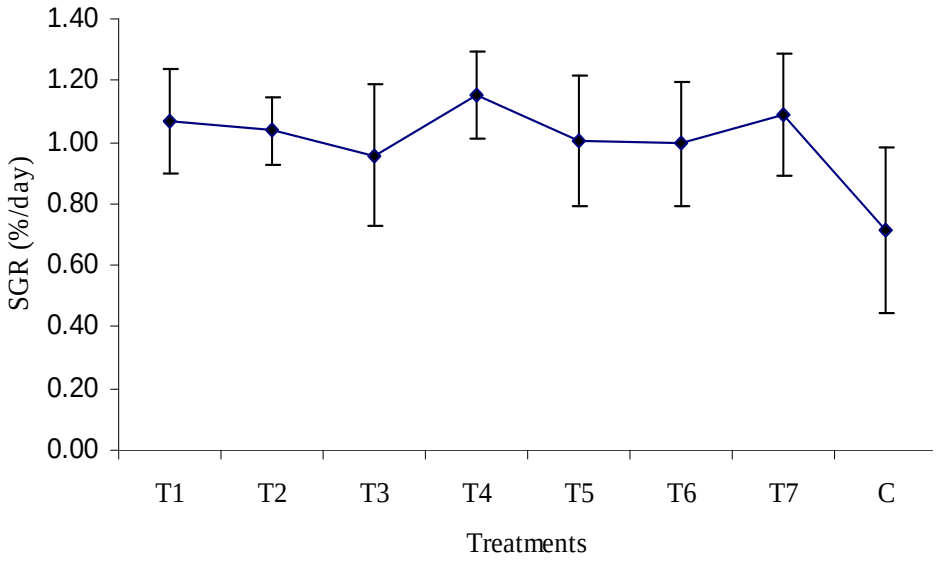

Fig. 7. Average Specific Growth Rate (SGR) for caged tilapia in all treatments and a control group by compiling data of 170-days culture period (Mean±SE).

5.2.4. Feed conversion ratio (FCR)

As shown in Tables 5 and 8, with increased culture periods, the amount of feed given per fish per day varies with different diets. Mean daily feed intake ranged between 2.57 g/day/fish in T3 to 3.52 g/day/fish in T4. The maximum and minimum overall FCR values were observed in T3 (3.3) and T4 (2.76), respectively.

FCR values ranged from 1.77 to 4.74 for T1, 2.26 to 4.80 for T2, 3.05 to 6.45 for T3, 1.31 to 5.11 for T4, 2.43 to 4.89 for T5, 2.53 to 4.61 for T6, and 1.53 to 4.94 for T7. FCR increases as the culture period extends and is significantly different among culture periods ($P < 0.05$) and significantly affected by different feeding types. The best FCR for caged tilapia was obtained from T4, T7, and T1 diets with insignificant difference (2.76 and 2.85, 2.85, respectively; $P > 0.05$), while the poorest FCR was obtained for *O. niloticus* fed the test diet containing 100% oil seed cake with a value of 3.33 ($P < 0.05$).

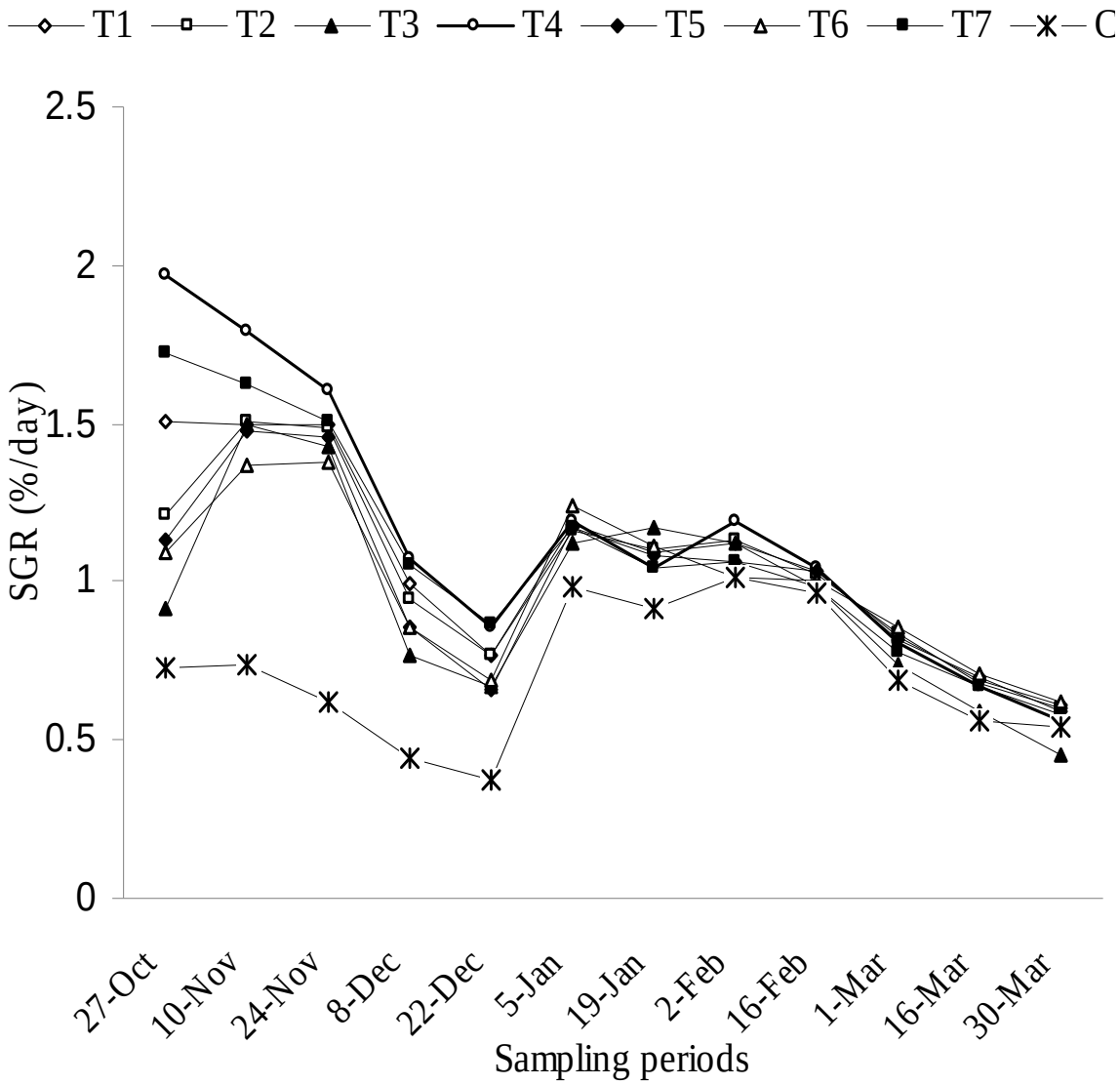

Fig. 8. Variation in mean Specfic Growth Rate (SGR) of caged tilapia in all treatments and a control group by compiling data of 170-days culture period.

Table 8. Total amount of feed supplied per fish per day, mean weight, and feed conversion ratio of caged tilapia for all treatments during each sampling period (units in g).

Treatments	Parameters	13-27 Oct	Oct 28-Nov 10	11-24 Nov	Nov 25-Dec 8	9-22 Dec	Dec 23-Jan5	6-19 Jan	Jan 20-Feb2	Jan 20-Feb16	Feb 17-Mar1	Mar2-Mar16	17-30 Mar	Oct 13-Mar 30
	Mean	42.27	52.17	64.33	73.87	82.30	97.10	113.13	132.40	152.90	171.80	190.53	207.43	
	Dry Feed	15.17	17.75	21.91	27.02	31.02	34.57	40.78	47.52	55.61	64.22	77.31	80.02	512.90
	Dry Feed/fish/day	1.01	1.27	1.57	1.93	2.22	2.47	2.91	3.39	3.97	4.59	5.15	5.72	3.02
T1	**FCR**	**1.77**	**1.79**	**1.80**	**2.83**	**3.68**	**2.34**	**2.54**	**2.47**	**2.71**	**3.40**	**4.13**	**4.74**	**2.85**
	Mean	40.13	49.57	61.07	69.67	77.57	91.20	106.37	124.67	143.80	161.67	178.93	194.60	
	Dry Feed	15.06	16.86	20.82	25.65	29.26	32.58	38.30	44.67	52.36	60.40	72.75	75.15	483.86
	Dry Feed/fish/day	1.00	1.20	1.49	1.83	2.09	2.33	2.74	3.19	3.74	4.31	4.85	5.37	2.85
T2	**FCR**	**2.26**	**1.79**	**1.81**	**2.98**	**3.70**	**2.39**	**2.53**	**2.44**	**2.74**	**3.38**	**4.21**	**4.80**	**2.92**
	Mean	37.83	46.70	57.07	63.60	69.90	81.80	96.40	112.80	129.37	143.40	156.70	166.90	
	Dry Feed	14.84	15.89	19.61	23.97	26.71	29.36	34.36	40.49	47.38	54.33	64.53	65.81	437.28
	Dry Feed/fish/day	0.99	1.13	1.40	1.71	1.91	2.10	2.45	2.89	3.38	3.88	4.30	4.70	2.57
T3	**FCR**	**3.05**	**1.79**	**1.89**	**3.67**	**4.24**	**2.47**	**2.35**	**2.47**	**2.86**	**3.87**	**4.85**	**6.45**	**3.33**

(Continued)

Table 8. (Continued)

Treatments	Parameters	13-27 Oct	Oct 28-Nov 10	11-24 Nov	Nov 25-Dec 8	9-22 Dec	Dec 23-Jan5	6-19 Jan	Jan 20-Feb2	Jan 20-Feb16	Feb 17-Mar1	Mar2-Mar16	17-30 Mar	Oct 13-Mar 30
	Mean	45.93	59.03	73.90	85.90	96.90	114.53	132.47	156.53	181.10	202.97	224.43	242.87	
	Dry Feed	15.39	19.29	24.79	31.04	36.08	40.70	48.10	55.64	65.74	76.06	91.34	94.26	598.43
	Dry Feed/fish/day	1.03	1.38	1.77	2.22	2.58	2.91	3.44	3.97	4.70	5.43	6.09	6.73	3.52
T4	**FCR**	**1.31**	**1.47**	**1.67**	**2.59**	**3.28**	**2.31**	**2.68**	**2.31**	**2.68**	**3.48**	**4.25**	**5.11**	**2.76**
	Mean	39.43	48.53	59.50	67.10	73.60	86.67	100.87	117.00	135.10	154.10	168.30	182.77	
	Dry Feed	14.97	16.56	20.38	24.99	28.18	30.91	36.40	42.36	49.14	56.74	69.35	70.69	460.68
	Dry Feed/fish/day	1.00	1.18	1.46	1.79	2.01	2.21	2.60	3.03	3.51	4.05	4.62	5.05	2.71
T5	**FCR**	**2.43**	**1.82**	**1.86**	**3.29**	**4.34**	**2.37**	**2.56**	**2.63**	**2.71**	**2.99**	**4.88**	**4.89**	**3.06**
	Mean	38.80	47.00	57.00	64.30	70.80	84.20	98.30	113.20	130.27	147.00	163.40	178.30	
	Dry Feed	14.82	16.30	19.74	23.94	27.01	29.74	35.36	41.29	47.54	54.71	66.15	68.63	445.22
	Dry Feed/fish/day	0.99	1.16	1.41	1.71	1.93	2.12	2.53	2.95	3.40	3.91	4.41	4.90	2.62
T6	**FCR**	**2.53**	**1.99**	**1.97**	**3.28**	**4.15**	**2.22**	**2.51**	**2.77**	**2.79**	**3.27**	**4.03**	**4.61**	**3.01**
	Mean	45.03	56.53	69.87	80.93	91.37	107.60	124.47	144.40	165.53	184.70	204.27	221.63	
	Dry Feed	15.66	18.91	23.74	29.34	33.99	38.37	45.19	52.28	60.65	69.52	83.12	85.79	556.58
	Dry Feed/fish/day	1.04	1.35	1.70	2.10	2.43	2.74	3.23	3.73	4.33	4.97	5.54	6.13	3.27
T7	**FCR**	**1.53**	**1.64**	**1.78**	**2.65**	**3.26**	**2.36**	**2.68**	**2.62**	**2.87**	**3.63**	**4.25**	**4.94**	**2.85**
	Mean	37.50	41.60	45.40	48.30	50.90	58.40	66.40	76.50	87.50	96.40	104.90	113.07	
C	**Weight gain**	**3.90**	**4.10**	**3.80**	**2.90**	**2.60**	**7.50**	**8.00**	**10.10**	**11.00**	**8.90**	**8.50**	**8.17**	**79.47**

5.2.5. Yield/ production

The increase in weight of *O. niloticus* during the culture period is given in Table 6. The total weight gained (yield) for each treatment per cage is given in Table 5. Weight increases were significantly different in all treatments ($P < 0.05$). The weight gained (net yield) per individual fish was highest in T4 (208.67g/fish) followed by T7 (186.83g/fish), T1 (173.73g/fish), T2 (161.13g/fish), T5 (149.50g/fish), T6 (145.37g/fish), and C (79.47g/fish). Moreover, the net fish biomass was computed for all treatments after harvesting. T4 (19.43 Kg/cage) and T7 (16.13 Kg/cage) had significantly higher net fish biomass than other treatments (Table 5). The biomass per cage calculated for non-feeding treatment (C, 6.53 kg/cage) was significantly lower than the feeding treatments ($P<0.05$). Similarly, the total net yield per year was also calculated for all treatments after harvesting (Table 5). It was observed that the total net yield was highest in T4 (41.67), followed by T7 (34.88), T1 (32.40), T2 (29.58), T5 (28.17), T6 (28.15), T3 (25.53) and C (14.15 Kg/ year). Moreover, total net yield was significantly different ($P < 0.05$) in all treatments except in treatments T5 and T6 ($P > 0.05$).

5.2.6. Fulton Condition Factor (FCF)

The mean Fulton condition factor (FCF) calculated for each sampling period (Table 9) ranged from 1.88 to 3.34 for T1, 1.88 to 3.21 for T2, 1.83 to 3.15 for T3, 1.87 to 3.43 for T4, 1.82 to 3.28 for T5, 1.80 to 2.80 for T6, 1.81 to 3.37 for T7 and 1.81 to 2.41 for C, respectively. FCF decreased with increasing culture periods up to the second sampling period for T5, T6 and C and the third sampling period for T1, T2, T3 and T4 with varying levels. Initially, FCF was not significantly different in all treatments ($P > 0.05$). However, significant variation in FCF between all treatments was observed as the culturing period increases after the third sampling period. FCF was statistically different between sampling periods in all treatments ($P < 0.05$). There was significant effect of feed quality and culturing period on condition factor ($P < 0.05$.

Table 9. Mean Fulton condition factor of caged tilapia in different treatments and a control group over a 170-day experimental period(Mean±SE). Mean values with the same superscript letters in the same row were not significantly different at P = 0.05.

Sampling date	Treatments and control							
	T1	T2	T3	T4	T5	T6	T7	C
13-Oct	1.88±0.03^{a}	1.88±0.02^{a}	1.83±0.02^{a}	1.87±0.03^{a}	1.82±0.02^{a}	1.80±0.01^{a}	1.81±0.02^{a}	1.81±0.01^{a}
27-Oct	1.83±0.02^{cd}	1.88±0.02^{cd}	1.79±0.02^{bc}	1.85±0.02^{cd}	1.76±0.03^{b}	1.78±0.03^{bc}	1.84±0.03^{cd}	1.62±0.01^{a}
10-Nov	1.80±0.02^{b}	1.84±0.02^{b}	1.71±0.03^{a}	1.79±0.03^{b}	2.01±0.03^{c}	2.10±0.03^{d}	1.77±0.01^{ba}	1.82±0.02^{b}
24-Nov	2.47±0.02^{cd}	2.40±0.02^{cd}	2.24±0.03^{b}	2.51±0.03^{e}	2.39±0.04^{c}	2.31±0.03^{bc}	2.27±0.02^{b}	1.99±0.04^{c}
08-Dec	2.35±0.03^{d}	2.26±0.03^{bc}	2.19±0.03^{c}	2.36±0.02^{b}	2.25±0.02^{bc}	2.29±0.03^{cd}	2.00±0.01^{a}	1.94±0.04^{a}
22-Dec	2.21±0.03^{c}	2.18±0.04^{c}	2.14±0.02^{bc}	2.33±0.02^{d}	2.08±0.01^{b}	2.19±0.02^{c}	2.32±0.04^{c}	1.89±0.04^{a}
05-Jan	2.66±0.02^{d}	2.59±0.02^{c}	2.71±0.02^{d}	2.82±0.02^{e}	2.41±0.03^{b}	2.42±0.03^{b}	2.55±0.03^{c}	1.95±0.02^{a}
19-Jan	2.81±0.01^{e}	2.70±0.03^{d}	2.79±0.03^{e}	2.84±0.02^{e}	2.50±0.03^{b}	2.44±0.05^{b}	2.60±0.01^{c}	1.99±0.03^{a}
02-Feb	3.21±0.03^{f}	2.72±0.02^{d}	2.82±0.03^{e}	3.15±0.02^{f}	2.73±0.02^{d}	2.50±0.04^{b}	2.61±0.02^{c}	2.14±0.03^{a}
16-Feb	3.27±0.01^{f}	2.81±0.03^{d}	2.83±0.05^{d}	3.27±0.02^{f}	3.15±0.03^{e}	2.64±0.03^{b}	2.73±0.01^{c}	2.24±0.03^{a}
01-Mar	3.29±0.02^{e}	2.85±0.02^{c}	3.11±0.05^{d}	3.37±0.01^{f}	3.26±0.02^{e}	2.74±0.01^{b}	2.81±0.01^{bc}	2.30±0.04^{a}
16-Mar	3.31±0.01^{e}	3.10±0.02^{c}	3.12±0.02^{c}	3.40±0.01^{f}	3.26±0.02^{e}	2.80±0.01^{b}	3.18±0.02^{c}	2.39±0.02^{a}
30-Mar	3.34±0.02^{f}	3.21±0.01^{d}	3.15±0.02^{c}	3.43±0.01^{g}	3.28±0.01^{e}	2.80±0.01^{b}	3.37±0.01^{f}	2.41±0.02^{a}
Average	2.65±0.02	2.49±0.02	2.49±0.03	2.69±0.02	2.53±0.02	2.37±0.03	2.45±0.02	2.04±0.03

5.2.7. Survival rate

Survival rates ranged from 88 % to 94% at all treatments (Table 10). Prior to the fifth sampling period, all fish survived (100% survival rate), and the mortality observed between the fifth and sixth sampling periods (14-20/12/2007) (after 69 days of culture) during which 162 fish died (Table 11) from all cages. Hence, the survival rate was not significantly affected by the quality of feed given and the experimental periods ($p < 0.05$). Low temperature condition (17.6^{o}C) was suspected for the cause of this mortality (Table 3).

Table 10. Number of deaths and survival rate of fish at each treatment over a 170-day experimental period.

	Number of deaths													
Treatments	13-Oct	27-Oct	10-Nov	24-Nov	08-Dec	22-Dec	05-Jan	19-Jan	02-Feb	16-Feb	01-Mar	16-Mar	30-Mar	Survival rate (%)
T1	-	-	-	-	-	23	-	-	-	-	-	-	-	88.50
T2	-	-	-	-	-	24	-	-	-	-	-	-	-	88.00
T3	-	-	-	-	-	19	-	-	-	-	-	-	-	90.50
T4	-	-	-	-	-	12	-	-	-	-	-	-	-	94.00
T5	-	-	-	-	-	20	-	-	-	-	-	-	-	90.00
T6	-	-	-	-	-	16	-	-	-	-	-	-	-	92.00
T7	-	-	-	-	-	23	-	-	-	-	-	-	-	88.50
C	-	-	-	-	-	25	-	-	-	-	-	-	-	87.50

5.2.8. Sex Ratio (Male: Female)

Sex ratios at different treatments are given in Table 11. The total number of fish harvested was 1438; 575 males and 863 females. The proportion of male to the total number of fish in each treatment was 33.33 % for T1, 43.33% for T2, 43.33% for T3, 40.00% T4, 40.00% for T5, 36.67% for T6, 43.33% for T6 and 40.00% for C. There were significant differences in growth and sex composition between sexes ($P < 0.05$). As indicated in Table 12, the males grew better (>1.06 growth ratio) than the females in all cases.

Table 11. Mean weight of male and female , growth ratio of male to female and proportion of males in each treatment during the culturing period (n_f = total number of fish harvested).

Treatment	Mean weight of Male	Mean weight of Female	Male to Female growth ratio	n_f	% of Male
T1	210.30 ± 5.17	206.00 ± 3.26	1.02	89	33.33
T2	200.31 ± 2.28	195.59 ± 3.63	1.02	88	43.33
T3	169.62 ± 2.86	164.82 ± 1.74	1.03	91	43.33
T4	249.75 ± 1.00	238.22 ± 2.70	1.05	94	40.00
T5	189.50 ± 3.20	178.28 ± 3.26	1.06	90	40.00
T6	181.09 ± 2.29	176.68 ± 2.04	1.02	92	36.67
T7	222.92 ± 3.73	220.65 ± 3.26	1.01	89	43.33
TC	116.00 ± 2.04	111.11 ± 1.97	1.04	88	40.00

5.3. Zooplankton Abundance

The taxonomic group of zooplankton identified during the study period is presented in Table 12. In all sites, rotifers contribute more to the total zooplankton abundance followed by copepods. On the other hand the cladocerans contribute the least to the total abundance. The total zooplankton number was 52560, 50247, and 49978 m^{-3} in sites 1, 2 and 3, respectively.

The zooplankton standing stock varied temporally (Fig. 9) and spatially (Fig. 10) over the study period. During all sampling periods, site 1 and 2 had the highest abundance than site 3 but the variation was not significant ($P > 0.05$).

Table 12. List of Zooplankton species identified during the study period in Lake Babogaya.

Copepods	**Cladocera**	**Rotifera**
Paradiaptomus africana	*Diaphanosoma excisum*	*Asplanchnia spp*
Afrocyclops gibsoni	*Moina micrura*	*Brachionus angularis*
Mesocyclops aequatorialis	*Ceriodaphnia Spp*	*B. calycifloris*
Thermocyclops consimilis		*B. urceolaris*
		B. quadridentatus
		Cephallodella spp
		Keratella tropica
		K.. quadrata
		K..cochelaries

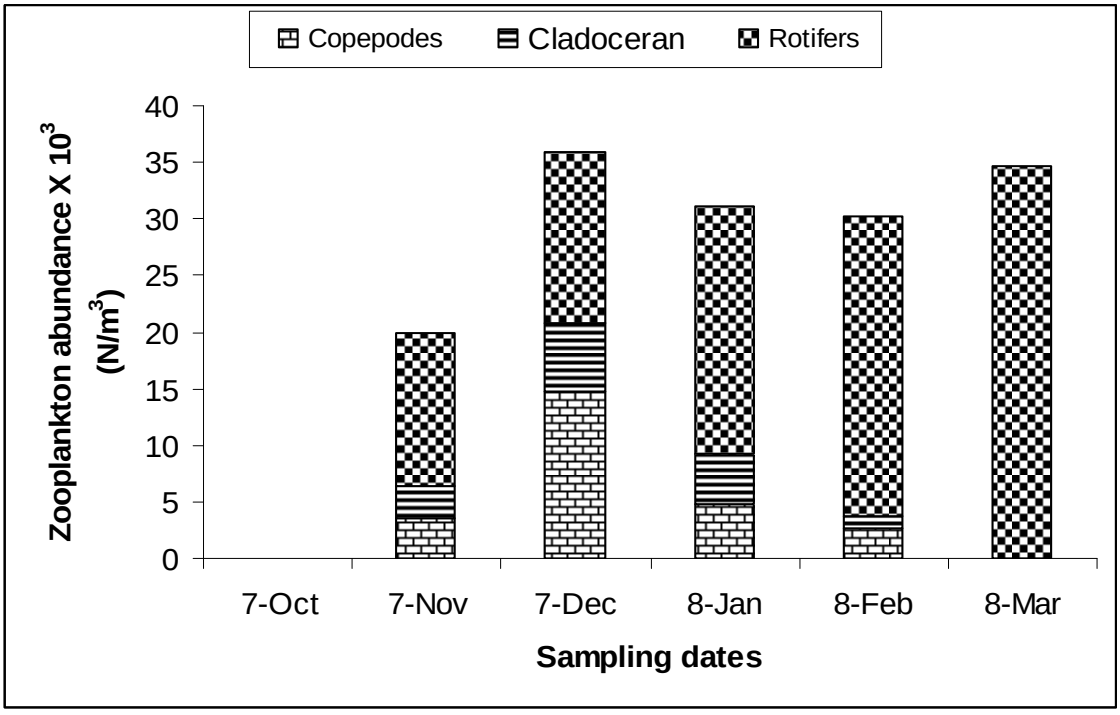

Fig. 9. Temporal dynamics of zooplankton abundance in Lake Babogaya during the study period.

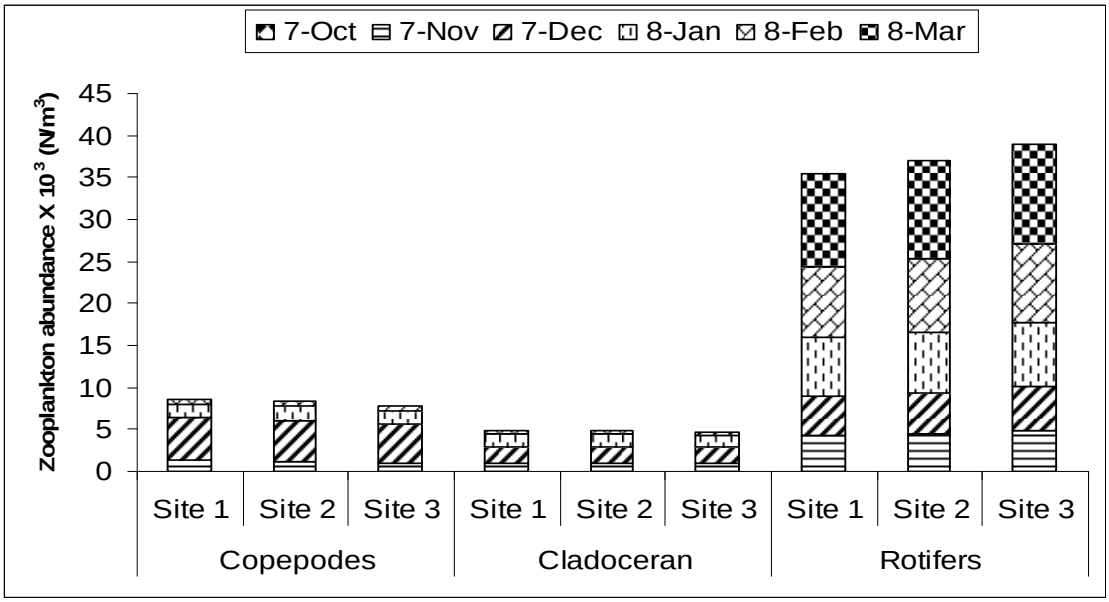

Fig. 10. Spatial dynamics of zooplankton abundance in Lake Babogaya during the study period.

5.4. Phytoplankton Abundance

The list of species of phytoplankton recorded for Lake Babogaya is presented in Table 13. Four phytoplankton groups were identified over the study period. Diatoms, blue-green, dinoflagellates and green algae were the most dominant groups in terms of abundance.

In all sampling period's, Cyanophyceae (61%) were the most abundant followed by Dinoflagellates (20%) and bacillariophytes (15%) and others including Chlorophyta constitute the remaining 4%. Blue green algae were the most dominant in almost all the months at all sites. During all sampling periods the variation in abundance was not significant ($P > 0.05$) between sampling sites.

Table 13. List of phytoplankton species identified during the study period in Lake Babogaya.

Bacillariophyceae (Diatoms)	Chlorophyceae (Green algae)	Cyanophyceae(Blue-green algae)	Dinophyceae (Dinoflagellates)
Cyclotella planctonica	*Cosmarium depressum*	*Chroococcus limneticus*	*Peridinium aciculiferum*
Cymbella cistula	*Pediastrum duplex*	*C. turgidus*	*Peridinium spp.*
Fragilaria capucina	*Pediastrum spp.*	*Cylinrospermopsis sp*	
F. ulna	*Scenedesmus arcuatus*	*Microcystis aeruginosa*	
Nitzschia nyassensis	*Tetraedron minimum*	*Raphidiopsis spp.*	
N. vermicularis	*T. triangulare*		
	Tetrastrum		
Surirella linearis	*hetercanthum*		
Synedra dorsiventralis			

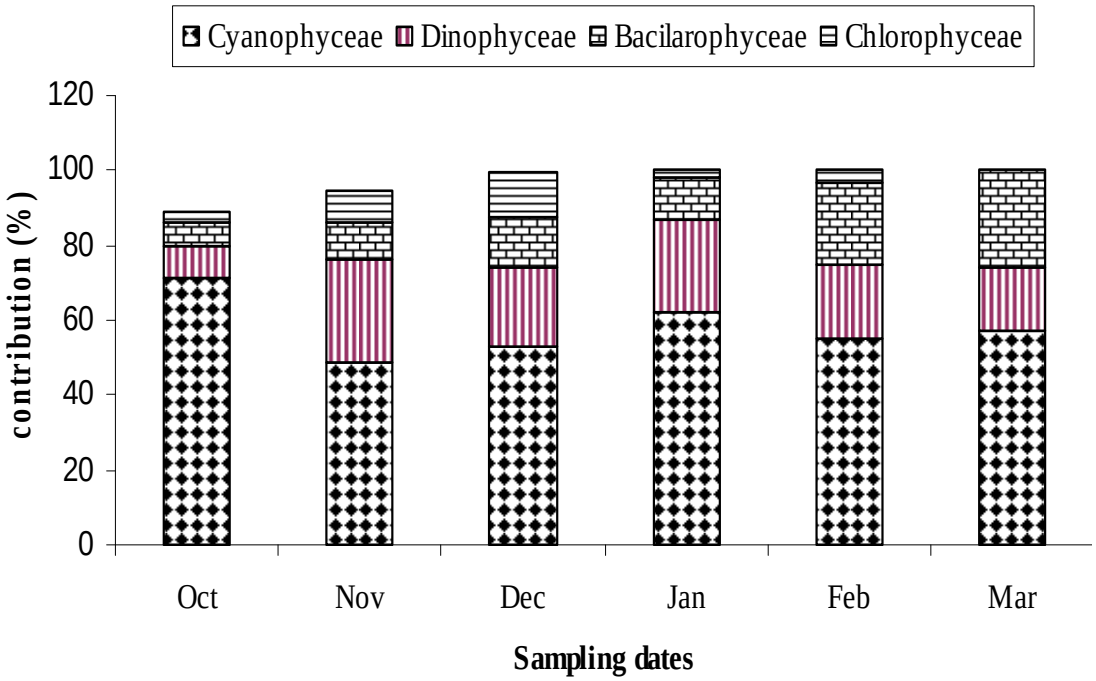

Fig. 11. Temporal dynamics of phytoplankton abundance in Lake Babogaya during the study period.

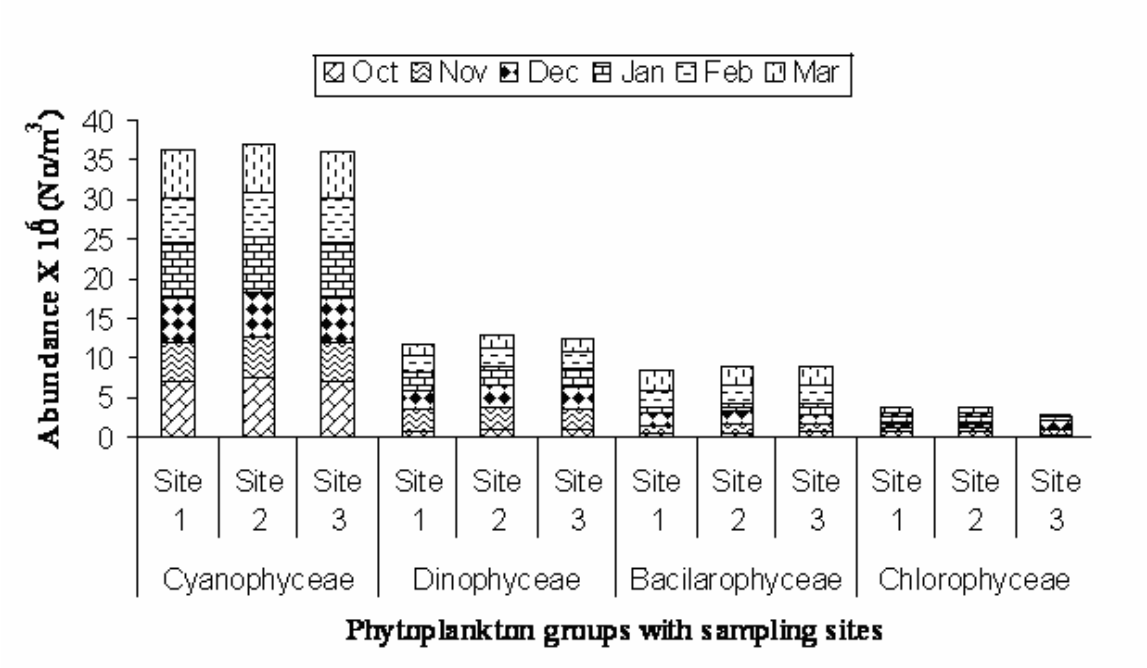

Fig. 12. Spatial dynamics of phytoplankton abundance in Lake Babogaya during the study period.

6. Discussion

In the present study, climatic and water quality parameters varied within acceptable ranges for normal growth of tilapia. Differences in water quality parameters between the three sampling sites were not significant implying that all experimental diets were environmentally suitable for tilapia culture ($P > 0.05$, Table 4). This confirmed that in the present study the water quality parameters were not significantly affected by the culturing condition. However, the lowest water temperature was recorded in November and December 2007 during which a total of 162 fish died (Table 11). Water quality parameters measured during the study period remained in agreement with the favorable range set for *O. niloticus* (Boyd, 1990).

Proximate analysis of oil seed cake (for the other two from literature) and feeding trials in the present study demonstrated that the test feeds differed both in nutritional quality and efficiency in promoting the growth of *O. niloticus*. Moreover, it was observed that the quality of feeds affected substantially growth of *O. niloticus* in some treatments (T1, T2, T4, and T7). These results indicate that difference in the nutritional value of the diets significantly affected mean weight gain, DGR, SGR, FCR, FCF, Net yield per individual fish, and Total Net Yield of *O. niloticus*.

It is reported that in aquaculture the quality of feed is an important factor affecting the culture period, feed conversion, and final weight gain of cultured fish (Lovell, 1989). In addition, stocking density, food quantity, physiological status and reproductive state of the organism, and environmental factors such as temperature, pH, etc, affect the growth of tilapia. In this study, there was a significant difference in growth parameters ($P < 0.05$) in all treatments using different diets.

These results are in agreement with the results reported by Abebe Tadesse (2007) and Ashagrie Gibtan *et al*. (2008) who studied the effects of stocking density and supplementary feeding on the growth performance of *O. niloticus* (50, 100, 150, and 200 fish/ $1m^3$ cages) in lake Elen and Kuriftu, respectively. Solomon Hailu (2008) who studied the effect of feed quantity on growth performance of the same species (1%, 2%, 3%, 4%, 5% 100 fish/$1m^3$ cages) in the same lake and culturing period also reported similar results with the present study. They reported that fish growth performance and production were significantly affected by stocking density and the amount of feed.

The daily growth rates of fish of treatments (T1, T2, T4, T5, T6 and T7) in this study were very close to the results obtained by Abebe Tadesse (2007) and Ashagrie Gibtan *et al*. (2008) which ranged from 0.82 to 1.26 g /day. Similarly caged tilapia which feed on 'Mill sweeping-Chicken dung-Oil seed cake'(T7) showed daily growth rate (1.16 g/day) close to results found by Solomon Hailu (2008) for treatments which feed at a rate of 3% of their body weight on similar feed composition (1.22 g/day). This similarity could be attributable to similar culturing condition.

A progressive decrease in the DGR (e.g., 1.06 to 0.79 g/day for T4) was observed in all treatments (November 24 to December 22/2007) during which 162 fish died between the fifth and sixth sampling periods (14-20/12/2007). This may be due to unusual low temperature condition because during the study period a temperature of 17.6^{o}C in the cage area was recorded (Table 3). However, the main reason why the growth rate decreases from November 24 to December 22/2007 was not clearly known. Further study should be conducted to know why the DGR decreases to such extent.

Similar observations have been made in previous studies by Francis *et al.* (2001) that growth rate of fish declined from 2.5 to 1.3 g/day with decrease in temperature from 30 to 20 ^{o}C under intensive culturing. Cherviniski (1982) reported that the optimum range of temperature for *O. niloticus* is 25 to 29 ^{o}C and a decrease from this level resulted in reduction on growth. The temperature at which 100% mortality occurs for most tilapia species has been reported as 10-11 ^{o}C for several days (Popma and Masser, 1999). Tilapia are generally characterized by a temperature preference in the range of 12-42 ^{o}C (Avella *et al*., 1992).

The production or yield, expressed as the biomass gained per unit of time, was statistica1ly greater in T4 (41.67) than in T7 (34.88) and in other treatments (25.53 to 32.40 Kg year^{-1}). Within these treatments, the total net yield obtained in the cages in which tilapia were fed on "Mill sweeping-Chicken dung" ration (T4) were significantly higher than that obtained in cages where fish-were fed on "other feed treatments. The greater growth with "Mill sweeping-Chicken dung" seems to be attributed to the higher survival rate (94%), which is the highest in all treatments and the quality of the feed used.

However, the results obtained in the present study (except T4) were found to be lower than the results obtained by Ashagrie Gibtan *et al.* (2008), which was 36 Kg year^{-1}. Similarly these results (except T4) were also found to be lower than the results obtained by Solomon Hailu

(2008), 39.54 Kg year^{-1} for treatments fed at a rate of 3% of their body weight. A number of factors, some of which mentioned below, might have contributed to the lower fish yields (except T4) observed in the present compared with those from the previous studies.

Females of *O. niloticus* grow at a slower rate than their male counterparts, possibly as a lack of feeding during oral incubation of eggs and young fry (Liti *et al.*, 2006). Therefore, the higher number of females and reduced proportion of males might have lowered the overall growth and yield of *O. niloticus*. Unlikely, Ashagrie Gibtan *et al*. (2008) had reported that 51.4 to 58% of the total harvest was males which were greater than the mean percentage of males in the present study (40%).

In addition, lower survival was recorded in all treatments (88.5 to 94%) in the present study compared with 95% (Ashagrie Gibtan *et al*., 2008), 96.5% (Abebe Tadesse, 2007) and 94% (Solomon Hailu, 2008) reported for 100 fish/1m^3 cages. Thus, total net fish yields in the present study were based on lower survival rates and lower number of males than those observed in the previous studies.

In the study the final mean weight and other growth parameters of caged *O. niloticus* that fed on 100% oil seed cake (with 36.38% crude protein, T3) was the lowest among the treatments and was found to be comparable to other results obtained by many researchers. For instance, in earlier studies, Ofojekw and Ejike (1984) and Robinson *et al*. (1984a) reported lower growth rates and feed efficiency in *O. niloticus* and *O. aureus* fed Cotton seed meal (CSM) and cottonseed cake (CSC) diets than fish fed with fishmeal (FM) based diets. Both FM and CSC are composed of crude protein of 65 % (Bekibele, 2000) and 38.9 % (Eyo, 2001), respectively. The poor response was attributed to the presence of gossypol, a toxic component for monogastric animals and cyclopropionic acids contained within CSM. Further, a low availability of lysine limits the nutritional value of this protein source (Jauncey and Ross, 1982).

Similar results were also reported by several other researchers for other diets. Jackson *et al*. (1982) evaluated the use of groundnut cake (45% crude protein; Bekibele, 2000), sunflower meal, rapeseed meal, and copra meal within diets containing 30% crude protein for *O. mossambicus* over a seven to nine week rearing period. They found that 25%, 75%, 75% and 50% of these protein sources, respectively, could effectively replace FM protein in the control diets without a significant retardation in fish performance.

More recently, similar results were also reported by Mbahinzireki *et al*. (2001). They found that Fish meal replacement at 75 and 100% by CSM resulted in a significant decline in growth rates after the 12th week. Moreover, fish which had 100% CSM in their diet had the lowest average weight gain, while fish fed with the control diet (100% FM) and diets including 25 and 50% CSM had significantly better daily weight gain, feed conversion ratio, and SGR. On the other hand, fish fed with 100% CSM exhibited 11% of cumulative mortality. This study demonstrated that up to 50% CSM could be used to replace fish meal as a protein source in the diet of tilapia without affecting the overall growth performance of fish. Beyond that level growth was depressed and the fish population experienced mortality when fed 100% CSM diet.

In the present study, T7 treatments which had provided with 33.3% oil seed cake with mill sweeping (33.3%) and chicken dung (33.3%) exhibited better performance on growth parameters (DGR, SGR, Mean Weight Gain) than treatments in T5 and T6 which use provided with 50% oil seed cake together with 50% Mill sweeping and Chicken dung, respectively. Moreover, there was no significant difference between T5 and T6 throughout the sampling periods in all growth parameters ($P<0.05$). This result was found to be similar to the results reported by many other researchers (Mbahinzireki *et al*., 2001).

However, it has been reported that the amount of CSM that can be included in feeds depends on the animal species, levels of free gossypol, dietary protein and available lysine (Martin 1990). Wu *et al*. (1996) indicated that a 40% protein diet for tilapia achieved the best feed conversion ratio and is suitable to examine alternative protein sources. Therefore, the lowest growth parameters (Mean weight Gain, DGR, SGR, FCR, Net yield) observed in treatment T3 in the present study may be due to the direct effect of dietary protein source in fish fed with oil seed cake-based diets. The results of the present experiment also indicate that caged *O. niloticus* cannot be raised successfully by feeding diets formulated on oil seed cake alone as a source of protein. The level of protein required for maximum growth has been estimated to be between 25 and 40% depending on species, age/size of the fish, ingredient digestibility and to what extent they are foraging on natural ingredients (Stickney, 1997). Laboratory results obtained (Table 2) from EHNRI indicated that oil seed cake had crude protein composition (36.38%) close to CSC (38.9%). However, further study should be conducted to determine the exact composition of essential amino acids (EAA) for oil seed cake locally made from Niger seed (*Guizotia abyssinica*) and Flax (linseed) (*Linum usitatissimum*).

These findings were consistent with those reported by other investigators. Ofojekwu and Ejike (1984) and Mbahinzireki *et al*. (2001) reported that CSM could not be used as a sole protein source for *O. niloticus* because they exhibited poor growth, food conversion and specific growth rate. Robinson *et al.* (1984a) also observed that CSM had limited utilization in tilapia and resulted in poor growth and decreased feed conversion. Similar results were reported by Robinson *et al*. (1984b) for channel catfish fed CSM. Fowler (1980) found that CSM was efficiently utilized as a partial replacement (34%) for FM protein in diets for Chinook and Coho salmon.

In addition to this, in the present study, the growth of caged tilapia revealed that the weight gain and other growth parameters were significantly higher in mill sweeping + chicken dung diet (50% each, T4), followed by those fish given three mixed diets (33.3% each, T7), mill sweeping (100%, T1), chicken dung (100%, T2), mill sweeping + oil seed cake (50% each, T5), chicken dung + oil seed cake (50% each, T6), and oil seed cake (100%, T3).

These findings were consistent with observations made by other investigators. For example, in earlier studies, Lu and Kevern (1975) found that a diet containing 30% poultry by-product meal (PBM) and 70% salmon feed lowered the growth rate of channel catfish, *Ictalurus punctatus*. On the other hand, up to 75% of fish meal could be replaced by defatted PBM in Coho salmon, *Oncorhynchus kisutch*, diets without adverse effects on growth (Higgs *et al*., 1979). At a 100% substitution level, growth was significantly compromised. However, a mixture of PBM and feather meal supplemented with essential amino acids effectively replaced fish meal in rainbow trout diets (Gropp *et al*., 1976; Tiews *et al*., 1976). However, Higgs *et al*. (1979) reported at least 28% of PBM may be included in the diet of coho salmon, without amino acid supplementation.

More recently, however, Abdel-Warith *et al.* (2001) for African catfish *Clarias gariepinus* demonstrated that PBM can replace up to 40% of a high-quality fish meal protein without amino acid supplementation, while not compromising growth performance and feed utilization. The highest mean final weight (175.5, 180.76 g), SGR (3.57, 3.68 %/day), and FCR (1.61, 1.58) values were recorded for fish fed the control diet (Fishmeal) and 20% PBM diets, respectively. The improved performance of these diets was probably due to a more favorable EAA balance than fish meal alone. Sadiku and Jauncey (1995) investigated the nutritional value of a feather meal and PBM blend for *C. gariepinus*. These authors reported similar conclusions.

The inclusion of alternative animal-derived protein sources for the partial or direct replacement of fish meal has been studied in previous investigations for numerous fish species. These have concluded that increasing animal-derived protein such as poultry by-product meal (PBM), hydrolyzed feather meal (HFM), blood meal (BM: 81.5% of crude protein; Bekibele, 2000), and meat and bone meal (MBM) to replace fish meal has a detrimental effect on growth rate and feed utilization above certain constraints. However, compared with fish meal, animal byproducts may be deficient in one or more essential amino acids (EAAs), the limiting EAAs generally being lysine, methionine and isoleucine. The feasibility of poultry by-products in fish diets was found to depend on fish species and size as well as composition and processing techniques. Poultry by-product meals (37% crude protein) is the milled dry rendered material originating from the processing of ground, rendered clean parts of the carcass of slaughtered chicken, turkey and duck carcass including heads, feet, undeveloped ova and intestines (exclusive of feathers) (Davies *et al.*, 1991; Abdel-Warith *et al.*, 2001).

Therefore, the inferior performance of the fish receiving the higher chicken dung diets (T2) compared with groups receiving mill sweeping + chicken dung diet (T4), three mixed diets (T7) and mill sweeping (T1) in the present study is possibly a result of the lower availability of nutrients and amino acid imbalance. Moreover, Hanley (1987) reported that the digestibility of protein and energy for tilapia *O. niloticus* was appreciably lower (74%) compared with fish meal (86%). In the present study this is probably another explanation for the reduced growth performance associated with increased levels of chicken dung for tilapia (100%, T2).

The specific growth rate for *O. niloticus* was 1.15 % day^{-1} in the mill sweeping-chicken dung treatment (50% each, T4), 1.07 % day^{-1} in the mill sweeping treatment (100%, T1), and 1.04 % day^{-1} chicken dung treatment (100%, T2). These results were within the range of those reported from pond systems for *Tilapia rendalli* where the specific growth rate was 0.83, 0.97 1.18, and 0.87 % day^{-1} in earthen ponds that were fertilized with chicken manure (100%), maize bran (25%)+chicken manure (75%), maize bran (75%)+chicken manure (25%), and Maize bran (100%), respectively (Mataka and Kang'ombe, 2007).

However, different results were reported by various researchers for *O. niloticus* reared in fertilized ponds using wheat bran (16% of crude protein; Bekibele, 2000), maize bran (9% of crude protein; Bekibele, 2000), and rice bran (12% of crude protein; Bekibele, 2000). Liti *et*

al. (2006) obtained net fish yields of 1288, 1891, 2036 kg ha^{-1} using rice bran, wheat bran and maize bran, respectively in fertilized ponds. Omondi *et al*. (2001) reported a net yield of 1582 kg ha^{-1} after feeding *O. niloticus* in fertilized ponds with rice bran. Liti *et al*. (2001) observed net yields of 2544 kg ha^{-1} of *O. niloticus* with rice bran in fertilized ponds. Liti *et al*. (2005) also observed higher net yields (4469 kg ha^{-1}) of *O. niloticus* for wheat brain.

Litie *et al*. (2006) also found Growth rate of (0.68, 0.42, and 0.52 g/day), Average weight of (117.50, 91.00, 102.80 g), and apparent feed conversion ratio of (3.40, 4.04, 3.41) for *O. niloticus* receiving maize bran, rice bran and wheat bran, in fertilized ponds respectively.

Condition factor, which used to compare the well-being or the fatness of fish, is based on the fact that the heavier fish of a given length is in a better condition. Mean Fulton condition factor in this study was higher in T4 (2.69) than the other treatments (T1, 2.65; T2, 2.49; T5 2.53; T6, 2.37, T7, 2.45 and C, 2.04). Thus, the fish in T4 had the best condition factor than fish in other treatments. Moreover, better Fulton conditions in feeding treatments indicate that it was positively correlated with the quality of feed used. This was reflected by the significant variation in Fulton condition of *O. niloticus* in all treatments ($p < 0.05$). This could be due to difference in the quality of feeds used for different treatments.

In this experiment, it was observed that the growth proportion (range 1.01-1.06, 33.33-43.33% males) of males to females was very close to the results obtained by Ashagrie Gibtan *et al.* (2008) (1.011±0.03 to 1.02±0.95 for 51.4%-58% of males). Moreover, Lower growth of females was also confirmed by results of the present study. However, the mean percentage of males 40% (range 33.33-43.33%) in the present study was lower than those results reported in earlier studies. Ashagrie Gibtan *et al.* (2008) reported that 51.4 to 58% of the total harvest was males. Similarly Liti *et al*. (2005) reported the faster growth of males than females (1.3±0.15 in Turkana, 1.9±0.15 in Victoria and 2.2±0.15 in Sagana for 48%, 50% and 36% of males, respectively). A number of factors might have contributed to the lower results observed in the present compared with those from the previous studies. In the present study, the experimental cages were stocked with mixed sex *O. niloticus* collected from the natural stock

The results of this experiment revealed that fish survival (ranged from 87.5% to 94%) was not significantly affected by feed quality and this result is lower than 96.5% (Abebe Tadesse, 2007) and 95% (Ashagrie Gibtan *et al*., 2008) for 100 fish/1m^3 cages in Lakes Elen and

Kuriftu, respectively. Moreover, those authors reported that fish survival was not significantly affected by stocking density. Similar results were reported by Solomon Hailu (2008) who reported that fish survival was not significantly affected by the amount of feed.

Although, 162 fish died between the fifth and the sixth sampling periods (14-20/12/2007), there was no fish death (100% survival rate) before and after these sampling periods. This may indicate that survival rate was not significantly affected by the quality of feed given and the experimental periods ($p < 0.05$). The death of the 162 fish may be due to the occurrence of low temperature condition. A large number of *O. niloticus* ranging from very small to 35 cm and 0.5 to 1 Kg adult non-caged fish had also died in the early morning and late afternoon during this period.

According to the local people, this is a natural condition which occurs once per year and the situation is much worse in intervals of 2 years. The local people during these times could capture 2 sacks of *O. niloticus* per day per fishermen and could earn 25 birr per kg of fish. On the other hand, other species such as catfish (*Clarias gariepinus*) and *Tilapia zilli* are not affected by this condition and are not commonly captured. This may be because they are more resistant and adaptable to these extreme conditions. However, further study should be conducted to know why *O. niloticus* alone gets a mass fish kill.

In the present study, the results obtained on zooplankton abundance indicate that rotifers were the most abundant contributing more to the total zooplankton community than copepods and cladocerans (Table.13). Moreover, there was no significant variation in the zooplankton abundance between the three sampling sites over the study period. This result showed that cage culture did not bring any direct adverse effect on the lake zooplankton abundance. However, further study should be conducted to evaluate exactly the effect of supplementary feeding on the water quality, zooplankton and phytoplankton community of the lake.

On the other hand, results obtained on the phytoplankton abundance indicate that blue- green algae were the most abundant constituting the major part of the total phytoplankton community over the sampling period. Moreover, there was no significant variation on the phytoplankton abundance between the three sampling sites over the study period. Similarly this result clearly showed that cage culture of *O. niloticus* in natural waters did not bring any adverse effect on the phytoplankton community.

7. Conclusions and Recommendations

In this study, all the growth parameters were affected by the test diets used. Hence, with regard to all the growth parameters the best result was achieved in 'mill sweeping-chicken dung (T4)' diet. Moreover, the test diets did not show any significant effect on the survival of the caged fish. If the survival rates of both fish treated with 'mill sweeping-chicken dung (T4)' and 'mill sweeping-chicken dung-oil seed cake (T7)' diets are increased by 100%, they can give the best result as revealed in this study (Table 5). For instance, 41.67 Kg $year^{-1}$ total net yield was obtained from T4 while T7 showed 34.88 Kg $year^{-1}$ total net yield. However, for 100% survival rate, they can give 44.80 Kg $area^{-1}$ $year^{-1}$ and 40.11 Kg $year^{-1}$ total net yield, respectively. The difference would decrease from 7 to 4 Kg $area^{-1}$ $year^{-1}$ that was seen in the actual experiment. Hence, T4 and T7 are the best diets preferred by *O. niloticus* in terms of all the growth parameters in this study.

On the other hand fish treated with 100% 'mill sweeping (T1)' and 100% 'chicken dung (T2)' in the experiment gave good results for all growth parameters but lower than the combined diets T4 (50% each) and T7(33.3% each, together with 'oil seed cake'). Moreover, when 'mill sweeping' and 'chicken dung' were combined with 'oil seed cake' as demonstrated in T5 and T6 diets, they gave insignificant differences ($P > 0.05$) for all growth parameters. In addition to this, when fish were provided with 100% 'oil seed cake (T3)', they showed the lowest value for all growth parameters with highest FCR value among treatments provided with supplementary diets (Table 5).

Thus, the total net fish yields in the study were based on lower survival rates (40%) and lower number of males than those observed in the previous studies (> 50%). Hence, to evaluate the optimum yield of these diets (T4 and T7) based on a healthy cohort and hatchery-derived monosex fingerlings, it needs further investigation. Moreover, development of hatchery centers both for aquaculture and natural stock enhancement should be taken in to consideration In conclusion, the results from this study indicated that 'mill sweeping' and 'chicken dung' are acceptable ingredients for formulation of fishmeal (balanced diet) from locally available diets with minimum cost. So chicken dung and mill sweeping should not be used separately if maximum growth performance of *O. niloticus* is desired. Moreover, oil seed cake can only partially be used as a source of protein in locally formulated feed, at a

limited amount of not more than 33.3% for tilapia raised in cages as demonstrated inT3, T5, T6 and T7 diets.

Moreover, there was no significant variation both in the zooplankton and phytoplankton abundance between the three sampling sites over the study period. The experiment demonstrated that cage culture did not bring any direct adverse effect on the lake phytoplankton and zooplankton abundance. However, further study should be conducted to evaluate exactly the effect of supplementary feeding on the water quality, zooplankton and phytoplankton community of the lake.

The study is one of the few researches done on fish cage culture in Ethiopia. However, as aquaculture in Ethiopia is nearly nonexistent, much more cage culture investigations need to be conducted in the future on other commercially important fish species like carp and catfish. Accordingly, similar studies using culturing systems like pond, pen, and tank culture should be conducted to develop aquaculture and hence, contribute to the nation's economy. Moreover, effect of cage culture on water quality and other aspects of cage culture like cage size (>1 m^3), cage type, effect of non-caged fish on caged fish, feeding frequency and its economic return should be investigated.

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Declaration

I, the undersigned, hereby declare that this thesis is my original work, has not been presented for a degree in any other University and that all sources of material used for the thesis have been duly acknowledged.

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