ADDIS ABABA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

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

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May, 2011

Addis Ababa

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A THESIS PRESENTED TO

ADDIS ABABA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

FACULTY OF LIFE SCIENCES

IN PARTIAL FULFILLMENT OF

THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE

IN BIOLOGY

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Addis Ababa

ACKNOWLEDGEMENTS

I thank God everyday for giving me the opportunity to pursue and complete this degree and for all the people that helped me through out. There are many people that have guided, encouraged, supported, and inspired me in this endeavor. I am truly blessed to have these people in life.

My advisor Dr. Abebe Getahun has been the one person that I relied on the most. His critical and constructive comments in designing the research, in the write-up and feedback of related literature enormously facilitated the smooth completion of this study. My respect and admiration for him cannot be adequately expressed in words. My gratitude also goes to Professor Krishen J. Rana, Stirling University, for his support especially while developing the proposal and during the final write up of this thesis.

Fisheries and Aquatic Sciences stream, Zoological Sciences Program Unit, Faculty of Life Sciences, Addis Ababa University, is gratefully appreciated for giving me the opportunity to study at the department and also assisting me with materials and resources during my stay. I must thank the Development Partnership in Higher Education (DelPHE) Project under the British Council and managed by Dr. Abebe Getahun for sponsoring this research. My thanks also go to my stream advisor and instructors Dr. Seyoum Mengistou and Dr. Demeke Kifle for their encouragement and help during my stay at the university. I am also highly grateful for friendly interaction and technical assistance accorded by Akewake Geremew and Ashagrie Gibtan. I would also like to thank Neway Andargie who helped me in preparing the pellet and Yitagesu Belachew who guarded the experiment site and fed my experimental caged fish. I would also thank all graduate students of the Fisheries and Aquatic Sciences Stream at AAU for their fruitful interaction.

Last, but not least, I am indebted to my elder sister Shewaye Bogale, younger brother Habtamu Alemayehu, and also Shishig Derese, Mekiya Shumet, and Wat Kong for all their assistance and taking responsibility of the family.

Finally, I wish to thank all those who helped me in one way or another throughout the study period.

DEDICATION

To my mother Almaz Alemayehu and my best friends Ziad Sherif, Menna Getachew, and Mulgeta Tilaye; I am grateful for your love, care, help, and encouragement that I will forever cherish.

TABLE OF CONTENTS

ACKNOWLEDGEMENTS iii
DEDICATION iv
LIST OF TABLES vii
LIST OF FIGURES viii
LIST OF PLATES ix
ABBREVIATIONS x
ABSTRACT xi
1. BACKGROUND 1
1.1. Trends in Aquaculture 1
1.2. Cage culture 5
1.3. Nile tilapia culture 7
1.4. Tilapia Feed 9
1.5. Aquaculture in Ethiopia 11
1.6. Objective of the study 14
2. DESCRIPTION OF THE STUDY LAKE 15
3. MATERIALS AND METHODS 19
3.1. Experimental site selection 19
3.2. Construction of experimental cages 20
3.3. Juvenile collection method 20
3.4. Transportation and stocking of juveniles 21
3.5. Feed and feeding 22
3.6. Juvenile stocking 24
3.7. Data collection 25
3.7.1. Growth parameters 25
3.7.2. Physical parameters for water quality analysis 25
3.7.3. Estimation of zooplankton abundance 26
3.7.4. Estimation of phytoplankton abundance 27
3.8. Data analysis 28
3.9. Economic Analysis 29

4. RESULTS AND DISCUSSIONS 30
4.1. Results 30
4.1.1. Physical and Chemical Parameters 30
4.1.2. Growth performance 32
4.1.2.1. Mean length and weight of the fish 32
4.1.2.2. Daily Growth Rate (DGR) 34
4.1.2.3. Specific Growth Rate (SGR) 35
4.1.2.4. Feed Conversion Ratio (FCR) 36
4.1.2.5. Food Conversion Efficiency (FCE) 38
4.1.2.6. Production at harvest 38
4.1.2.7. Fulton Condition Factor (FCF) 38
4.1.2.8. Survival Rate (SR) 39
4.1.2.9. Sex ratio (Male: Female) 41
4.1.2.10. Visceral to Body Weight Ratio (VBWR) 41
4.1.3. Plankton 42
4.1.3.1. Zooplankton abundance 42
4.1.3.2. Phytoplankton abundance 44
4.1.3.3. Economic Analysis 46
4.2. Discussion 47
4.2.1. Physico-chemical parameters 47
4.2.2. Growth performance 48
4.2.3. Plankton 54
4.2.4. Economic Analysis 55
5. CONCLUSIONS AND RECOMMENDATIONS 56
6. REFERENCES 58

LIST OF TABLES

Table 1: Summary of reported total aquaculture production in sub-Saharan Africa 3
Table 2: Environmental conditions favorable for tilapia 5
Table 3: Some of limnological features of Lake Hora-Arsedi 17
Table 4: Proportion (%) of different ingredients used in formulated diets 22
Table 5: Feed types used and their nutrient proximate composition 23
Table 6: Composition of crude nutrients of the feeds and their respective dry matters 24
Table 7: Initial and final body weights and lengths, and growth performances of *O. niloticus* in terms of growth parameters for each treatment and the control 33
Table 8: Total amount of feed supplied, mean weight gain, feed conversion ratio, and feed conversion efficiency of treatments 33
Table 9: Survival and mortality of experimental caged fish along the experimental period 40
Table 10: Sex ratio and mean weight of the caged fish with respect to their sex 41
Table 11: Comparison of visceral to body weight of the experimental fish 42
Table 12: The amount and proportion of feed ingredients used for this study 43
Table 13: The economic analysis parameters of feed used in this study 43
Table 14: Zooplankton taxa identified from Lake Hora-Arsedi 44
Table 15: Phytoplankton taxa identified from Lake Hora-Arsedi 45

LIST OF FIGURES

Figure 1: Map of Lake Hora-Arsedi (Bette Mengist) 15

Figure 2: Meterological data of Lake Hora-Arsedi 18

Figure 3: Water temperature (^{o}C) vs. time profile at the study site 30

Figure 4: PH and DO (gm/lit) vs. time profile at the study site 31

Figure 5: Secchi depth (cm) and Euphotic depth (cm) vs. time profile at the study site 31

Figure 6: Weight gain measured during sampling weeks of the experimental period 34

Figure 7: Mean specific growth rate of caged *O. niloticus* in the treatments and the control 35

Figure 8: Mean specific growth rate of caged *O. niloticus* in the treatments and the control

Figure 9: Fulton Condition Factor of *O. niloticus* in all the treatments 39

Figure 10: Temporal and spatial zooplankton abundance (N/m^3) of Lake Hora-Arsedi during study period at littoral and open water 40

46

Figure 11: The dominant species of phytoplankton (Cyanophyceae) in N/lit

Figure 12: Abundance of Bacillariophyceae and Chlorophyceae 46

Figure 13: Abundance of Euglenophycaeae and Cryptophyceae 46

LIST OF PLATES

Plate 1: The walkway (jetty) of the experimental site 19

Plate 2: Juvenile collection and selection in the field 21

Plate 3: Juvinle transportation 21

Plate 4: Feed preparation (A) and shade dry (B) 23

Plate 5: Taking weight and length measurement at the experimental site 25

Plate 6: Taking physical parameter measurments 26

Plate 7: Zooplankton and phytoplankton sampling 27

ABBREVIATIONS

AAU	-	Addis Ababa University
ANOVA	-	Analysis of Variance
DGR	-	Daily Growth Rate
DO	-	Dissolved Oxygen
FCR	-	Food Conversion Ratio
FCF	-	Fulton Condition Factor
FCE	-	Food Conversion Efficiency
ROM	-	Rice bran, Oil seed-cake and Mill sweeping
RM	-	Rice bran and Mill sweeping
RO	-	Rice bran and Oilseed cake
MO	-	Mill sweeping and Oil seed cake
NFLARC	-	National Fisheries and other Living Animals Research Center
SGR	-	Specific Growth Rate
SR	-	Survival Rate
T_o	-	Non- feeding
VSWR	-	Visceral to Somatic Weight Ratio
PVC	-	Poly Vinyl Chloride

ABSTRACT

Six months (Jun 7 to November 22/ 2010) feeding trial was conducted to investigate the effects of feed quality on growth performance and water quality in cage culture system of mixed-sex Nile tilapia (Oreochromis niloticus) in Lake Hora-Arsedi using fifteen suspended 1 m^3 *net cages. The initial length and weight of the fish ranged from 119.32 ±1.44 to 125.00 ±1.50 mm and 42.80 ± 2.53 to 43.51 ±2.36 gm, (mean ±SD), respectively. Fish diets were prepared from three kinds of locally available plant protein source feeds, i.e. oil seed cake (O), mill sweeping (M), and rice bran (R). In all the combination 20% of blood and bone meal (B) was added to increase the crude protein level and supplement growth limiting mineral, phosphorus. Therefore, four combination of feeds were prepared as diet-1 (ROM+B), 22.87% crude protein (CP); diet-2 (RM + B), 22.22% CP; diet-3 (MO+B), 22.00% CP, and diet-4 (RO+B), 24.28% CP). About 26.67% each of plant protein source ingredient was in diet-1, whereas 40% of it in the other combinations. There was a triplicate of control cages in which fishes were provided with only the natural feeds. Each treatment was assigned to triplicates of 100 fish in a completely randomized design along the U-shaped jetty (walkway). The fish were fed sinking extruded feeds, 3% of their body weight, twice a day manually using feeding tray. The results showed significant differences among the test diets. Diet-1 gave the best mean weight gain (MWGs) of 197.38 ± 5.57 followed by diet-3 with MWGs of 182.16 ±* 4.12, *diet-2 with MWGs of 169.27 ± 6.31. Diet-4 and the control gave MWGs of 146.27 ±* 6.82 *and 80.62 ±3.34 gm, respectively. MWGs in treatment fed with diet-1 were significantly higher (P < 0.05) than MWGs of other treatments. Mean DGR ranged from 0.28 for the control treatment to 0.92 for the fish fed with diet-1. Specific growth rate was also highest in the treatment fed diet-1 (0.9%/ fish) and lowest in the control (0.38%/ fish). Food conversion ratio and efficiency were best with diet-1, followed by diet-3 and least with diet-4. Visceral to body weight ratio for the treatment fed with diet-1 was significantly better (P < 0.05) than the values for other treatments. Percentage survival ranged from 80% in the control to 94% in cages fed with diet-1. The study showed that diet-1 can be effectively used in the diet of O. niloticus and also in terms of cost it sees more efficient than other followed by diet-3. This study also showed that the feeds did not bring any effect on water quality at least in experimental level.*

Key words: Economic analysis, feed conversion, mill sweeping, rice bran, oil seed cake

1. BACKGROUND

1.1. Trends in Aquaculture

According to FAO (2008), aquaculture is defined as the farming of aquatic organisms, including fish, mollusks, crustaceans, and aquatic plants. Farming implies some form of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators, etc. Similarly, Li and Fu, (2001) also defined aquaculture as a form of agriculture that involves the propagation, cultivation, and marketing of aquatic plants and animals in a more-or-less controlled environment. It mainly includes water sources, water quality, types and methods of aquaculture, production phases, market, and trade. It also implies ownership of the stock being cultivated. Aquaculture is also defined as a diverse and important rural activity encompassing production and sale of fry and fingerlings and the raising of wild or artificially-reared fry and fingerlings in enclosed or semi-enclosed water bodies, such as ponds, rice fields and fish cages, for both sale and home consumption.

The historic origin of aquaculture dated back to the eastern civilization before 4,000 years. The Bible refers to fish pond and sluices (Isaiah 19:10), and ornamental fish ponds appear in paintings from ancient Egypt. European aquaculture began sometimes in the middle age and transformed the ‘art’ of Asian aquaculture into a science that studied spawning, pathology, and food web (Swann, 1992). There is a belief as it was commenced in China by fishermen who kept their surplus catch alive temporarily in baskets submerged in rivers or small bodies of water created by damming one side of a river bed, possibly due to the desires of an emperor to have a constant supply of fish. Another possibility is that aquaculture developed from ancient practices for trapping fish, with the operations steadily improving from trapping-holding to trapping-holding-growing, and finally into complete husbandry practices (Ling, 1977). For over 3,000 years, fish have been farmed in China, a country that continues to dominate the industry by producing 83% of the world's aquaculture output (Li and Fu, 2001). The other key producers include India (6%), Philippines (4%), Indonesia (3%), Republic of Korea (2%), and Bangladesh (1%), a list overwhelmingly concentrated in the developing world (FAO, 2008).

Though aquaculture is rerported to be an age old practice that originated in China, its significance to the contribution of ‘human food basket’ is of only three to four decades old. According to De Silva and Davy (2007) aquaculture, though considered to have over a 2,500 years history, was mostly practiced as an art. It began to be transformed into a modern science in the second half of the 20th century.

Recently, aquaculture is developing, expanding and intensifying in almost all regions of the world. It is the fastest growing sector of the world food economy increasing by more than 10% per year and currently accounts for more than 30% of all fish consumed. This may be due to increased global population demand for aquatic food products, the production from capture fisheries has leveled off, and most of the main fishing areas have reached their maximum potential. Sustaining fish supplies from capture fisheries, therefore, will not be able to meet the growing global demand for aquatic food. Aquaculture appears to have the potential to make a significant contribution to this increasing demand for aquatic food in most regions of the world (FAO, 2008).

Two key criteria, ownership of stock and deliberate intervention in the production cycle (husbandry), distinguish aquaculture from capture fisheries. Fish farming typically involves the enclosure of fish in a secure system under conditions in which they can thrive (Lirasan, and Twide, 1993).

A number of different types of aquaculture practices exist; that means, its practices are diverse, ranging from single pond subsistence farming to highly intensive pump-ashore abalone farms (Hecht, 2000). Among these practices, the simplest is the releasing of young organisms into the wild to increase the natural population size. The next level of aquaculture contains the organisms in a pen or cage open to water and nutrients, however, that restrains them from leaving the site. The most complex aquaculture type is a closed system. In this situation, there is no exchange between the aquaculture facility and the environment.

Aquaculture, in Africa, is unevenly developed and relatively a new phenomenon though it had been practiced since the colonization era of European countries (FAO, 2004). It is still nascent in the countries with less than 1% of global production; thus, it is not much influencing international market development. The total aquaculture production of Africa only amounts to

570,000 tons annually in 2004. Until the mid-1990s production was relatively stable at around 50,000 to 100,000 tons, however, developments since then have shown that there is both room and possibilities for growth. Growth in particularly Egypt's production has contributed to a five-fold increase in less than 10 years though the country has been the largest producer in African aquaculture since as far back as 1950 (Hishamunda & Nathanael, 2001). In 2004, according to Hecht **(**2000), Africa as a whole contributed 1.8% to world aquaculture fish production, while the Sub-Sahara Africa region contributed 0.26%.

Egypt was the largest contributor to African aquaculture (84.5%) followed by Nigeria (7.9%) and as a whole the Sub-Saharan Africa region contributed 14.6% to African aquaculture output. During the period 2000 to 2004 aquaculture production in Sub-Saharan Africa increased by 50.8% from 54,109 to 81,598 tons. The highest increases in production were recorded in Uganda (575%), Cameroon (560%) and Kenya (102%). Nigeria was the largest producer in sub-Saharan by culturing 43,950 tons in 2004, followed by Uganda and Zambia with around 5,000 tons each.

Table 1: Summary of reported total aquaculture production in sub-Saharan Africa (FAO, 2007)

Country	Production in tons	Values in billion (USD)
Nigeria	56,355	0.156
Uganda	10,817	0.012
Madagascar	8,500	0.034
South Africa	6,142	0.034
Tanzania	6,142	0.036
Zambia	5,125	0.009
Congo D.R.	2,965	0.007
Zimbabwe	2,452	0.005
Togo	1,535	0.003
Mozambique	1,278	0.007

Freshwater, brackish water and marine environments are used for aquaculture practices for a great variety of culture organisms. In 2004, 89% of African aquaculture is done in inland waters, lakes, reservoirs and rivers (Hecht, 2000). Freshwater aquaculture is carried out either in fish ponds, fish pens, fish cages or, on a limited scale, in rice paddies. Brackish water aquaculture is done mainly in fish ponds located in coastal areas. Marine culture employs either fish cages or substrates for mollusks and seaweeds such as stakes, ropes, and rafts (Goldburg, *et al.,* 2001). Brackish-water aquaculture is practiced only in Nigeria and at a low level. There is some marine aquaculture, mainly in the Mediterranean and the Indian Ocean, while activities on the Atlantic coast have been very limited until now. Marine culture in Sub-Saharan Africa is restricted mainly to shrimp culture in Madagascar and Mozambique, Seychelles and abalone aquaculture in South Africa and also experimental shrimp (*Penaeus* species) culture in Kenya (Dadzie, 2006).

More than 220 species of finfish and shellfish are farmed; the range includes giant clams, which obtain most of their nutrients from symbiotic algae; mussels, which filter plankton; carps, which are mainly herbivorous; and salmon, which are carnivorous. The main species cultured includes finfish (96.2%), aquatic plants (1.8%), crustaceans and mollusks (0.6%). Freshwater finfish makes up about 80% of total aquaculture production. Nile tilapia is the dominating cultured species in Egypt. In 2004 Egyptian farmed tilapia production amounted to some 200,000 tons, accounting for over 42% of the total aquaculture production of the country (Ridler and Hishamunda, 2001). In recent years, however, aquaculture has been developed in other countries like Congo Democratic Republic, Nigeria, Madagascar, South Africa, Tanzania, Uganda, Zambia and Zimbabwe. In Nigeria, it is particularly catfish farming that has contributed to this development. In 2004, production of catfishes accounted for about 63% of the total Nigerian aquaculture production (Hecht, 2000).

Although a large number of fish species are being cultured, the bulk of aquaculture and fisheries enhancement production is accounted for by a small number of species which have been introduced widely beyond their native ranges (DIAS, 2004). For example, the largest species in African aquaculture in terms of volume include tilapias, grey mullet, carps and catfishes. There is also some production of shrimp, mainly black tiger shrimp (*Penaeus monodon*), and in 2004 African farmed production of this species amounted to 7,600 tons (Hecht, 2000). Herbivorous or omnivorous tilapia and carp species are a case in point, having been introduced throughout the tropics and accounting for about 80% of tropical inland aquaculture production. Like the common agricultural animal domesticates, these species have attributes that make them particularly attractive for rising in captivity (Bilio, 2008). This species can be mentioned as working examples of cage culture in the Sub-Saharan African aquatic farms like in Ghana, Kenya, Malawi, Uganda, Zambia and Zimbabwe. All farms grow Nile tilapia (*O. niloticus*) with the exception of those in Malawi, which use the local species *O. siranus* and *O. karongae*, both known as "*chambo*". The growth performances of tilapias other than *O. niloticus* and of wild strains of *O. niloticus* are unlikely to be globally competitive (Blow and Leonard, 2007). *O. niloticus* is the second culture species in the world because of its fast growth, short food chain, high food conversion ratio, readily accepting artificial feeds, ease of breeding in captivity, disease resistance, high fecundity, tolerant to a wide range of environmental conditions and good taste and market price (Stickney, 1986).

However, generally in the case of Sub-Saharan Africa, the main reasons for poor aquaculture development have been discussed in details by Machena and Moehl (2001). They include poor aquaculture development policies, few fish farming traditions, lack of access to quality feed, lack of quantity of fingerlings, inadequate research and extension services, limited coordination between research and development sector and inaccessibility of capital.

1.2. Cage culture

Cage aquaculture is an old practice. It dates back to early 10^{th} century when Chinese fishermen used to fatten fish fry in cage made bamboo stick (Beveridge, 1996). The production of fish in cages has been practiced for many years in various countries worldwide. The earliest record of cage culture practices dates back to the late 1800s in Southeast Asia, since that similar culture practices have been reported in both freshwater and marine environments, including open ocean, estuaries, lakes, reservoirs, ponds and river (Eng & Tech, 2002). Norwegians are mentioned for introduction of salmon fish cage culture in the marine (Beveridge, 2004). However, expansion of cage aquaculture has taken place in the past three decades particularly since the late 1980s.

Cage culture is commonly used in water bodies that cannot be drained, such as lakes, estuaries, reservoirs or coastal marsh areas. Cage culture practices have numerous advantages over other culture systems. By integrating the cage culture system into the aquatic ecosystem the carrying capacity per unit area is optimized because the free flow of current brings in water and removes metabolic wastes, excess feed and faecal matter (Beveridge, 1984). The other aadvantages of cage culture include low investment costs, easy management, easy and low cost of harvesting, opportunities for close observation of feeding and health. Application of cage culture practice has also some disadvantage including vulnerability to poachers and structural damages, less tolerance of fish to poor water quality, more dependence on commercial diets and the increased risk of disease out breaks (McGinty and Rakocy, 2005). Furthermore, the risk of escaping from cages has potential impacts on wild fish population, including potential gene pool and social impacts (Ferguson *et al.,* 2007). Other risks might be mentioned as cage culture solely depends on the natural catch of the fingerlings where hatchery development is new or production is not currently sufficient to meet the demand (Ottolenghi *et al.*, 2004).

McGinty and Rakocy (2005) explained that the knowledge of the behavior of cultured species is crucial for constructing fish cage. In the case of *O. niloticus*, which is less active and sometimes territorial in habitat, the shape of the cage does not affect its mobility, however, for easy assemblage and management rectangular cage is appropriate (Fitzisimmons, 2004). Availability of aeration, size of the water body, and the method of harvest determine the size of the cage. An increment of cage size has inverse relation with costs and production per unit volume as a result of decrement of rate of water exchange. Cages can be floating surface or standing surface cages. The former requires floating device to stay at a surface whilst the latter could be tied to stakes driven into the bottom substrate (McGinty and Rakocy, 2005). The material by which the cages constructed should be durable, lightweight, and cheap, such as galvanized and plastic coated welded wire mesh, plastic netting and nylon netting (Fitzsimmons, 2004).

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 while holding relatively small fingerlings (100 to 130 mm) at the beginning of the population cycle (Dikel *et al.*, 2005). A large mesh size can be used if large fingerlings are stocked. The mesh size for tilapia cages should be at least 12.5 mm, but 20 mm is preferred. These mesh sizes provide adequate open space for good water circulation through the cage to renew the oxygen supply and remove wastes.

The use of large mesh size requires a large fingerling size to prevent gill entanglement or escape. A 20 mm plastic mesh, for example, will retain 9 gram tilapia fingerlings while a 25 mm mesh requires a fingerling weighing at least 25 gm with plastic netting and 50 - 70 gm with nylon netting (Silva *et al.,* 2000). 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. Cages should be equipped with cover to prevent fish losses from jumping or bird predation. Covers are often eliminated on large nylon cage if the top edges of the cage walls are supported 300 to 600 mm above the water surface (McGinty, 1991). Larger mesh sizes facilitate the entry of wild fish into cages.

While installing cage culture, site selection is mandatory. It should be put in a place where at least 60 cm of water between the bottom of the cage and lake bottom to avoid undesirable accumulation of wastes from the fish and the feed given (Bardach *et al.,* 1972). Water circulation freely through and around the cage should also be considered. Furthermore, vascular plants (those with stem), wind protected cover, and areas around excessive structure should be avoided in order to allow water movement (Coche, 1982). Cages should be placed usually to the windward side, where water current is greatest. Calm stagnant areas should be avoided (Konikoff, 1975).

Tens of finfish species have been cultivated in various cage systems all around the world. Tilapia and carps are predominant in freshwater in Asia while salmon are commonly farmed in Europe and America (Eng and Teck, 2002). Cage culture is very popular because mixed sex tilapia can be produced without the risk of reproduction when mesh is large enough to let eggs fall through. From water quality standpoint, cage culture is similar in some ways to pond aquaculture. Although fish are confined, metabolic wastes leave the cages and are broken down throughout the body of water (Boyd, 1990).

1.3. Nile tilapia culture

According to Hickling, (1962), tilapia culture is believed to have begun in 1939, by the year five *O. mossambicus*, originally from southern Africa, was discovered in lagoon in Java. However, the earliest known representation of fish culture pond from an Egyptian tomb dating from before 2,500 B.C. shows a pair of small fish that can be identified as *O. niloticus*, a species abundant in the Nile Valley (Jhingram, 1987). According to Jhingram, (1987) the engravings apparently show tilapia being fished out of artificial drainable ponds.

Tilapia (commonly called "the aquatic chicken") belongs to the family *Cichlidae* which is widely distributed naturally in Nile River, in most parts of African rivers and lakes as well as in the Middle East. Tilapia is perciform fish that originated in Africa and Jordan Valley and it contains approximately 1,399 species, of which 150 can be called tilapia (www.fishbase.org).

Next to carps, tilapia has become one of the most common cultured fish in the world (El-Sayed, 2002) and is likely to be continued being the most important cultured fish in the 21st century (Fitzsimmons, 2000). Most tilapia species of the tribe *Tilapinii* now being used in aquaculture were grouped initially into one genus, Tilapia. The species within this genus were later classified according to their mode of reproduction (Trewavas, 1983). Species which evolved as substrate spawner but guard their eggs were retained in the genus tilapia while those which orally reared their clutches were grouped into new species *Sarotherodon*. Classifications of these commercially important tilapia genera are: *Oreochromis*, *tilapia* and *Sarotherodon* having approximately 79, 41, and 10 species, respectively. The classification of the genus *Oreochromis* was based on the difference on their reproduction, feeding habits, and biogeography.

Genus *Oreochromis* includes Nile tilapia (*O. niloticus*), Mozambique tilapia (*O. mossambicus*) and blue tilapia (*O. aureus*) which are most commercially important species (Wohlfarth *et al.*, 1990). 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). In the case of *O. niloticus*, females solely involve in broad care. After spawning female leaves nest to rear her clutch in safety. Fry brooded up until free swimming. There is an external period of care during which fry seeks shelter in bucal cavity for safety. First feeders have well developed fins for swimming and fry survival is high.

Its rising popularity is due to their hardness, resistance to disease, ease to breeding without a need of high tech hatchery, reasonable growth rate, good taste, and tolerance to a wide range of environment, i.e. it can adapt to diverse habitats: permanent and temporary rivers, rivers with rapids, large equatorial lakes, tropical and subtropical rivers, open and closed estuaries, lagoons, swampy lakes, deep lakes and coastal brackish lakes (Trewavas, 1983). Therefore, the species is considered as best researched species for culturing and there is affluence of experience in its husbandry (FAO, 2007). Due to these facts earthen ponds, concrete tanks, raceways, and cages can be used for growing tilapia (Nandlal and Pickering, 2004). Thus, tilapia was originally considered for aquaculture as a means of producing cheap protein (Pillay and Kutty, 2005).

Nile tilapia (*O. niloticus*) is a benthopelagic fish adapted to freshwater and low salinity brackish water condition. It is naturally distributed in Africa and coastal river of Israel and it is capable of tolerating temperature from 8^0C to 42^0C (Trewavas, 1983). It is the most widely farmed tilapia species in the world, representing approximately 83% of total tilapia production (Hempel, 2002). The rapid growth to market size of Nile tilapia has made it a well accepted fish with tilapia farmers.

Table 2: Environmental conditions favorable for tilapia

Parameter	Level	Comment
Temperature	8 – 42^oC	Survival range
	25 – 33 ^{o}C	Optimum for reproduction and growth
DO	3	Minimum for optimum growth
pH	6.5 – 9	Optimum for primary reproduction
	6.8 - 8	Optimum for enhanced growth

1.4. Tilapia Feed

Tilapia culture is advantageous for the reason that tilapia feeds on low trophic level. The members of the genus *Oreochromis* are all omnivores, feeding on algae, aquatic plants, small invertebrates, detritus, and associated bacterial films (Getachew Teferra, 1987; Diana *et al.*, 1991).

Fishmeal is a major source of protein in tilapia feeds, but increasing costs and scarcity stress the need for alternative protein sources. Therefore, for countries in which the economy is not developed yet, industrial well-compounded fish feeds are expensive and can account for over two-third of the variable costs in fish culture operations (Balogun *et al.*, 1992). For example, about 4,000 tons of quality fishmeal is imported into Nigeria each year (AIFP, 2004 cited in Gabriel *et al.*, 2007). This has contributed, in no small way, to increasing the total cost of production which will ultimately translate to high cost of fish thereby making it expensive for the population of the poor living in Sub-Saharan Africa.

In cage culture practice, it is mandatory to use supplementary feeds. This is because fish are not able to forage for insects and other food items that are available in the water body. In addition to this, the dissolved nutrients that promote primary and secondary production in the natural environment are seasonal or may not occur in required proportion to meet the nutritional demand of cultured fishes (Ugwumba and Ugwumba, 2003). Therefore, the non-availability of suitable and cost effective supplementary feeding is one of the disadvantages of fish cage culture in developing countries.

To address the major problem of cage culture fish feeds, several feed ingredients have been investigated in an attempt to find substitutes for fishmeal in the diets of tilapia. The feed produced and used in Africa are categorized into non-conventional (non-standardized) and conventional (standardized) feed stuff; According to Gebriel *et.al* (2007) the categorization is based on the availability and acceptability of the feed stuff involved. The non-conventional fish stuffs include kitchen wastes (e.g. Cassava and yam peels, leftovers like bread, etc), Plant sources of feed, and animal sources of feed (tadpole meal, maggots, earthworm meal, housefly larvae). The conventional feed stuffs are regularly used in the formulation of fish feed. They are usually agro-industrial by-products (wheat bran, rice bran, oil seed cake), animal source (blood meal, shrimp meal, hydrolyzed feathers), and plant source (maize, soya bean meal, cotton seed meal, etc), along with aquatic plants such as *Azolla pinnata*, duckweed and single-cell proteins (Ogunji, 2004; El-sayed and Tacon, 1997 cited in Ogunji *et al.*, 2008).

These supplementary feeds mentioned above are not only considerably cheaper than fishmeal but also enjoy high availability and accessibility in certain regions of the world. Unfortunately, attempts to use these ingredients to replace the fishmeal components in farmed tilapia diets have met with variable success with some leading to reduce feed efficiency and growth. Some of the factors which may have contributed to the variation in the results obtained are summarized by

Ogunji (2004) to include the protein composition, amino acid profile; apparent digestibility, phosphorus content, anti-nutritional factors (especially in plant protein sources), palatability and accessibility of alternative feeds.

In order to enhance aquaculture production, improve production, improve food security, and reduce the level of poverty in developing countries like Ethiopia, a search for cheap and locally available feedstuffs is mandatory. In some countries of Africa like Kenya, Namibia, Nigeria, Uganda, Madagascar, Ghana and Cote D'ivoire, where little quantity of fish feeds are produced locally, the quality is very poor and production rate inconsistent (Gabriel *et al.,* 2007).

1.5. Aquaculture in Ethiopia

Like most countries of Sub-Saharan Africa, fish production in Ethiopia is far below the estimated yield and the pattern of production is by no means uniform; only capture fisheries. The country is endowed with a number of natural lakes, reservoirs and large rivers containing substantial qualities of fish stock. Water bodies of Ethiopia have a surface area estimated at 7,334 km^2 of major lakes and reservoirs, and 275 km^2 of small water bodies, with 7,185 km of rivers within the country (Shibru Tedla, 1973).

According to Abebe Getahun, (2003), the country has about 153 indigenous and additional 10 exotic fish species (Among these, six species are commercially most important ones and belong to the following families: Centropomidae (*Lates niloticus*), Cichlidae (*O. niloticus*), Clariidae (*Clarias gariepinus*), Bagridae (*Bagrus dockmak*), and Cyprinidae (*Labeobarbus spp*. and *Labeo sp*.). *O. niloticus* is the most exploited species constituting about 80 % of the total fish capture in Ethiopia (Breuil, 1995). It is one of the most important species in the ecology and fisheries of almost all Ethiopian inland waters (Shibru Tedla, 1973). Consequently, fish resources became depleted from time to time because of overexploitations of capture fisheries (FAO, 2008). Fish culture is assuming greater popularity as an alternative means to capture fisheries for increasing fish supply due to habitat degradation, over-exploitation, and pollution of natural water bodies in developing countries (Singh *et al.,* 2007). Therefore, the current increasing market demand for fish protein in Ethiopia can be met only when the capture fishery is supplemented by culture fishery.

Tesfaye Wudneh (2009) mentioned that the overall potential annual sustainable fish yields of the country from the lakes, reservoirs and rivers combined is roughly estimated at about 50,000-60,000 tons. This includes a potential yield of about 35,000 to 40,000 tons per year from the lakes and reservoirs and about 20,000 tons per year from the major rivers.

Aquaculture in Ethiopia, like most countries of the continent, remains more potential than actual practice, despite the fact that the country's physical and socio-economic conditions support its development. This country is endowed with abundant aquatic resources but has not been able to realize substantial production from aquaculture due to lack of educated labor and technology in all aspects. The aquaculture or fish farm development in the country has been very limited and the practice mainly consisted of stocking of fish fingerlings into dams and small water bodies that are devoid of fish or to diversify species composition and enhance production (Tesfaye Wudneh, 2009).

Extensive aquaculture in the form of stocking and enhancing artificial lakes, reservoirs and small water bodies have been practiced since 1975 through the Sebeta Fish Breeding and Research Centre (SFBRC). The research center released over 2.5 million fingerlings, primarily consisting of Nile tilapia, *Tilapia zilli* and carp, but in the absence of systematic monitoring and evaluation (due to weak institutional capacity) the success or failure of the program is unknown.

Aquaculture development in Ethiopia has been among the less attended sector of the economy for a longer time, with limited budget and manpower allocated to it. It needs to be recognized as an alternative means of achieving food security and poverty reduction in the rural area, and is now considered an integral part of rural and agricultural development policies and strategies. However, much remains to build institutional capacity in the areas of research, technology and training, which will require external assistance.

In recent years, the situation in fishery and aquaculture is changing. This is may be due to changed pattern of fish consumption because of increased awareness of the food value of fish by the community and the economic benefit.

The tilapia fish especially *O. niloticus* (locally called “Koroso”) are widely distributed in Ethiopia. The BOMOSA project was the one who pioneered the cage culture system of *O.*

niloticus in the country. The project document was developed in 2005 in Machakos, Kenya and officially launched in the year 2006. The project was completed in 2009. Recently, some academic graduate students of AAU have conducted researches on cage culture practices of Nile tilapia. These include researches on the effect of stocking density and supplementary feeding on growth performance, survival and yield of Nile tilapia reared in cages by Abebe Tadesse (2007), Ashagrie Gibtan *et al.,* (2008), Kemal Mohammed (2008), and Abdilahi Dill (2010). Solomon Hailu (2008) and Belistie Fentie (2008) were also conducted an experiment on the effect of feed quantity and quality, respectively, on growth performance and water quality of Nile tilapia in cage culture system.

According to Zenebe Tadeses (2010) about 70 feed ingredients were analyzed in East Africa, i.e., 48 in Kenya, 14 in Uganda and 16 in Ethiopia by the BOMOSA project that thoroughly studied proximate chemical composition, formulation of fish feeds and feeding and growth experiments. These include:

- Animal origin - Omena/Mukene (*Rastrineobola argentea*), Haplochromines and Fresh water shrimp (*Caridina nilotica*), Poultry feathers, tilapia & catfish remains.
- Plant origin - Leaves from Banana, Papaya, Cassava, Leucena, Arrowroot, Sweet potato, Water fern, Water hyacinth, Mexican sunflower, Sesbania, etc. Seed meals/cakes: Cotton, Sunflower, Mango, Papaya, etc.
- By-products - Bran from Maize, Wheat, Rice, various seed husks, Vegetable residues, Tea leaves residues, Brewery waste, etc.

Study was also done by Belsti Fetene (2008) to prepare low-cost farmer made high quality locally available ingredients for tilapia production to manufactured aqua-feeds. This is because locally available extruded feeds are not known in the country and also the cost of imported fishmeal to the newly emerging aquaculture is unaffordable. He evaluated 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 cubic meter net cage. He studied the effect of mill sweeping, chicken dung and oil seed cake as supplementary feed and the combination of either of the feed type in 50% proportion and all of the three feed types in 33.33%; even so, his study has not shown the percentage of crude nutrients in the mixed formulated feeds. 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 (1 m^3) in the same area. Thus, this study is a continuation of the above studies especially that of Belsti Fetene (2008).

On the other hand, the use of these supplementary feeds might cause water quality deterioration. Therefore, water quality management is a key component in a successful operation including cage culture. Such feeds can be traced to water quality problems. Thus, water quality management is undoubtedly one of the most difficult problems facing the fish farmer. Water quality problems are more difficult to predict and to manage. A more thorough study on water quality problems should address such problems. Therefore, there is an urgent need to prepare a low-cost farmers made fish feed for tilapia culturing, hence the purpose of the present study was to evaluate the effects of supplementary feeding on the growth performance of Nile tilapia (*O. niloticus*) and its effect on water quality during cage culture practice in Lake Hora-Arsedi, Ethiopia.

1.6. Objective of the study

The general objective of the study was to explore alternatives of locally available cost-effective farmer made feeds on cage culture in order to improve food security, reduce poverty, protect unwisely exploited lake and reservoir environment and maximize the contribution of fisheries to the economy of the country.

The specific objectives were to:

- ✓ compare growth performances of fishes fed naturally and with different supplementary feed types
- ✓ assess the effect of quality of different feed types on growth performance of *O. niloticus* and yield in cage culture
- ✓ examine the effect of cage culture on water quality

2. DESCRIPTION OF THE STUDY LAKE

Lake Hora-Arsedi, one of the Debre Zeit (Bishoftu) crater lakes, was believed to be created around 7000 years ago by volcanic collapse above zone of fractured rocks. The lake is a double crater with a maximum depth of 38 m (North crater) and 31m (South crater) and a mean depth of 17.5 m, located 47 km away from Addis Ababa in the south eastern direction at 8^{o} 50' and 39^{o}E at an altitude of 1850 m (Mohr, 1961; Prosser, *et al.*, 1968; Wood, *et al.*, 1984).

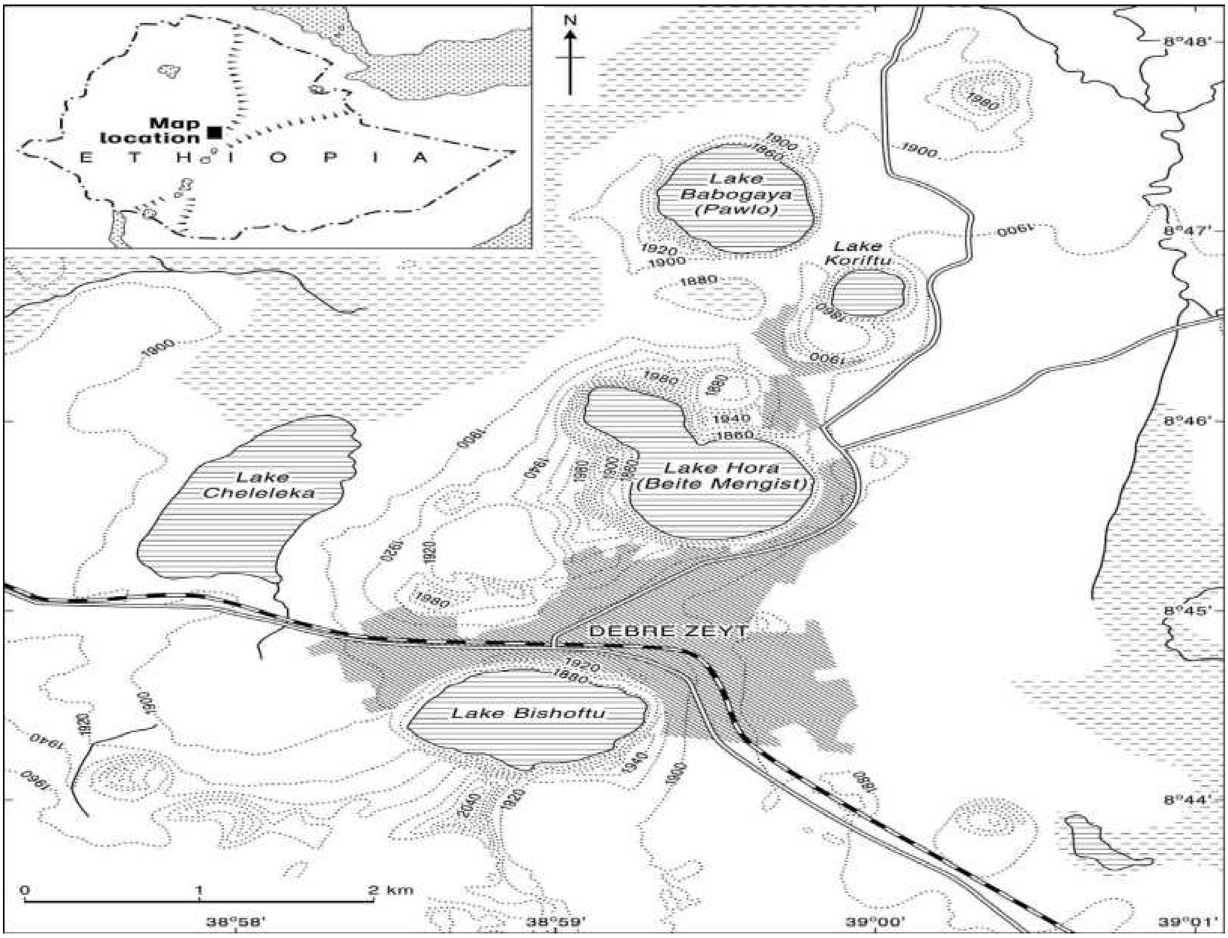

Figure 1: Map of Lake Hora-Arsedi (Bette Mengist) (Lamb, 2001)

The vertical distance from the crater rim to the lake surface is about 80 m. Lake Hora-Arsedi receives 43% of its total inflow from groundwater, but almost all water lose (97%) is by evaporation. The annual variation in depth of this lake is less than a meter, which suggests the maintenance of water level by seepage to and from the water table (Baxter and Wood, 1965). The residence time of water in the lake, calculated as lake volume divided by water flux (Evaporation plus groundwater outflow), is 10 years in Hora-Arsedi (Odada and Olago, 2002). The lake has a surface area of about 1.03 km^2 and a volume of 0.018 km^3. Like all the other volcanic crater lakes in this area, Lake Hora-Arsedi is a closed system, surrounded by very steep and rocky hills and cliffs. The catchment of the lake is formed from volcanic rocks of basalt, rhyolite and tuff (Mohr, 1961).

Previous limnological studies on Lake Hora-Arsedi described bathymetry (Prosser *et al.,* 1968), water chemistry (Prosser *et al.,* 1968; Wood *et al.,* 1984; Rippey and Wood, 1985; Zinabu Gebre-Mariam, 2002), thermal stratification and mixing (Baxter and Wood, 1965; Wood *et al.,* 1976), chlorophyll "a" and phytoplankton (Wood and Talling, 1988), community structure of Rotifera (Green and Seyoum Mengistou, 1991), temporal dynamic of phytoplankton biomass and primary production (Abebaw Wendie, 2006), secondary production of the dominant zooplankton (Ageze Abza, 2009), grazing impact of the zooplankton community on phytoplankton (Tamiru Gebre, 2006), composition and abundance of benthic fauna (Habiba Gashaw, 2010), and temporal changes of species composition (Tigist Wubshet, 2010).

The region around the lake is characterized by moderate rainfall, varying around about 850 mm per annum (Rippey and Wood, 1985), high incident solar radiation and low relative humidity. The region has two rainy periods, the minor one extending roughly from February to April and the major one beginning in June and ending in September. The temperature of its surface water was frequently found to be about 22^0C with a maximum of 24.5^0C and minimum of 19.2^0C, while the bottom temperature was almost constant (19.2^0C-19.4^0C) (Wood *et al.,* 1976). Its seasonal cycle of stratification and mixing is probably similar to that of the nearby Lake Babogaya (Pawlo), which mostly resembles hydrochemically (Lamb, 2001). The lake stratifies during the February - October wet season, and mixes as a result of heat loss to clear night skies during the dry season (Lamb, 2001). Through their studies over extended periods, Baxter and Wood *(*1965) and Wood *et al.* (1976) have shown the frequent occurrence of pronounced and deep-seated thermal stratification with a consequent stratification of various chemical species in Lake Hora-Arsedi (Wood *et al.,* 1984). The lake is a dilute lake with Na^+ as the dominant cation and carbonate-bicarbonate as the dominant anion. The water is alkaline, with the erosion of basaltic and hyper-alkaline rocks surrounding the lake playing an important role in increasing the alkalinity of the water (Prosser *et al*., 1968).

Table 2: Some limnological features of Lake Hora-Arsedi [Chemical data from Baxter (2002) and morphometric data from Prosser, *et al.*, (1968)].

Parameter	value
Surface area (km^2)	1.03
Location	$8^0$50'N,39^0E
Altitude (m)	1850
Maximum depth (m)	38 m in North crater and 31 m South crater
Mean depth (m)	17.5
Volume (km^3)	0.018
Conductivity (µS /cm)	2350
Salinity (g/l)	2.57
Alkalinity (meq/ l)	26.5
pH	9.2
PO_4–P (g/l)	<5
NO_3-N (g/l)	<5
SiO_2 (mg/l)	<0.1
Sum of cations (meq/l)	29.5
Sum of anions (meq/l)	32.9
Na^+ (meq/l)	23.9
Cl^- (meq/l)	5.7
Chlorophyll '*a*' (µg/l)	36

The phytoplankton community is dominated by the colonial cyanobacterium *Microcystis aeruginosa* (Wood and Talling, 1988) which is known to form blooms in some Rift valley and crater lakes of Ethiopia. The zooplankton community includes the rotifers *Asplanchna sieboldi* Leydig, *Brachionus calyciflorus* Pallas, *B. dimidiatus* Bryce, *B. urceolaris* Müller and *Hexarthra jenkinae* de Beauchamp (Green and Seyoum Mengistou, 1991) and copepod and cladocera

(Tamiru Gebre, 2006). The Lake Hora-Arsedi fish fauna consists of only *O. niloticus* which was introduced around 1943 (Shibru Tedla, 1973). Currently it supports a pisci-fauna, which is exclusively composed of Nile tilapia and *Tilapia zillii* although not much fishing is done except a few tons of fish caught for consumption by people of the town.

Monthly average maximum and minimum air temperature and rainfall of experimental period of the study lake area were gathered from Ethiopian National Meteorological Service Agency (Figure 1). From the recorded data mean maximum monthly air temperature varied from 24^{o}C to 27.9^{o}C whereas the minimum air temperature ranges from 6.1^{o}C to 13.8^{o}C within the experimental time frame. The highest monthly rainfall (in mm) was recorded in time frame extended from June to September while the climax was reached in July with rainfall of 197.9 mm. No rainfall was recorded from October to the harvest time.--------------------------------------

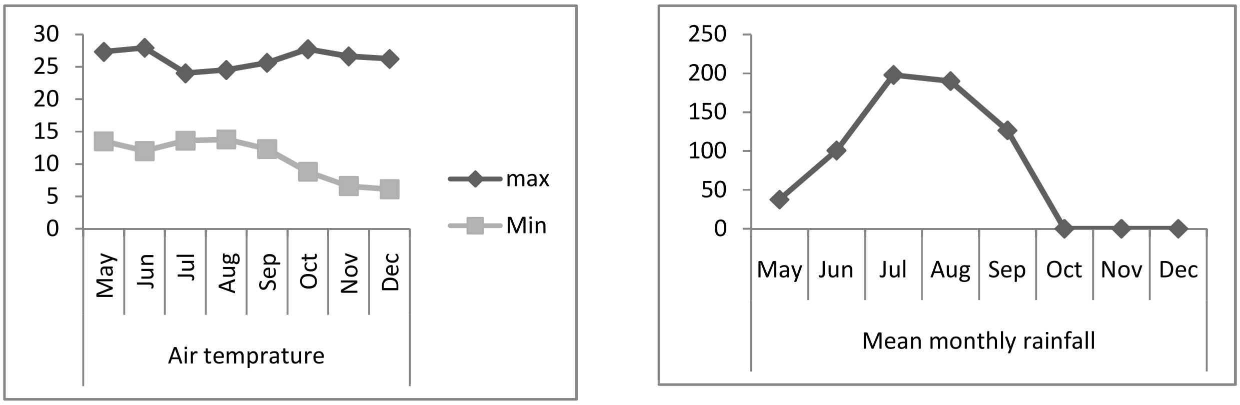

Figure 2: Meteorological data of Lake Hora-Arsedi (ENMA, 2010). [monthly average maximum and average minimum air temprature (^{o}C) and monthly average rainfall (mm)]

3. MATERIALS AND METHODS

3.1. Experimental site selection

Easily accessible and secured experimental site for cage placement was selected in Lake Hora-Arsedi. Before the experiment starts the landing structure, walkway or jetty, for cage placement was constructed by using eucalyptus wood. It had a U-shape with an average depth of 3.5 m and a total length of 20 m (5 m away from the shore and 10 m connecting the two sideways in the direction of off-shore) and also extended to right side from offshore side by 5 m for water sampling (Plate 1). Cares were taken for site selection as per Coche (1982) so that there would be sufficient water and oxygen circulation around the experimental site. Three sites, one in cage area, the second on the other side of the shore, and one from off shore were chosen for physical parameters, water quality data, phytoplankton and zooplankton sampling.

Plate 1: The walkway (jetty) at the study site

3.2. Construction of experimental cages

The cages were constructed in the Fisheries Laboratory of the Zoological Sciences Program Unit, AAU by previous graduate students for experimental purposes. Due to lack of netting materials in the country, it was difficult constructing new cages for experiment. Thus, the researcher maintained the cages and re-used for this study. The standards of the constructions of the cages were as mentioned in Beverage and Stewart (2002). The size of each cage was 1 m^3 (1 m x 1 m x 1 m). The basic structural materials that were used for the construction of the frame was poly vinyl chloride (PVC) material and an enclosure of netting material. The PVC was type 50, tube of 10 cm with 1 mm polyethylene material. The PVC were cut at 1 m interval and fixed together by using jointer and gum. The joints were fastened by using scotch-tape as additional re-enforcement. The net mesh with 4 cm stretch length was used to enclose the whole cages. The knotless net (provided by NFLARC) was cut according to the desired specification to enclose the cages.

Finally, every mesh were double-laced, at every side of the four corners, using nylon twine (type 210D / 24). The lower square frames of the upper part were perforated so that the cage distends and weigh down due to the entrance of water. Then, the cages were placed under the constructed walkway (jetty) in line-ups at 1 m intervals. Cages were installed in a way that they all have equal access to the natural food and water circulation in the two sites.

3.3. Juvenile collection method

O. niloticus juveniles of mixed sex were collected for one week from Lake Hora-Arsedi (21-28 May 2010). They were collected by using beach seine hauls 50 m *x* 2.5 m (with stretched mesh size of 20 mm). Immediately after capture, the fingerlings were stored and acclimatized for ten days (28 May 2010 to 6 June 2010). After acclimatization, the stocked fingerlings were screened out from other species like *Tilapia zillii* by using external morphological features (Plate 2). Total length (TL, nearest 1mm by measuring board) and total weight (TW, nearest 1 gm by Ohaus balance) of each fingerling were measured and fish of length 120 mm - 130 mm with 40 gm - 45 gm weight were selected as experimental juveniles.

Plate 2: Juvenile collection and selection in the field

3.4. Transportation and stocking of juveniles

The amount of fish that can be safely transported in a fixed volume of water depends on the species, the size of the fish, and whether or not aeration is supplied (Bocek, 1996). Because the fingerling collection and the experimental site was in the same lake, however, the researcher used appropriate beach seine nets to collect the required size and then transported the fingerlings to the experimental cages by plastic bags and plastic barrel half-filled with lake water using small boats (Plate 3).

Plate 3: Juvenile transportation

3.5. Feed and feeding

Fish diets were prepared from locally available feeds. These were Oil seed cake (O), Mill sweeping (M), Rice bran (R) and Blood and Bone meal (B). Four combination of feeds were prepared as diet-1 (ROM+B), diet-2 (RM+B), diet-3 (MO+B), and diet-4 (RO+B) (Table 4).

Table 4: Proportion (%) of different ingredients used in formulated diets

Ingredients	Diets (%)			
	Diet-1	Diet-2	Diet-3	Diet-4
Blood and bone meal	20	20	20	20
Rice bran	26.67	40	-	40
Oil seed cake	26.67	-	40	40
Mill sweeping	26.67	40	40	-

In all the diets, 20% of blood and bone meal was added to increase the protein composition and solve the Potassium (P) limitations which are major nutrient and mineral for fish growth, respectively.

The nutritional proximate were analyzed for all tested feed types in the laboratory of School of Chemical Engineering, Baher Dar University (BDU). The analyzed average proximate nutritional compositions of diets used in this study are presented in Table 5:

Table 5: Feed types used and their nutrient proximate composition

Feed type	Nutrient Compositions				
	Moisture (%)	Ash (%)	Fat/oil (%)	Protein (%)	Fiber (%)
Blood & bone[b]	10.8305	20.8602	11.3638	52.4763	4.1839
Rice Bran[rb]	11.9914	14.2442	12.4849	17.4748	14.4190
Mill sweeping[ms]	14.0437	10.5271	5.78248	11.9150	10.8875
Oil seed cake[ok]	4.0955	7.8139	9.17430	17.0556	12.9498

(b) Dried and grounded blood and bone of cattle from Addis Ababa abattoirs (rb) Bran from rice, brought from Amhara regional state Bahir Dar, (ms) 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 and (ok) By-product of local oil production system from Niger seed (Guizotia abyssinica).

The extruded feeds (pellet) were made in Fishery laboratory of AAU in the ratio mentioned (Plate 4A). Whilst preparing the feed, the oil seed cake was soaked in water one day before the pellet preparation. After measuring the needed amount of the feed, it was thoroughly mixed and put in electrical extruder machine. The extruded feeds were dried under shed condition to protect heat loss of the nutrients (Plate 4B).

Plate 4: Feed preparation (A) and shade dry (B)

Table 6 presents the supplementary feeds crude nutrients composition with respect to their dry matters. For all formulated feed diets, the crude nutrients analyzed by using *Win feed 2.8 software*. The mean dietary rude protein was 22.84%.

Table 6: Composition of crude nutrients of the feeds and their respective dry matters

Treatments	Crude protein, %	Crude fiber,%	Crude fat/oil, %	Dry matter, %
Diet-1	22.87	16.1	13.2	89.43
Diet-2	22.22	10.9	9.5	90.92
Diet-3	22.00	10.3	8.2	90.00
Diet-4	24.28	11.7	10.9	87.4

These compositions of dry feed, which are extruded to make pellet, were given two times per day early morning at 7:30 AM and late afternoon at 4:00 PM as suggested by Chapman (2006) and Cruz (1997) using small hand operation aluminum boat to reach the walkway. Feed rations were placed in feeding trays, which were suspended at the midpoint in each cage. Stones were hanged in the mid-point of the tray to prevent floating. The stocks had free access to the natural foods. Feeding rates were adjusted every two weeks based on the average weight increment of fish. Feeds were offered to the caged fish only at 3% of the body weight for the feed treatments as described in Cruz (1997), Chapman (2006), and Solomon Hailu (2008) except for the controls where fish get their food directly from the natural environment only.

3.6. Juvenile stocking

Equal number of mixed sex juveniles (100 fingerlings per each cage) with average 42.5 gm, were stocked as proposed by Abebe Tadesse (2007) and Ashagrie Gibtan *et al.* (2008). Hence, four feeding treatments (diet-1, diet-2, diet-3 and diet-4) with the same stocking density (100 fish per cage) were used to evaluate the effect of feed quality on growth performance (where diet-1= MOR, diet-2=RM, diet-3=MO, and diet-4=MR). Furthermore, triplicates of control groups (C_1, C_2 and C_3) with equal stocking density (100 fish per cage) but without feeding, were used to evaluate the difference in growth performance between natural and supplementary feeds.

3.7. Data collection

3.7.1. Growth parameters

Initial weight, length and number of the stocks were recorded for each cage. Dead fish were removed and recorded daily. From each cage 15 % of the fish were sampled randomly by scoop net every 2 weeks. The fish length (using measuring board) and weight (using Ohaus portable balance) were measured and recorded (Plate 5). At the end of the experiment, the fish were harvested and counted, and weight and length of all fish were measured, and sexed.

Plate 5: Taking weight and length measurements at the experimental site

3.7.2. Physical parameters for water quality analysis

Water temperature was measured with thermometer in-situ monthly at 25 cm below the surface of water at experiment (cage area) and the two control sites (Plate 6). Visibility was measured monthly at 12:00 am using Secchi disk at the two sites. 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, 1990). The Secchi disk depth was used to estimate the euphotic depth of the lake. Concentrations of dissolved oxygen (DO) were determined in-situ using Oxygen meter; the pH of the water was also measured in-situ using pH meter.

Plate 6: Taking physical parameter measurements

3.7.3. Estimation of zooplankton abundance

Water was collected at one meter depth at the three sites in order to investigate zooplankton abundance. Zooplankton samples were collected with a net mesh size of 67μm and diameter of 31cm. The samples were immediately preserved in 5 % formalin. The volume of the water filtered through the net were determined by using the formula ($V = 3.14\ r^2h$) where, r is the radius of the net mouth and its depth from which the sample is taken. Based on this, the number of organisms per cubic meter of the lake was calculated and then the number of each category of zooplankton of the lake was expressed as per m^3. Sub-sample 20 – 25 ml were taken for counting using pipette with wider mouth and poured into a gridded petri dish. Three grids were counted for each sample after allowing the sample to settle and checking the uniform distribution throughout the grids and then extrapolation were made. Counting was done with stereoscope microscope (magnification of 50 *X*) in the Limnology Laboratory of the Zoological Sciences Program Unit, AAU. Zooplankton species were identified using keys (Fernando, 2002).

3.7.4. Estimation of phytoplankton abundance

Samples for estimation of the relative abundance of the different taxonomic groups of the phytoplankton community were collected with plankton net of 10 μm mesh size at 1 m depth of the open water from the three sampling sites (Plate 7). The samples were stored in brown bottles preserved using 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 genus or species level was made using different identification keys including Whitford and Schumacher (1973); Talling (1987); and Willen (1991). Aliquots of the preserved samples were used, after sedimentation, for the estimation of the relative abundance of the major algal groups with Sedgewick-Rafter cell under an inverted microscope (Nikon) following the procedures outlined in Hotzel and Croome (1999).

Plate 7: Zooplankton and phytoplankton sampling: Offshore (a) and at the experimental site (b)

3.8. Data analysis

Growth performances of fish were determined and feed utilizations and survival were calculated in terms of Weight Gain, Daily Growth Rate, Specific Growth Rate, Feed conversion Ratio, Survival Rate and Net yield as described by Sveier *et al. (*2000). The visceral bodies to the fish ratio were also compared. The above were estimated based on the following relationships:

- ✓ Weight Gain = Final weight (W_2) - initial weight (W_1)
- ✓ Daily Growth Rate (DGR, g / day) = $\frac{\text{Total waight gain by the fish}}{\text{Culturing days}}$
- ✓ Specific Growth Rate (SGR, % / day) = $\frac{\ln(W1)-\ln(W2)}{\text{No. of culturing days}} X100$ where W_1 and W_2 are initial and final weight in gram respectively
- ✓ Survival Rate (SR, %) = $\frac{N2}{N1} X\ 100$, where N_2 – no. of fish harvested and N_1 - no. of fish stocked
- ✓ Net yield (Kg/year) =$\frac{\text{Biomass gain}}{\text{Culturing days}} X\ 365$ days
- ✓ Food Conversion Ratio (FCR, %) = $\frac{\text{Total weight of Dry Feed Given}}{\text{Total Weight Gain by Fish}}$ X 100
- ✓ Food Conversion Efficiency (FCE, %) = $\frac{\text{Gain in wet weight of fish}}{\text{Feed Fed}}$ X 100
- ✓ Visceral to somatic Weight Ratio (VSWR, %) = $\frac{\text{weight of the viseral body}}{\text{weight of the fish}} X\ 100$

Sex was differentiated at harvest time and sex ratio (male: female) was compared in terms of percentage by their relative occurrence. The well being of fishes were studied by calculating the Fulton Condition Factor (FCF). According to Bagenal and Tesch (1978) it was calculated as,

- FCF (% in gm/m^3)= $\frac{TW}{(TL)3}$ X 100, where TW is total weight (gm) and TL = total length (cm)

The significance of relationships of growth performance data were statistically tested using one-way ANOVA. Moreover, to check the variation in physical parameters, zooplankton and phytoplankton abundance, one-way ANOVA, was used. These analyses were done using software like SPSS (1999) and the graphs were plotted by Sigma plot and the excel software. All statistical tests were considered significant at $p < 0.05$ as indicated in Sokal and Rohlf (1995).

3.9. Economic Analysis

The production cost of the experiment was calculated following the method used by Edward *et al*. (2010) based on the current market price of the ingredients in Ethiopia used for formulating the diets. Economic evaluation in terms of Investment Cost Analysis (ICA), Production Value (PV), Net Profit Value (NPV), Profit Index (PI) and Incidence of Cost (r) of caged Nile tilapia using different mixtures of rice bran, oil seed cakes and mill sweeping as protein sources were determined.

- Investment Cost Analysis (ICA) = Cost of Feeding (ETB) + Cost of Fingerlings stocked (ETB) + Construction cost + Materials cost + Labor
- Production Value (PV) = Mean weight gain of fish cropped (kg) x Total number of survival (n) x cost per kg (ETB/kg).
- Net profit Value = Production Value – Investment cost

4. RESULTS AND DISCUSSIONS

4.1. Results

4.1.1. Physical and Chemical Parameters

Water temperature (T), power of hydrogen (pH), dissolved oxygen (DO), secchi depth were measured at monthly interval during the study period. Figure 3 indicates that maximum water temperature (27.5°C) was measured in June and July at Site I (littoral) and 27.3°C at Site II (open water), whereas the minimum water temperature was registered as 18.5°C and 18.1°C in November for the littoral and off-shore sites, respectively. Mean water temperature was above 27.2°C till the end of July and decreased to 21°C in August. It had progressively increased in September, and then cooled down in the last two consecutive months of the experimental period (Figure 3). The physic chemical measurements at the two littoral sites were congruent to each other that the researcher omitted the littoral measurements away from the cage for comparison.

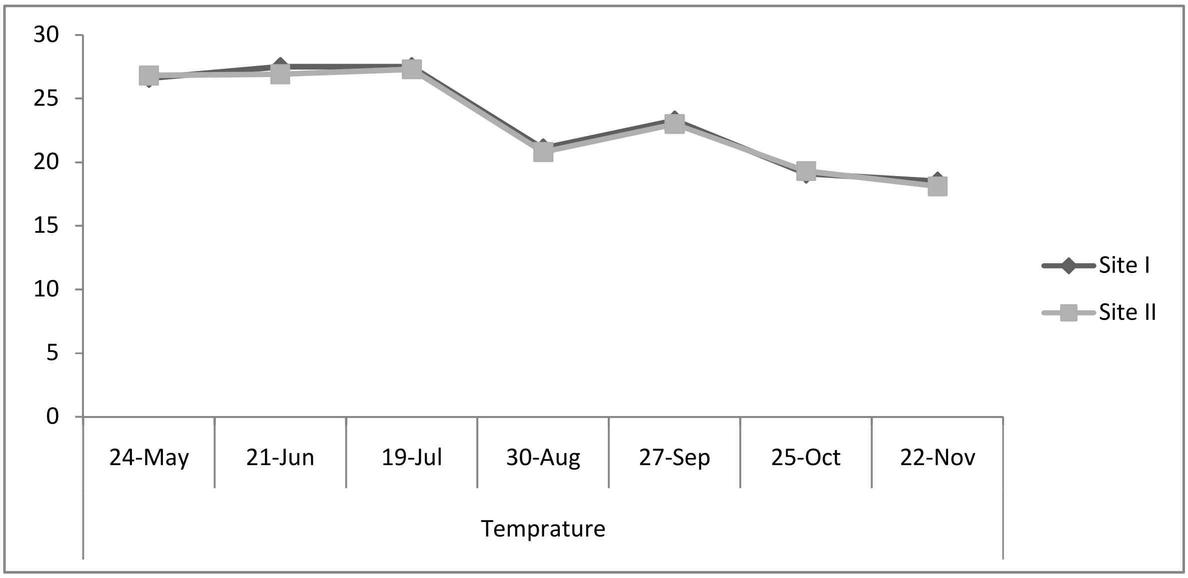

Figure 3: Water temperature (^{o}C) vs. time profile at the study site

The pH of the water ranged from 8.4 to 9.4 whilst the range of the DO measured varies from 4.79 to 7.53 (littoral) and 4.32 to 7.98 (off-shore) (Figure 4). The secchi depth ranged from 88 cm to 124 cm at the littoral site while 89 cm – 130 cm was recorded for open water. High water light transparency was measured in July at the two sampling sites (Figure 5). In spite of the variations in the measurement value at different sampling periods, all the values of physical parameters were not significantly different among sampling sites at 5% probability.

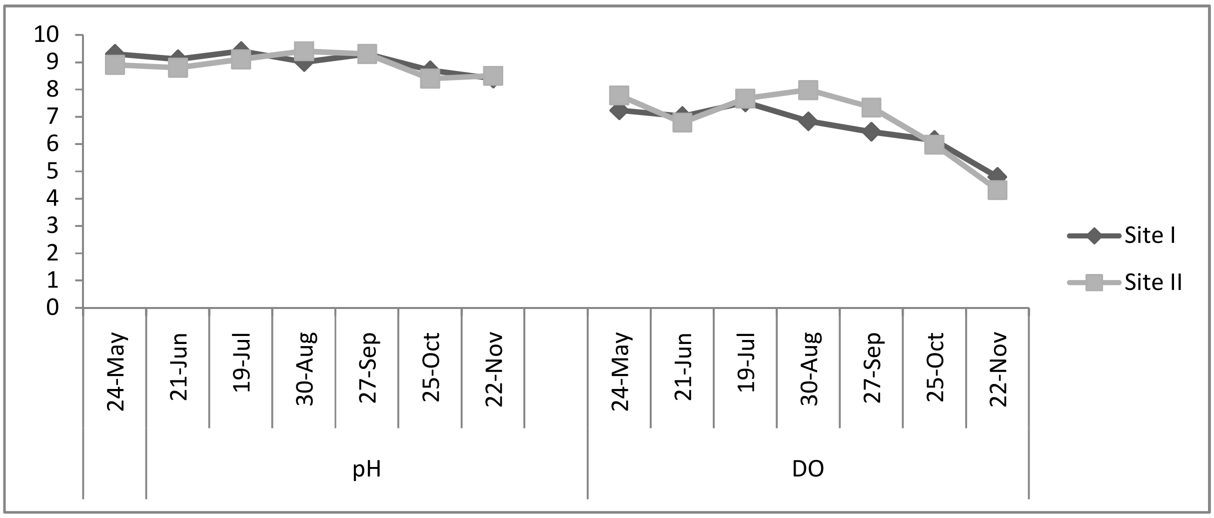

Figure 4: pH and DO (gm/lit) vs. time profile at the study site

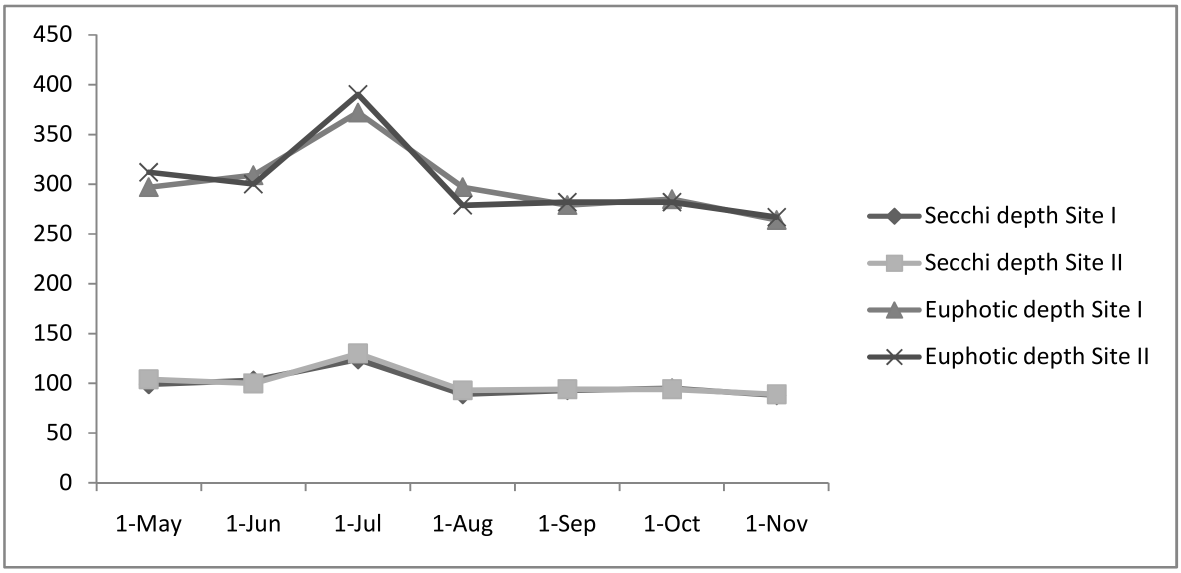

Figure 5: Secchi depth (cm) and Euphotic depth (cm) vs. time profile at the study site

4.1.2. Growth performance

Four kinds of different supplementary feeds were given to triplicates of caged *O. niloticus*, whereas a triplicate caged fish was left for natural foods. Initial and final body weights gain (gm) and lengths (mm) with their net weight gain (kg) and annual production (kg) were measured and are given in Table 6. There was insignificant difference in weight and length of stocked fish at the beginning of the study ($P > 0.05$). There were no significant differences among the triplicates in all the sampling weeks ($P > 0.05$) (Appendix I). Hence, data from triplicate were pooled for each treatment prior to analysis. However, significant statistical differences were found between treatments in terms of final growth parameters ($P < 0.05$).

4.1.2.1. Mean length and weight of the fish

The mean initial length of the fish were 123.36 ± 1.43, 119.71 ± 1.14, 123.57 ± 1.32, 125.00 ± 1.50, and 119.32 ± 1.44 mm whereas the mean initial weight of the fish were 42.92 ± 2.12, 43.51 ± 2.36, 42.98 ± 1.97, 43.27 ± 2.21, and 42.80 ± 2.53 for diet-1 (ROM), diet-2 (RM), diet-3 (MO), diet-4 (RO), and T_0 (non-feeding), respectively. The mean final fish length and weight in all the treatment, at harvest time, were measured and presented in Table 7. As shown in the table, the mean final length of the experimental fish were 180.5 ± 1.43, 181.2 ± 1.57, 184.5 ± 1.34, 171.0 ± 1.61, and 171.4 ± 1.91, whereas the mean final weight of the fish were 197.38 ± 5.57, 169.27 ± 6.31, 182.16 ± 4.12, 146.27 ± 6.82, and 80.62 ± 3.34 for Diet 1, 2, 3, 4, and T_0, respectively. The highest weight gain (197.38 gm) of *O. niloticus* was observed in diet-1 followed by diet-3 (182.16 gm) , diet-2 (169.27 gm) , and diet-4 (146.27 gm). The data were also tested at 5% probability and the growth performance of the fish was significantly affected by supplementary feeding at 100 fish/m^3 cage when they were fed 3% of their body weight. Generally, on the basis of net weight gain and growth parameters the following trend emerged: diet-1 > diet-3 > diet-2 > diet-4 (Figure 6).

The measurement of the control group (T_o) was significantly lower than the ones with supplementary feeds after the first sampling weeks ($P < 0.05$). Until the fifth sampling week, the caged fish fed diet-1 and diet-3 did not show significant variation at 95% confidence interval of

Table 7: Initial and final body weights and lengths, and growth performances of *O. niloticus* in terms of growth parameters for each treatment and the control

Treatment	Stocking density (Fish/m^3)	Final total harvest number	Mean length of initial stock (mm)	Mean weight of initial stock (gm)	Mean length of final stock (mm)	Mean weight of final stock (gm)	Total weight gain (Kg/cage)	Total net yield (Kg/yr)
Diet-1	100	94	123.36± 1.43	42.92± 2.12	180.5 ± 1.43	197.38± 5.57	15.26	30.93
Diet-2	100	88	119.71± 1.14	43.51± 2.36	181.2 ±1.57	169.27± 6.31	12.56	25.49
Diet-3	100	92	123.57± 1.32	42.98± 1.97	184.5 ± 1.34	182.16± 4.12	13.92	27.84
Diet-4	100	88	125.00± 1.50	43.27± 2.21	171.0 ± 1.61	146.27± 6.82	11.67	23.33
T_0	100	80	119.32± 1.44	42.80± 2.53	171.4 ±1.91	80.62± 3.34	3.79	7.56

analysis of variances, however, after the fifth sampling period the variation went to differ significantly ($P < 0.05$) until the end of the experimental periods. The other remaining supplementary feed items, diet-2 and diet-4 showed significant difference after the first sampling week and throughout the entire experimental period. Diet-4 showed the least growth performance in all sampling weeks, whereas diet-1 took the highest growth performance among the tested feed items.

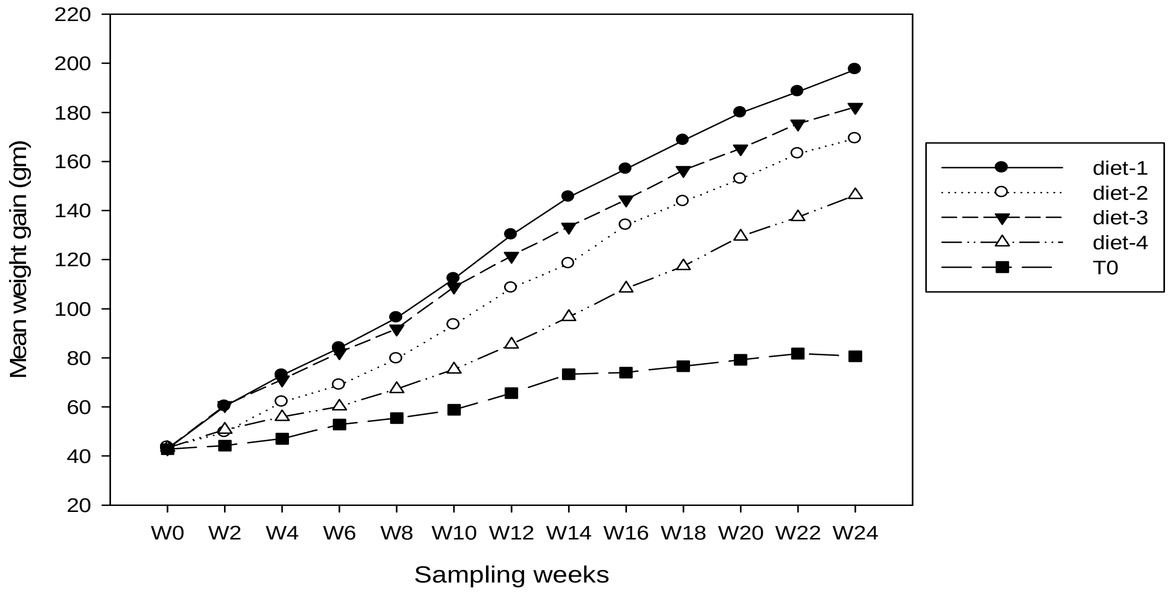

Figure 6: Weight gain measured during sampling weeks of the experimental period

4.1.2.2. Daily Growth Rate (DGR)

For each triplicate treatment, the mean daily growth rate (DGR) was calculated between each sampling period of the study time (Figure 7). The maximum mean of the DGR (0.92 gm/individual/day) was observed in diet-1, and minimum mean of the DGR (0.68 gm/individual/day) was observed in the experimental fish which fed diet-4. The control DGR was 0.28 gm/individual/day. The mean DGR, however, was significantly affected by supplementary feeding ($P < 0.05$).

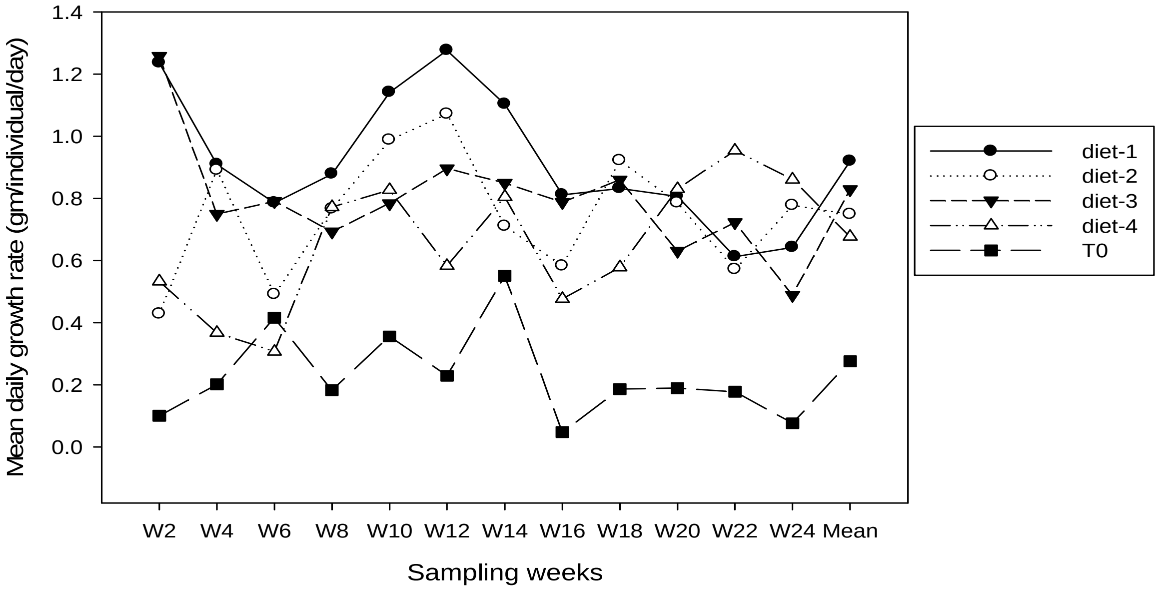

Figure 7: Mean daily growth rate of caged *O. niloticus* in treatments and the control

4.1.2.3. Specific Growth Rate (SGR)

Maximum mean SGR 0.90%/day/fish was exhibited in the treatment with diet-1, whereas the minimum mean SGR was recorded as 0.78%/day/fish in diet-4. The control had the lowest mean SGR of 0.38%/day/ fish (Table 8). The specific growth rate increased from diet-4, to diet-2, to diet-3, and to diet-1(Figure 8). These data were statistically tested at 95% confidence interval and there were significant variation among the treatments. The best SGR was seen by the triplicate caged fish fed with diet-1, whilst the least growth performance among the treatment was recorded in diet-4.

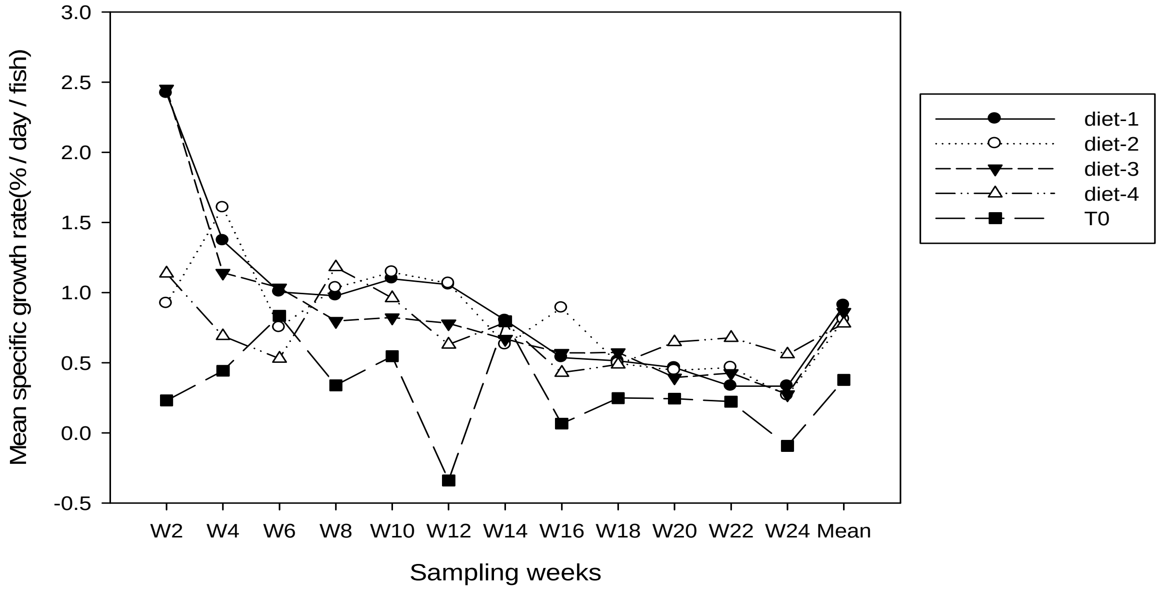

Figure 8: Mean specific growth rate of caged *O. niloticus* in treatments and the control

4.1.2.4. Feed Conversion Ratio (FCR)

The food intake and food conversion ratio of the different feed treatment are shown in Table 8. The food conversion ratio ranged between 1.04 to 8.81 for diet-1 to 1.67 to 11.13 for diet-2, 1.03 to 10.78 for diet-3, and 2.44 to 6.40 for diet-4. The mean FCR recorded in the treatments did not significantly vary to tell the differences of the conversion ratio. However, the best food conversion ratio was seen in the treatment fed diet-1, till week 14, whilst the least FCR exhibited from the experimental cages fed with diet-4 before sampling week 12. Therefore, there was a significant difference of the FCR when the data was tested at 5% probability.

Table 8: Total amount of feed supplied, mean weight gain, feed conversion ratio and feed conversion efficiency of treatments

Parameters	W_2	W_4	W_6	W_8	W_{10}	W_{12}	W_{14}	W_{16}	W_{18}	W_{20}	W_{22}	W_{24}
Diet-1	60.22	72.95	83.94	96.24	112.22	130.09	145.53	156.89	168.54	179.83	188.00	197.38
Dry feed	18.03	25.29	30.64	35.26	40.423	47.13	54.64	61.12	65.90	70.79	75.53	79.12
dry feed/day/fish	1.29	1.81	2.19	2.52	2.89	3.37	3.90	4.37	4.71	5.06	5.39	5.65
FCR	1.04	1.99	2.79	2.87	2.53	2.64	3.54	5.38	5.66	6.27	8.82	8.80
FCE	95.97	50.32	35.90	34.89	39.53	37.91	28.27	18.58	17.67	15.95	11.34	11.36
Diet-2	49.50	61.97	68.84	79.56	93.38	108.38	118.33	134.02	143.62	152.84	163.11	169.27
Dry feed	18.27	20.79	26.03	28.91	33.41	39.22	45.52	49.70	56.29	60.32	64.19	68.51
dry feed/day/fish	1.31	1.49	1.86	2.07	2.39	2.80	3.25	3.55	4.02	4.31	4.59	4.89
FCR	3.05	1.67	3.79	2.70	2.42	2.61	4.58	3.17	5.86	6.54	6.25	11.13
FCE	32.78	59.96	26.38	37.08	41.37	38.26	21.85	31.58	17.05	15.29	15.99	8.99
Diet-3	60.60	71.08	82.15	91.84	108.90	121.44	133.33	144.35	156.38	165.21	175.32	182.16
Dry feed	18.06	25.45	29.85	34.50	38.57	45.74	51.01	56.00	60.63	65.68	69.39	73.64
dry feed/fish/day	1.29	1.82	2.13	2.46	2.76	3.27	3.64	4.00	4.33	4.69	4.96	5.26
FCR	1.03	2.43	2.70	3.56	2.26	3.65	4.29	5.08	5.04	7.44	6.86	10.77
FCE	97.52	41.19	37.07	28.10	44.21	27.43	23.31	19.68	19.85	13.44	14.57	9.28
Diet-4	50.72	55.86	60.15	67.28	75.24	85.38	96.63	108.27	117.28	129.38	137.27	146.27
Dry feed	18.17	21.30	23.46	25.26	28.26	31.60	35.86	40.58	45.47	49.25	54.34	57.65
dry feed/fish/day	1.30	1.52	1.68	1.80	2.02	2.26	2.56	2.90	3.25	3.52	3.88	4.12
FCR	2.44	4.14	5.47	3.54	3.55	3.11	3.19	3.48	5.05	4.07	6.89	6.40
FCE	41.02	24.14	18.28	28.23	28.15	32.11	31.36	28.70	19.79	24.59	14.52	15.61

4.1.2.5. Food Conversion Efficiency (FCE)

The food conversion efficiency (FCE) of the caged fish was highest at the first sampling week for diet-1 and diet -3 (95.97% and 97.52%, respectively) (Table 8). The two combined diet with rice bran (diet-2 and diet-4) were the least in their efficiency to be converted by the fish than diet-1 and diet3. Therefore, the rice bran was re-grinded to increase its digestibility. As a result relative increased FCE recorded after the third sampling time. Generally, the trend of FCE for this study decreased with increasing experimental time.

4.1.2.6. Production at harvest

The final net yields of *O. niloticus*, during 180 days of the experiment, were significantly affected by supplementary feeding ($P < 0.05$). The total average weight gained (production) for each treatment per cage is given in Table 6. Net yield per fish was positively affected by supplementary feeding. Thus, the weight gained (net production) per individual treatment of the feed was highest at diet-1 (197.38 gm/fish), followed by diet-3 (182.15 gm/fish), diet-2 (169.27 gm/fish), and diet-4 (146.27 gm/fish). Furthermore, the net fish biomass was computed for all treatments after harvesting. Total weight gain of the experimental fish had the following measured value at the end of the experiment, i.e. diet-1= 15.26 Kg/cage, diet-2 = 13.92 kg/cage, diet-3 = 12.56 Kg/cage and diet-4 = 11.67 kg/cage (Table 5). The biomass per cage calculated for the control (T_o = 3.79 kg/cage) was significantly lower than the feeding treatments ($P < 0.05$). These net weight gains were also extrapolated in annual net production and the calculated value showed 30.93 kg/year for diet-1, 25.49 kg/year for diet-2, 27.84 kg/year for diet-3, 23.33 kg/year for diet-4 and 7.56 kg/year for the control cages. The result showed that there is significant difference among the treatments in annual net production ($P < 0.05$).

4.1.2.7. Fulton Condition Factor (FCF)

The Fulton Condition Factor (FCF) calculated for each sampling period ranged from 1.81 to 3.57 for diet- 1, 1.69 to 3.15 for diet- 2, 1.75 to 2.90 for diet- 3, 1.56 to 2.96 for diet- 4, and 1.42 to 1.92 for Co (T_0). The initial FCF of the experiment for the treatments ranged from 1.75 to 1.90, which were not significantly different (P > 0.05). Except the caged fish fed with diet-3 all the remaining caged fish measured less during the first sampling time. There were no significant difference between the non-feeding, diet-2 and diet-4 until the sixth sampling period (P > 0.05), however, the FCF after August 30 was significant in all treatments (P < 0.05). The data reveals that there was significant effect of feed quality and culturing period on conditioning factor (P < 0.05), i.e. diet-1 was the better feed regarding this and followed by diet-3 and diet-2. Best Fulton condition was seen in diet-3 from sampling weeks twelve to the end of the study time, i.e. the values were approximately three in these times, while the FCF value of diet-1 was greater than 3. Whereas, in all sampling times the control showed FCF value less than 3.

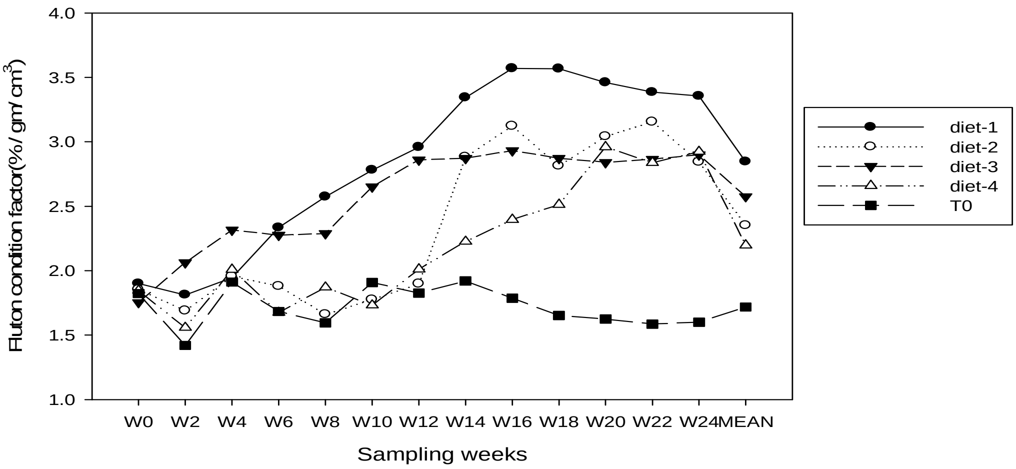

Figure 9: Fulton condition factor of *O. niloticus* in all the treatments

4.1.2.8. Survival Rate (SR)

A majority percentage of the mortality rate, i.e. 20%, was observed in T_o (control cages). The survival rate for those supplemented with feeds, however, ranged from 88% to 94%. These are 94 % for diet-1, 92% for diet-3, and 88% for both diet-2 and diet-4. Before the 5th sampling period and between 7th and 10th sampling times the survival rate was almost 100% (Table 9). Maximum death (high mortality) was registered in between the two last sampling weeks i.e. eleventh and twelfth weeks. This was the time when the temperature of the water fell down and mixing of water took place. Other fish deaths were noted at the tenth and

Table 9: Survival and mortality of experimental caged fish along the experimental period

Treatment	No. of stocked fish	Number of dead fish													Total number of dead fish	No. of harvested fish	%
		7-Jun	21-Jun	5-Jul	19-Jul	2-Aug	16-Aug	30-Aug	13-Sep	27-Sep	11-Oct	25-Oct	8-Nov	22-Nov			
Diet-1	3x100	-	-	-	-	1	-	3	-	-	-	-	5	9	18	282	94
Diet-2	3x100	-	-	-	--	2	2	-	-	-	-	-	14	18	36	264	88
Diet-3	3x100	-	-	-	-	1	2	-	-	-	-	-	8	13	24	276	92
Diet-4	3x100	-	-	-	-	2	1	-	-	-	-	-	9	14	36	264	88
T_0	3x100	-	3	-	-	3	2	-	-	-	3	-	19	30	60	240	80

twelfth sampling time, by the time the measured temperature values were also small and high rain fall was recorded. Generally, in the experimental study survival rate of the fish were not significantly affected by the supplementary feeding in the confidence interval of 95% for diet-1 and diet-3 and also for diet-2 and diet-4, however, along the experimental treatments, there was significant difference ($P < 0.05$) in percentage of survival rate.

4.1.2.9. Sex ratio (Male: Female)

Male to female fish sex ratio at different treatment are given in Table 10. Out of the total stocked 1,500 fish about 1,326 fish (88.40%) were harvested at the end of the experiment, whereas sex-wise 804 (60.63%) of them were males and 522 (39.37%) of them were females. The proportion of male to the total harvested number of fish was 55.09% for diet-1, 56.02% for diet-2, 51.81% for diet-3, 68.79 for diet-4, and 75% for T_o. The growth performance of the males was better than the females ($P < 0.05$).

Table 10: Sex ratio and mean weight of the caged fish with respect to their sex

Treatment	Mean weight of the male	Mean weight of the female	Male to female growth ratio	Mean number of harvested fish	% of the male
Diet-1	201.79 ± 4.32	188.38±5.22	1.071	94	55.09
Diet-2	184.35±5.10	172.59±4.45	1.068	88	56.02
Diet-3	185.97±3.99	170.13±3.35	1.093	92	51.81
Diet-4	165.22±3.25	154.36±4.01	1.070	88	68.79
T_0	83.11±3.67	78.15±3.78	1.063	80	75.00

4.1.2.10. Visceral to Somatic Weight Ratio (VSWR)

At the end of the present study, 15% of the fish were randomly sampled and weighted and then the visceral body of the fish was weighted after removal by dissection. Table 11 showed that the percentage of the visceral body to the total weight gain along the experimental period was significantly different ($P < 0.05$). The largest percentage of the VSWR was found in diet-4 (12.64%) whereas the smallest one was recorded in the control groups (6.10%). The remaining treatments were 7.39%, 8.01%, and 9.56%, in increasing order, in diet-1, diet-3 and diet-2, respectively.

Table 11: Comparison of visceral to somatic weight of the experimental fish

Treatment	Sex	Somatic weight	Visceral weight	% of VSWR	Total percentage
Diet-1	Male	201.79	14.32	7.09	7.39
	Female	188.38	14.51	7.70	
Diet-2	Male	184.35	15.63	8.48	9.56
	Female	172.59	18.50	10.72	
Diet-3	Male	185.97	13.84	7.44	8.01
	Female	170.13	14.67	8.62	
Diet-4	Male	165.22	19.00	11.49	12.69
	Female	154.36	21.57	13.97	
T_0	Male	83.11	4.50	5.41	6.10
	Female	78.15	5.35	6.84	

4.1.3. Plankton

4.1.3.1. Zooplankton abundance

List of zooplankton identified during the study period is presented in Table 12. Rotifers were the dominant species of zooplankton in abundance and diversity regarding both sampling months and the sampling sites, whereas cladeceran were hardly to occur both at the littoral and off-shore in all sampling months. However, there were temporal and spatial significant variations of the zooplanktons abundance at 5% probability (Figure 13). There were also significant variation in abundance among the rotifers, copepods and cladoceran. There was insignificant variation in between the two littoral sites (P > 0.05) but significant variation between littorals and off-shore sites (P < 0.05).

Table 12: Zooplankton taxa identified from Lake Hora-Arsedi

Rotifers	Copepode	Cladoceran
Brachionus angularis^{+}	Cyclopoida	*Moina Micrura* $^{-}$
B. bidentata^{+}	• *Thermocyclops consimilis* $^{++}$	*Ceriodaphnia spp* $^{-}$
B. calyciflorus $^{+++}$	Calanoida	
B. pilicatilis^{++}	• *Paradiaptomus Africana*$^{+}$	
B. quadridentatus^{++}		
B. dimidiatus^{+}		
B. plicatilis^{+}		
Keratella sp^{-}		

+ ++ most dominant, ++ dominant, + common, - rare

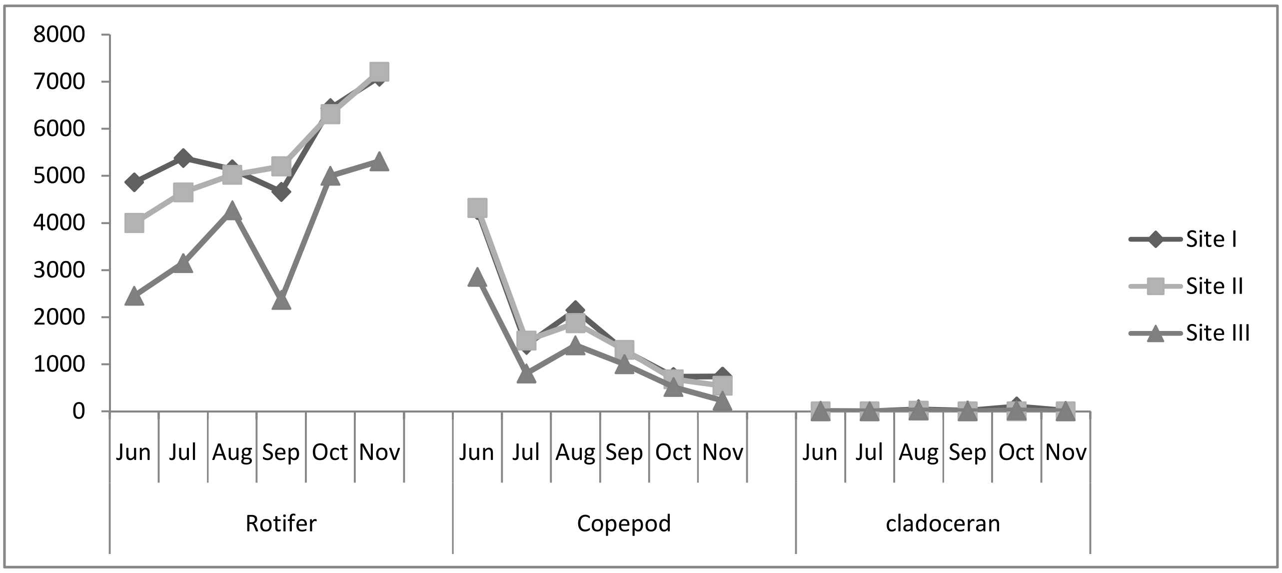

Figure 10: Temporal and spatial zooplankton abundance (N/m^3) of Lake Hora-Arsedi during the study period at littoral and open water

4.1.3.2. Phytoplankton abundance

Five classes of phytoplankton were identified in this study from Lake Hora-Arsedi. These were Cyanophyceae (blue-green algae), Bacillariophyceae (Diatoms), Chlorophycea (Green algae), Euglenophyceae and Cryptophyceae (Crytomondas). These classes were further identified into ten species and seven genera (Table 15). Blue-green algae were the abundant species that reached climax in October (Figure 11). The abundance of the diatoms and green algae increased from July to September and June to September (Figure 12), respectively. The other remaining classes of phytoplankton decreased throughout the study period from June to November (Fig.14).

Table 13: Phytoplankton taxa identified from Lake Hora-Arsedi

Classification	Identified Species
Cyanophyceae (Blue-green algae)	*Microcystis aeuruginosa*$^{+++}$
	Anabaena Raciborskii^{+++}.
	Cylindrospermosis sp^{+}
	Planktolyngbya sp^{+}
Bacillariophyceae (Diatoms)	*Achananthes sp.*$^{+}$
	Fragilaria crotonensis^{+++}
	Cyclotela sp.$^{+}$
	Cymbella sp.$^{+}$
	Synedra nana $^{+}$
Chlorophycea (Green algae)	*Pediastrum simplex*$^{+++}$
	Scenedesmus sp.$^{++}$
	Chlamydomonas sp.$^{++}$
	Kirchnerilla sp.$^{+}$
	Phacatus lenticularis^{++}
	Staurastrum sp.$^{+}$
Euglenophycaeae	*Phacus longicauda* $^{+}$
Cryptophyceae (Crytomondas)	*Cryptomonas ovate*$^{++}$

+++ most dominant, ++ dominant, + common

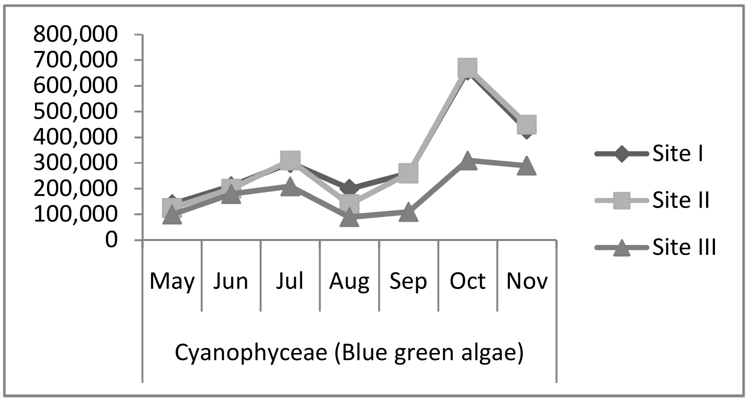

Figure 11: The dominant species of phytoplankton species (Cyanophyceae) in N/lit during the study period

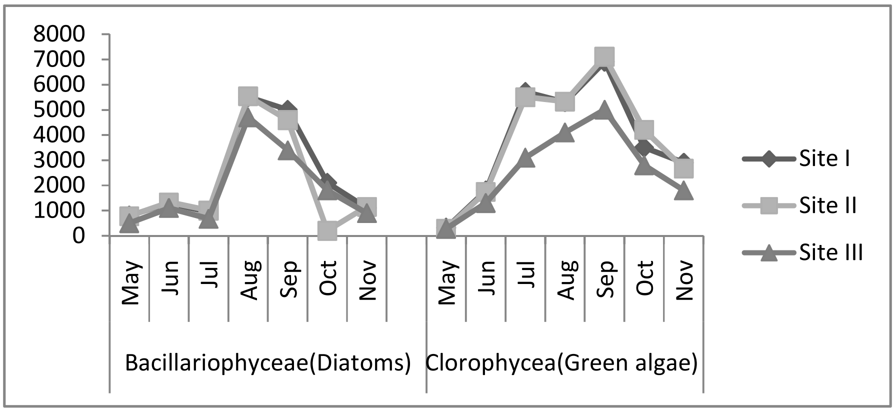

Figure 12: Abundance of Bacillariophyceae and Chlorophyceae

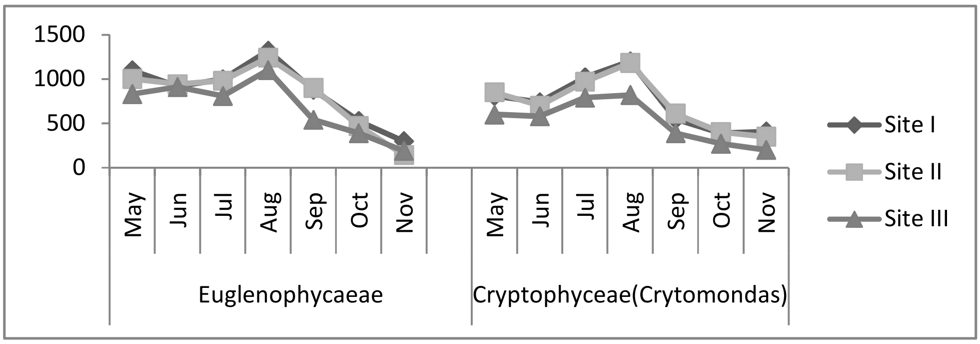

Figure 13: Abundance of Euglenophycaeae and Cryptophyceae

4.1.3.3. Economic Analysis

A total of 722 kg feed ingredients were used to prepare the food, i.e. 144 kg of blood and bone meal, 184 kg of rice bran, 191 kg of oil seed cake and 202 kg of mill sweeping. The price of blood and bone, rice bran, oil seed cake, and mill sweeping were cost 5, 0.80, 2.50 and 2 birr /kg, respectively. Therefore, 1,753.20 Birr was paid to buy the whole ingredients of the fish feed of this study (Table 13). Since, the fingerlings were collected from wild and assuming the labor cost might be covered by the farmer itself, the ICA equals the cost of feeds plus construction cost and material cost. To construct twenty meter walkway (jetty) and fifteen 1 m^3 net cages, as per this experiment, an estimated capital of 19,200 Birr is needed. Producing twice a year, the service year of the installation is expected to be eight years. Therefore, dividing the construction and material cost for the service years gives 1,200 Birr in each culturing period. Further analyzing the share of 1,200 Birr construction and material cost for the four treatments and one non-feed triplicates valued 240 birr for each. The current fish price per kilo gram is 30 Birr. Therefore, the total PV and NPV were calculated as 6148.83 and 3195.43 Birr, respectively (Table 15).

Table 14: The amount and proportion of feed ingredients used for this study

Treatments	Amount of feed given (kg)	Proportion of the ingredients used (in kg)			
		Blood and bone meal	Rice bran	Oil seed cake	Mill sweeping
Diet-1	206	41	55	55	55
Diet-2	175	35	70		70
Diet-3	194	39		77	77
Diet-4	148	30	59	59	
Total	722	144	184	191	202

Table 15: The economic analysis parameters of feed used in this study

Treatment	Cost of feed	ICA	PV	NPV
Diet-1	496.50	736.50	1667.72	931.22
Diet-2	371.00	611.00	1340.62	729.42
Diet-3	541.00	781.00	1401.56	620.56
Diet-4	344.70	584.70	1158.46	573.76
To	0.00	240.00	580.47	340.47
Total	1,753.20	2,713.20	6148.83	3195.43

4.2. Discussion

Obtaining fingerlings from the wild has some disadvantages: it disturbs the natural stock, difficulty of collecting the same year group (cohort group) and failure to have mono sex (only male sex is preferred for culturing). Particularly, the starved fish having equal size with the required fingerlings size grew faster when they are provided with supplementary feeds by compensation growth and this leads the standard deviation to vary largely. For example, the standard errors in final measurement of the harvested fish were also varied largely than the stocked initial weight measured value (Table 6).

According to McGinty (1991), the possibility of the wild fish to enter the cage is unlikely, however, the researcher observed some fish smaller than the size of the caged fish since the 6^{th} sampling week around feeding tray while the caged fish provide their daily ration. This was also reported by Ashagrie Gibtan *et al.*, (2008). The presence of these small sized fish inside the cage may have influenced the result obtained since these wild fish were at fry and fingerling stage and compete for the supplementary feed given to the experimental fish. The wild fish will not only enter to the cages and compete for the fish feed and influence the density of the stocked fish, but also they were attracted to the outer wall of the cages. According to Ashagrie Gibtan *et al.*, (2008) this attraction to the outer side of the cage has its own merit in preventing sedimentation of wasted feed and minimizing the effect of feed on the natural environment, like nutrient loading when it is in large scale of production.

4.2.1. Physico-chemical parameters

The present study started in May and extended to heavy rain season and completed in dry season, after one week of fingerling collection and additional ten days of acclimatization. Especially, in the last two months of the research, there was some problem of caged fish kill as a result of lake mixing that could be as a consequence of heat loss to clear night skies during the dry season (Lamb, 2001). Therefore, for deep lake like the study site, vertical mixing is expected during dry season due to reduction in water temperature. Thus, stocking seasons need to consider the time of harvest to minimize fish deaths.

Though the water temperature range is between acceptable ranges for tilapia survival [capable of tolerating temperature from 8^0C to 42^0C (Trewavas 1983)], tilapia shows better growth performance at water temperature in between 25^oC to 33^oC (Guerrero, 1985). Probably due to low crude protein content of the diets, low water temperature and heavy rainfall, there was relatively decreased maximum growth performance within the six months time interval when compared with previous similar study by Belsti Fetene (2008). The pH of the lake was equivalent to Abebaw Wendie (2006) and Tigist Wubshet (2010) who reported the range of 8.6 to 9.3. The optimum range of 6.5 – 9.0 of pH is recommended for warm water fish culture (Sophin, 2001). However, better growth of *O. niloticus* is expected from pH level of 6.8 to 8 (Coche, 1982).

Suspended and dissolved solids, re-released chemicals from the sediments and fish respiration may affect water chemistry (Shakouri, 2003). Oxygen consumption by mass fish in a cage could be significant; for example, according to EAO (1996) report in one cubic meter of cage the demand would be 500 gm of O_2/day. Though DO level at 25 cm below the surface at the two sampling sites showed insignificant difference ($P > 0.05$), this research did not analyze the difference at depth and the impacts of adding supplementary feed to the bottom fauna. However, due to severe accumulation of biological and chemical processes in enriched sediments, the water next to the bottom may be affected, particularly in deep and stagnant waters with low exchange rates (EAO, 1996). According to Nash, (2001), for example, in salmon cage culture, DO concentrations decline to a critical level for benthic fauna. In this study, the effect of supplementary feeds to the bottom strata in cage culture system of Nile tilapia was unknown.

4.2.2. Growth performance

According to Levell, (1989), feed quality, energy content of the diet, physiological status of the fish, reproduction state, stocking density, sex, and the environmental factors such as temperature, pH, DO, etc influence the growth performance of tilapia (*O. niloticus*). Coche (1982) had explained that when natural food is insufficient but still an important part of the diet, supplementary feeding is practiced with relatively low cost, locally available agricultural by-product. This study, therefore, tried to test four different, low cost, locally available, and plant source supplementary feeds so as to contribute to the tilapia aquaculture practice of the country. However, according to Foutainhas-Fernandes *et al.*, (1999), complete replacement of fishmeal partially or totally with plant protein in particular diets of varies warm water fish has had varying degree of success. It is generally observed that plant proteins have lower nutritive value than fish meal and high levels of inclusion of plant protein usually results in reduced growth and feed efficiency. The ability of fish to utilize plant proteins also differs among species. Taking this into account there was an attempt to enhance fish growth by incorporating blood and bone meal (crude protein, 52%) to all the formulated diets. This is also credited for solving the limitation of phosphorus in the diets.

Proximate analysis of the feeds tested in this experiment showed that the test feeds differed in nutritional quality and efficiency in promoting the growth of *O. niloticus*. This study, like similar study done by Belsti Fetene (2008) in the country, found that the quality of the supplementary feeds significantly affect the growth performance of the caged fish without affecting the water quality for at least at experimental level. Other studies by Abebe Tadesse (2008), Ashagrie Gibtan *et al.,* (2008), Kemal Mohammed (2007), Abdillahi Dill (2010) and Solomon Hailu (2008) who did their experiments on stocking densities, feed quantity and feed quantity of different lakes and reservoirs also mentioned that supplementary feed increases the growth performance of *O. niloticus* without harming the water quality.

In the present study, relative comparisons of growth performance of *O. niloticus* in response to supplementary feeds showed that caged-fish fed with diet-1 (rice bran – oil seed cake - mill sweeping) attained best growth (197.38 gm), whilst caged-fish fed with diet-4 (rice bran-oil seed cake) exhibited the least growth performance (146.27 gm) though the crude fiber and crude fat in the former diet and crude protein percentage in the latter diet is greater. Against this finding, Lenna *et al*., (2004) has verified that it is possible to use, in the diet, levels up to 12.00% of crude fiber and its excess tends to decrease the weight gain and the protein efficiency rate, besides worsening the feed to gain ratio; the fiber significantly affect the dietary apparent digestibility, with positive and negative effect on the protein and dry matter digestibility, respectively, and without effect on the ether extract digestibility; the crude fiber did not significantly affect the carcass yield and the eviscerated fat deposition. The possible justification of the better growth performance of the caged tilapia supplemented with diet-1 might be nutritional contents of the diet; that is the fish might obtained plant protein from different sources for essential amino acids. This can be explained more probably due to more favorable EAA balance than the other diets

(diets- 2, 3, and 4). The one missed in either of the feed might be found in the third ingredient. The non-fed triplicates were the ones who perform lowest growth (80.62 gm) than fed fish.

Study by Belsti Fetene (2008) proved lower nutritional value for 100% oil seed cake (protein, 36%) than mill sweeping (protein, 12.5%) and chicken dung (protein, 23%). Earlier study by Liti *et al.,* (2005) also compared rice bran with two locally formulated feeds and observed lower growth in the rice bran. In the present study, the lower growth performance was observed in the mix feed of oil seed cake and rice bran (diet-4) than the other formulated feed types. These findings revealed that mixed feed of these two plant protein sources or either of rice bran or oil seed cake in 100% proportion did not favor growth of *O. niloticus*. Other studies done on seed meal and seed cake of cotton reported that lower growth rates and feed efficiency in *O. niloticus* and *O. aureus* than fish fed with fishmeal based diets [Ofojekw and Ejike (1984) and Robinson *et al*. (1984a) cited in Belsti Fetene (2008)]. They concluded that the poor response was attributed to the presence of gossypol, a toxic component for mono-gastric animals and cyclopropionic acids contained within cotton seed meal. Further, a low availability of lysine limits the nutritional value of this protein source [Jauncey and Ross, (1982); cited in Belsti Fetene (2008)]. Generally, the reasons for poor growth performance of the fish might be: a) presence of ant-nutritional factors or toxic substances, b) improper balance of essential nutrients such as amino acid, energy and minerals c) presence of high amounts of fiber and carbohydrate, d) decrease of palatability of the feed, e) reduction of pellet quality especially their water stability and, f) the uncontrolled environment.

In spite of having small amount of crude protein, diet-3 (mill sweeping-oil seed cake) ranked second in increasing the growth of tilapia. This might be credited for the presence of essential amino acids and least content of crude percentage and crude fiber in the formulated diet. It is most important to take into consideration that plant source proteins are low in content (Oresegum and Alegbeleye, 2001; Ibiyo and Olowosegun, 2004), amino acid imbalance (Eyo, 2001) and presence of anti-nutritional factors (Oresegun and Alegbeleye, 2001). Though the present study deals with low percentage of crude protein plant source diets, it did not check the composition of EAA in the diets and also the anti-nutrition effect of the diets. Regarding this, further study needs to be conducted.

In this study, mean DGR was observed in the range between 0.68 gm/day in diet-4 to 0.92 gm/day in diet-1 for those that are supplemented with feed and 0.28 gm/ day for the non-feed cages. These mean DGR values are relatively smaller than the previous cage culture researches done in Ethiopia. For example, Abebe Tadesse (2007) and Ashagrie Gibtan *et al.,* (2008) reported 0.82 to 1.26 gm/day. This difference could be attributed to probably the difference in culturing season besides the difference in feed quality mentioned above. The present study started just before the rainy season, passed the high rainfall time and extended to the dry season whereas all the other researches were done either immediately after the rainy season or in dry season and extends to the just before the rain season. Chervinski and Lahav, (1997) mentioned that exposure to reduced temperature leads to reduced DGR and mass mortality. They also explained wintering as a serious economic challenge in major tilapia producing countries such as China and Egypt. In addition to the nutritional values of the diet the culturing season might affect the growth of the fish. For example, with decreasing water temperature from 30 to 20^{o}C, Francis *et al*., (2001) observed declined fish daily growth rate from 2.5 to 1.3 gm/day.

The SGR for *O. niloticus* was 0.91, 0.85, and 0.81 %/day/fish, respectively, for diet-1and diet-3. The SGR of the control was 0.38%/day/ fish. For *Tilapia rendalli,* in agreement to this study, the specific growth rate was 0.83, 0.97, and 0.87 % day^{-1} in earthen ponds that were fertilized with chicken manure (100%), maize bran (25%) + chicken manure (75%), and Maize bran (100%), respectively (Mataka and Kangombe, 2007).

FCR is a reliable indicator, which integrates all farming condition into a qualitative scale. Lower FCR means less input of organic matter and consequently less wastage (Shakouri, 2003). Nevertheless, this study was not considered the natural fish feed found in the lake which brought about average 37 gm growths in the control during the study period while calculating the FCR and FCE. In addition to this, solubility of the pellet was not tested and the un-eaten feeds were not re-collected and measured to have the figure of the ingested food by the fish. Anyhow, the least value of FCR was calculated from diet-1, diet-3 then diet-2. From September on wards, the FCR become increasing to a large number with decreasing the temperature of the water. The higher protein composition was in diet-4, but it showed lower FCR. Wee and Wand (1987) also observed very poor FCR values while they fed high level of plant sources crude protein to tilapia. According to Al-Hafedh (1999), FCR values decreased with increasing protein level. Similar to this report, the present study showed better FCR in diet-3 and diet-2 than diet-4 (protein, 24.28%). This is probably due to the higher composition of the fiber in rice bran and oil seed cake and also it might favor fat accumulation than body building in diet-4. It is also very important to find out if there is anti nutritional effect of the feeds and the presence of essential amino acids (EAA).

The present observation found out better food conversion efficiency in diet-1 and diet-3. Diet-2 and diet-4 had FCE smaller than diet-3 though percentages of their crude proteins are large. Siddiqui *et al*., (1988) reported that feed conversion efficiency increased with increasing protein level up to 40% and then decreases for the diet containing 50% protein in culturing *O. niloticus*.

There is a direct link between supplementary feed and total production, i.e. good quality of the feed brings highest biomass gain. This is in agreement with that reported by Belsti Fetene (2008) who conducted similar study with different feed combination and other studies conducted by Abebe Tadesse (2008) and Ashagrie Gibtan *et al.,* (2008) who worked on stocking density. The annual estimated production ranged from 7.56 kg/ year for non-fed to 30.93 kg/ year for diet-1, respectively, which signifies the effectiveness of the supplementary feed in the culture system. However, these values are relatively less than the previous study by Belsti Fetene (2008) who extrapolated annual production of 41.67 kg/year. This difference was probably the combination of mixed feed he used to obtain this production (chicken dung-mill sweeping) might favor increased tilapia growth and/or the experimental season difference might bring the differences in growth performance.

This study indicated a significant effect of feed quality on condition factor. Keeping length constant, the heavier the fish the better its condition is. Fish condition or well-being (fatness of the fish) has a large influence on growth, survival and reproduction of fish population (Lambert and Dutil, 2000). Best mean FCF of the present study was recorded in diet-3 (which was approximately equal to three gm/cm^3 after twelfth sampling week, Figure 9). This was relatively better FCR than the best feed of this experiment and study by Ashagrie Gibtan *et al.,* (2008) who reported 5.64 for 100 fish per cubic meter cage. However, the FCF value for diet-1 was greater than three after the twelfth sampling week. This showed that the fish increased in weight being reduced in length. The difference between the conditioning of the fish in all treatments indicates the presences of quality difference in the feeds given to respective treatments. The FCF value that equals to three indicates that the growth with respect to their weight and length is proportional. This is as a consequence of good quality and highly digestible feeds (diet-1 and diet-3).

In all the treatments, the harvested male population was greater than the female population. It ranges from 51.81 to 75%, whereas the proportion of the males to the females ranges from 1.063 to 1.093 for 75% and 51.81%, respectively. With regard to their final weight gain the males grow better than the females in all the treatments (Table 9). Previous research by Liti *et al.,* (2005) mentioned that males have better growth performance than females. Similar result was found by the studies done in Ethiopia by Ashagrie Gibtan *et al.,* (2008) and Belsti Fetene (2008). Relative higher growth of the male than the female is possibly due to increased energy being channeled towards metabolic maintenance and somatic growth in males while the females use their energy from the diets for spawning (Tran-Duy *et al.*, 2008). There is other study by Dan and Little (2000) which showed enhanced yield of mono-sex male Nile tilapia population under experimental condition in pond system. The predominant advantage of mono-sex culture is in those aquaculture situations where one sex displays marked growth superiority.

In the case of tilapia species, females are mouth brooder and certainly they need nest to undergo fertilization, however, during sampling times the researcher has found some females fish caring eggs and young fry in their mouth. This might have starved them and could be considered as possible reason for reduced growth than their male counter-parts (Liti *et al*., 2005).

In tilapia, prior acclimatization temperature and rate of temperature reduction are considered as important factors in determining mortality (Stauffer *et al*., 1988). In the present study, there were two times when considerable fish death was observed (Table 8); the former was at the time when the rainfall was high and the latter was while the temperature of the water was reduced to a minimum, and therefore, the lake undergone vertical mixing. Similarly, at the middle of his experiment, Belsti Fetene (2008) observed that some fish died due to water temperature fall in November and December. However, the first two well performing treatments with respect to weight gain and growth parameter (diet-1 and diet-3) exhibited less mortality whilst the non-fed treatments (T_o) showed high mortality. This can be credited for the better feed quality. Other study by Stauffer *et al*., (1988) suggested that by increasing fish conditioning factor, one can increase winter survival of *O. niloticus*.

The supplementation of high dietary lipid levels decreases the carcass composition and result in higher gut fat deposition (Lenna, *et al.*, 2004). In agreement to this, the greater fat accumulation in the gut was observed in diet-4 than diet-2 and diet-3, but diet-1 had lower VSWR despite its higher crude oil in the diet. This could be probably due to fat accumulation than using the feeds to build their body make up. On the other hand, diet-1 had lesser percentage of VSWR (7.39%) although it has maximum composition of crude protein and crude fat/oil. This is also supported by the maximum amount of weight gain by the treatment than all the others. The more the varieties of plant source for fish diet the less is the fat accumulation and better growth. The least percentage of the VSWR (6.10%) was measured in the control (T_0). This may be that the natural feed of the lake has too small oil to be accumulated.

4.2.3. Plankton

The abundance of planktons in either of the sites around littoral areas of the lake showed insignificant variation ($P > 0.05$). This insignificant plankton variation, besides the phsico-chemical parameters, probably explained lesser impact of the cage culture to the lake at least at experimental level. However, plankton counts at the offshore had lesser abundance. This might not be as a consequence of the feed given to the fish.

Similar to findings of Tamiru Gebre (2006), there was an interesting shift in time in the abundance of zooplankton groups in Lake Hora-Arsedi. Rotifers were the dominating species among the zooplankton community in this study; they increased in abundance across the experimental period while the copepods decreased with increasing duration of this study. Cladocerans were found in very small amount than others.

Blue-green algae were the dominant phytoplankton among the identified phytoplankton. They showed increment from May to July then fall down to a minimum number in August and September then continue to increase in dry season after September. Similar to findings of Tamiru Gebre (2006), this study showed relatively greater count of diatoms and chlorophytes from August to September. Earlier studies by Abebaw Wendie (2008) and Tigist Wubshet (2010) explained that blue-green algae dominate the phytoplankton community of the lake. They also stated that diatoms and green algae become quantitatively very important when rainfall is high.

The high rainfall flushes blue-green algae out for some time. The other classes of phytoplankton, euglenopyceae and cryptophyceae, were found in small amount along the experimental period. They decreased from May to July then increased to climax in August. Finally, their abundance falls down up to the end of this experiment.

4.2.4. Economic Analysis

Lack of hatcheries in the country makes the source of seed from wild for aquaculture practices. Assuming the labor costs were covered by the farmer itself, the economic returns are high enough to justify investment in Nile tilapia culture using locally available feed ingredients. For example, for this study assuming 100% survival and applying diet-1 or diet-3, respectively, in all the fifteen cages can bring a Net Profit Value of 7,670.85 Birr and 6417.16 Birr. From the control caged (non fed fish), keeping the fish in the entire fifteen cages can also expected to give a net profit of 2,427.90 Birr. However, the success of the formulated fish feeds for cage culture will depends on the large scale production with the availability of fingerlings and netting materials. Perhaps, the results are expected to have a wide range of application in different lakes and reservoirs of the country.

5. CONCLUSIONS AND RECOMMENDATIONS

In this study, locally available plant source diets were incorporated into the diet of Nile tilapia (*O. niloticus*) and tested against each other (without fishmeal). With respect to mean weight gain and all growth parameters (DGR, SGR, FCR, FCE, FCF, VBWR, and SR), the best result was achieved in “rice bran - oil seed cake - mill sweeping” (diet-1) followed by “mill sweeping - oil seed cake” (diet-3). The difference in mortality rate of caged fish seems to show significant variation among the treatments and the control (it was only 6% in the best diet of the experiment while 20% in the control). The net annual productions obtained from treatment fed diet-1 (30.93 kg/year) and diet-3 (25.49 kg/year) can be scaled up to net annual production of 32.90 kg/year and 30.26 kg/year, respectively, for 100% SR. Therefore, this study concludes that diet-1 and diet-3 are the best diets preferred by *O. niloticus* in terms of all growth parameters.

Generally, a mixture of ‘rice bran’, ‘mill sweeping’, and ‘oil seed cake’ together with bone and blood meal can be used as substitute of fishmeal in cage culture of tilapia. In the absence of ‘rice bran’ which is not available in many parts of the country ‘mill sweeping and oil seed cake’ and blood and bone meal can be used as acceptable ingredients for formulation of fishmeal from locally available cheaper ingredients.

On the other hand, the triplicate fed with “rice bran-mill sweeping” (diet-2) showed good performance with respect to weight gain and growth parameters, however, it performed much less than diet-1 and diet-3. Diet-4, which was formulated from ingredients of ‘rice bran-oil seed cake’, showed least performance in all acceptable values of parameters.

Monthly water physical and chemical measurements at the study sites and plankton diversity and abundance at the study sites showed that the cage culture experiment did not bring significant adverse effect to the water quality and plankton abundance.

However, several complications arose during the study period that precluded accurate comparison and effect on the growth performance of the four tested feed. Among these, the absence of healthy cohort and hatchery derived mono-sex fingerlings, the entrance of small sized wild fish into the cages and incubation of females’ eggs and young fry were the major ones. In addition to this the essential amino acids needed by the fish were not analyzed in the diets. Based on the above findings of the study the following recommendations were forwarded:

- In future studies, it is important to determine digestibility and palatability of the tested diets and the presence of the essential amino acid in the diets chosen as an alternative of fish feed ingredients. There is also a need to determine the best production and processing method of the diets to ensure the availability of consistent quality product.

- The incubation of eggs and fry by the female fish in cage culture was not understood in this study. Therefore, future study should need to incorporate how females incubate egg and fry in their mouth in cage culture system and also the effect of non-caged fishes to the caged fish with respect to feed computation.

- Similar to results of other studies, no adverse effect of the experiment on the lake water quality and plankton abundance was observed; this needs to be studied when the cage culture is intensive. Besides, samples should be taken from different grab to analyze the organic matter, total organic carbon, total nitrogen and phosphors in different depth of station at various distances from the cage to indicate localized impact of cage farming to the environment.

- It is strongly recommended that there should be hatchery and nursery sites in the country so as to commence aquaculture and for its development. In addition to this, there should be netting material to construct and maintain cages and also effectiveness of feeding trey needs to be studied.

6. REFERENCES

Abebaw Wondie (2007). Temporal dynamics of biomass and primary production of Phytoplankton in relation to some physico-chemical variables in Lake Hora-Arsedi, Ethiopia. M.Sc. Thesis, School of Graduate Studies, AAU. Addis Ababa.

Abebe Getahun (2003). *The Nile in the Ethiopian Territory: Riverine fish and fisheries*. AAU, Ethiopia.

Abebe Getahun and Stiassny, M.L.J (1998). The fresh water biodiversity crisis: the case of the Ethiopian fish fauna, *SINET: Eth. J.Sci*. **21(2):**207-230.

Abebe Tadesse (2007). The effect of stocking density and supplementary feeding on growth performance of Nile tilapia [*Oreochromis niloticus* (L., 1758)] in cage culture system in Lake Elen, Ethiopia. M.Sc. Thesis, School of Graduate Studies, AAU. Addis Ababa.

Ageze Abza (2009). Secondary production of the dominant zooplankton in relation to some physico-chemical and biological factors in Lake Hora, Ethiopia. M.Sc. Thesis, School of Graduate Studies, AAU. Addis Ababa.

Abdilahi Dill (2010). The effect of stocking density and supplementary feeding on growth performance of Nile tilapia [*O. niloticus* (L., 1758)] in cage culture system in Wenji Reservoir, Ethiopia. M.Sc. Thesis, School of Graduate Studies, AAU. Addis Ababa.

Al-Hafedh, Y. S. (1999). Effects of dietery protein growth and compostion of Nile tilapia (*Oreochromis niloticus L.). Aquacult. Res*. **30:**385-393.

Ashagrie Gibtan, Abebe Getahun and Seyoum Mengistou (2008). Effect of stocking density on the growth performance and yield of Nile tilapia [*Oreochromis niloticus (L., 1758)*] in a cage culture system in Lake Kuriftu, Ethiopia. *Aquacul. Res*. **39:**1450-1460.

Bagenal, T.B. and Tesch, F.W. (1978). *Methods for assessment of fish production in freshwaters.* Blackwell Scientific Publication ltd. London, England. 101 – 136pp.

Balogun A. M., Bello-Olusoji O. and Fashakin E.A. (1992). *Protein and amino-acid requirement of warm-water fishes: A tool to the effect and low cost fish feed production in Nigeria*. Proc. 10th FISON Conference. Abeokuta, Nigeria. 95-104pp.

Balarin, J.D. and Halton, J.P. (1979). *Tilapia: A guide to their biology and culture in Africa*. University of Stirling. 21-30 pp.

Bardach, E., Ryther, H., and McLarney, O., (1972). *Aquaculture: The farming and Husbandary of Fresh Water and Marine organisms*. John Wiley and Son. New York. 47-37pp.

Baxter. R.M. (2002). Lake morphometry and chemistry. **In:** *Ethiopian Rift Valley Lakes*. (Tudorancea, C. and Tylor, W.D., eds). pp. 45-60, Backhuys Publishers, Leiden, The Netherlands.

Baxter, R.M. and Wood, R.B. *(*1965). Studies on stratification in Bishoftu crater lakes. *J. appl. Ecol.*, **2**:416 - 423.

Belstie Fetene (2008). 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. M.Sc. Thesis, School of Graduate Studies, AAU. Addis Ababa.

Beveridge, C. and Stewart, K. (2002). *Management and Practice in Cage Culture*. FAO. Rome. 423p.

Beverage, M. C. (2004). *Cage Aquaculture*. 3rd ed. Oxfored. UK, Blackwell Pub. Ltd.

Beveridge, M. C. (1984). *Cage and pen fish farming. Carrying capacity model and environmental impacts*. FAO Fisheries technical paper. Rome. **255**:131.

Beveridge, M., (1996). *Cage Aquaculture*. (2nd edition). Fishing News Book.

Bilio, M., (2008). *Controlled reproduction and domestication in aquaculture*. European Aquaculture Society. Oostende. 36 p.

Blow, P. and Leonard, S. (2007). A review of cage aquaculture: sub-Saharan Africa. **In:** *Cage aquaculture – Regional reviews and global overview* pp. 188–207. *(*Halwart, M., Soto D. and Arthur, J.R. eds.*), FAO Fisheries Technical Paper*. No. 498., FAO. Rome

Bocek, A. (1996). *Water Harvesting and Aquaculture for Rural Development*. International Center for Aquaculture. Auburn University. USA.

Boyd, C. (1990). *Water Quality in Ponds for Aquaculture*. Alabama Agriculture Experiment Station. Auburn University. Alabama. USA.

Breuil, C. (1995). *Review of the Fisheries and Aquaculture Sector: Ethiopia*. FAO Fisheries Circular. Number 890. Rome. 29p.

Chapman, F. (2006). *Culture of Hybrid Tilapia: A Reference Profile*. University of Florida. Institution of Food and Agriculture Science. USA.

Chervinski, J., and Lahav, M. (1976). The effect of exposure to low temperature on fingerlings of local tilapia (*Tilapia aurea*) (Steindacher) and imported tilapia (*Tilapia vulcani*) (Trewavas) and *Tilapia nilotica* (Linne) in Israel. *Bamidgeh.* **28**:25 -29.

Coche, A. (1982). Cage culture of tilapia. **In:** *The Biology and Culture of Tilapia,* 205-246pp. (Pullin, R. and Lowe-Mcconnel, R.eds.*)*. ICLARM conference Proceeding 7. Manila. Philippines.

Conway, D., 1997. A water balance model of the Upper Blue Nile in Ethiopia. *Hydrolog. Sci. J.* **42**: 265–286.

Cruz, P. (1997). *Aquaculture feed and Fertilizer Resource Atlas of the Philippines*. FAO Fisheries Technical Paper. Rome.

Dadzie, S.L. (2006). An overview of aquaculture in Eastern Africa. *Hydrobiologia*. **232**:99 -110.

Dan N.C. and Little D.C. (2000). The culture performance of monosex and mixed sex new-season and overwintered fry in three strains of Nile tilapia (*Oreochromis niloticus*) in northern Vietnam. *Aquaculture.* **184**:221-231.

Delgado, C.L., Wada, N., Rosengrant, M.W., Meijer, S. and Ahmed, M. (2003). *Fish to 2020: supply and Demand in Changing Global Market*. International Food Policy Research Institute (IFPRI), Washington and WorldFish Center, Penang, Malaysia. 226pp.

De Silva, S.S. and Davy, F.B., (2007). Aquaculture Successes in Asia: Contributing to Sustained Development and Poverty Alleviation. Pp. 1-15 **In**: *Success stories in Asian Aquaculture*. (De Silva, S.S. and Davy, F.B., eds.). Springer. Bangkok, Thailand.

De Silva, S.S. (2001). A global perspective of aquaculture in the new millennium. ***In****: Aquaculture in the third millennium* (Subasinghe, R.P., Bueno, P., Philliops M.J., Hough, C., McGladdery S.E., and Arthur R. (eds.).) 431-459. Technical Proceedings of the conference on Aquaculture in the third millennium. NACA. Bangkok, Thailand.

Diana, J., Lin, C. and Jaiyen, K. (1994). Supplemental feeding of tilapia in fertilized ponds. *J.Wor. Aquacult. Soc*. **25:** 497 - 506.

Diana, J.S., Lin, C.K., and Schneeberger, P.J. (1991). Relationships among nutrient input, water nutrient concentrations, primary production, and yield of *Oreochromis niloticus* in ponds. *Aquaculture.* **92:**323-341.

DIAS (2004). Database on Introductions of Aquatic Species. Fisheries Global Information. Systems/FAO, Rome, Italy. Available online at: (http://www.fao.org/figis/servlet/static?dom=root&xml= Introsp/introsp_s.xml).

Dikel, S., Kiris, G. and Alev. V. (2005). The Potential of Phytoplankton based Culture of Tilapia (*Oreochromis niloticus*) in the floating cages in Seyhemdam Lake. The seventh Balkan conference on operational research "BACOR". Constantan, Romania.

EAO (1996). The salmon aquaculture review. Environmental Assessment Office of the British Colombia. Available at http:www.interafish.com/laws-and-regulations/report_bc.

Edward, A., Ladu, B.M. and Elihu, A. (2010). Growth, survival and production economics *of Clarias gariepinus* fingerlings at different stocking densities in concrete tanks. *Afr. J. Gen. Agricult.*. **6(2):** 59-66.

El-Sayed, A.F.M., (2002). Effect of stocking density and feeding level on growth and feed efficiency of Nile tilapia (*Oreochromis niloticus* L.) fry. *Aquacult. Res.* **33**:621-626.

Eng, C.T. and Tech, E. (2002). History of cage culture. **In**: *Disease and disorders of finfish in cage culture.* Pp 138. (Woo, P.T.K. (ed).). CABI publishing.

Eyo, A.A, (2001). Chemical composition and amino acid content of the commonly available feed stuff used in fish feeds in Nigeria. Fish Nutrition and fish feed technology in Nigeria. **In:** *Proceedings of the first Symposium on fish Nutrition and Fish Technology* Pp. 58 – 71 *(Eyo, A.A. ed.).* NIOMR Legos, Nigeria.

FAO (2008). *Aquaculture System and Practice: A selected Review.* Fishery and Aquaculture Department. FAO. Rome, Italy.

FAO (2007). Fishstat Plus: Universal software for fishery statistical time series. Version 2.3.2000. Rome, Italy

FAO (2005). *Aquaculture production (2003).* Year book of Fishery Statistics - Vol.96/2. FAO. Rome, Italy.

FAO, (2004). *Aquaculture extension in sub-Saharan Africa.* FAO fisheries circular, No. 1002. Fisheries department, Inland water Resource and aquaculture Service 2004. Rome, pp 55.

Fernando, C. (2002). *A Guide to Tropical Freshwater Zooplankton: Identification, Ecology and Impact on Fisheries*. Backhuys Publisher. Leiden. The Netherlands. 291 pp

Ferguson, A., Fleming, LA., Hindar, K. Skaala, O., McGinty, P., Cross, T. and Prodohl, P. (2007). Farm escapes. **In**: *Atlantic Salmon:Genetics, Conservation and Management*, pp 367-409 (Verspoor, E. Stradmeyer, L. and Nielsen, J. eds.), Oxford, Blackwell publishing Ltd.

Fitzisimmons, K. (2004). Development of new products and markets for the global tilapia trade. **In:** *Proceeding of the 6th International Symposium on Tilapia in Aquaculture*, 624-633pp. (Bolivar, R., Mair, G. and Fitzsimmons, K. eds.). Manila. Philippines.

Fitzsimmons, K. (2000). Tilapia: the most important aquaculture species of the 21st century. **In**: *Proceedings of the Fifth International Symposium on Tilapia in Aquaculture*, pp. 3-8, (Fizisimmons, K. and Filho, J.C. eds). Panorama da Aquaculture Magazine, Rio de Janeiro, Brazil.

Foutainhas-Fernandes, A, Gomes E. Reis-Henriques M.A. and Coimbra, J. (1999). Replacement of fish meal by plant proteins in the diet of Nile tilapia: Digestibility and growth performance. *Aquacult. Internat*. **7**:56-108.

Francis, G., Makkar, H. and Becker, K. (2001). Effect of quality saponins on growth, metabolism, egg production and muscle cholesterol in individually reared Nile tilapia (*Oreochromis niloticus* (L.)). *Comp. Biochem. Physiol.* **129**:105-114.

Gabriel U.U., Akinrotimi O.A., Bekibele, D.O. Onunkwo D.N. Ayanwu P.E. (2007). Locally produced fish feed: potentials for aquaculture development in sub-Saharan Africa. *Afr. J. Agricult. R.* **2(7):** 287-295.

Getachew Teferra (1987). A study on herbivores fish, *Oreochromis niloticus* L., diet and its quality in two Ethiopian Rift Valley lakes, Awasa and Zwai. *J. Fish. Biol*. **30**:439 – 449.

Goldburg, R.J., Elliot, M.S. and Naylor, R.L. (2001). Marine Aquaculture in the United States*: Environmental Impacts and Policy Options.* Arlington, VA: Pew Oceans Commission.

Green, J. and Seyoum Mengistou (1991). Specific diversity and community structure of Rotifera in salinity series of Ethiopian inland water bodies. *Hydrobiologia*. **209**: 95-06

Guerrero R.D. (1985). Tilapia farming in the Philippines: problems and prospects. **In**: *Philippines tilapia economics. Philippines Counsel for Agriculture and resource Research and Development/ICLARM. Proc. 12.* Pp 3-14. (Smith I.R., Torres E.B. and Tan E.o. Eds.), Manila, Philippines.

Habiba Gashaw (2010). Ecological assessment of Lake Hora, Ethiopia, using benthic and weed-bed fauna. M.Sc. Thesis, School of Graduate Studies, Addis Ababa University, Addis Ababa.

Hecht, T. (2000). Consideration on African aquaculture. *Wor. Aquacult.*. **31**:12-19

Hemple, E., Winther, U. and Hambrey, J., (2002). *Shrimp farming and the environment: can shrimp farming be undertaken sustainably*. World Bank. Available online at: http://www.enaca.org/Shrimp/Publications/WBfinal.pdf.

Hickling, C.F. (1962). *Fish Culture*. Faber and Faber, London, 295p.

Hishamunda , N. K. & Nathanael H.R., (2001). *Investment and economic feasibility: Promotion of sustainable commercial aquaculture in sub-Saharan Africa.* FAO Fisheries Technical Paper 408.

Hotzel, G. and Croome, R. (1999). *A Phytoplankton Methods Manual for Australian Freshwaters*. Land and Water Resource Research Development Corporation. Canberra. Australia. 51pp.

Ibiyo L.M. and Olowosegun, T. (2004). The potential for improving profitability in Aquaculture. **In***:* Proceedings of the 19th Annual conference of the Fisheries Society of Nigeria (FISON) pp. 45 – 53. **(**Araoye A. ed.). Legos, Nigeria.

Jauncey, K. and Ross, S. (1982). *A guide to Tilapia feeds and Feeding*. University of Stirling, Scotland.

Jhingram, V.G. (1987). *Introduction to aquaculture*. RAF/82/009. Port Harcourt, Nigeria: UNDP/FAO/ Nigerian Institute for Oceanography and Martine Research Project.

Kemal Mohammed (2008). The effect of stocking density and supplementary feeding on growth performance of Nile tilapia [*Oreochromis niloticus* (L., 1758)] in cage culture system in Lake Babogaya, Ethiopia. M.Sc. Thesis, School of Graduate Studies, AAU. Addis Ababa.

Konikoff, M. (1975). *Feasibility of cage culture and other aquaculture schemes at Kainji Lake, Nigeria*. FAO. Rome.

Lamb, H. (2001). A 10,000 – year oxygen and carbon isotope record of hydrological change in Ethiopian crater lakes. *The Holocene*. **10**:167-177.

Lambert, Y., and Dutil, J.D. (2000). Energetic consequences of reproduction in Atlantic cod (*Gadus morhua*) in relation to spawning level of somatic energy reserves. *Can. J. Fish. Aqu. Sci.* **57**: 815 – 825.

Lenna, E.A., Pezzato, L. E., Furuya, W.M., Vicentini C.A., Cecon, P.R. and Barros, M.M. (2004). Crude fiber and oil in diets for Nile tilapia (*Oreochromis niloticus*). *R. Bras. Zootec.* 33 (6): 2177 – 2185.

Levell, T. (1989). *Nutrition and Feeding of Fish.* An AVI Book- Van Nostrand Reinhold. New York. USA. 260pp.

Li, D.T. and Fu, Z.E. (2001). *Knowledge Warehouse: A Web-Based Integrated Information System for Fresh Water Aquaculture.* China Agricultural University. Beijing, China.

Liti, D., Fulanda, B., Munguti, J.; Straif, M., Waidbacher, H. and Winkler, G. (2005). Effect of open-pond density and caged biomass of Nile tilapia (*Oreochromis niloticus*, L.) on growth, feed utilization, economic returns and water quality in fertilized ponds. *Aquacul.* R*es.* **36:** 1535 – 1543.

Ling, S.W. (1977). *Aquaculture in South east Asia*. University of Washington, Seattle, USA. P 190.

Lirasan, T.T. and Twide, P.R., (1993). Farming *Eucheuma in Zanzibar,* Tanzania. *Hydrobiologia* **260 (261):** 353-355.

Machena, C. and Moehi, J (2001). Sub-Saharan African aquaculture: regional summary. **In**: Technical Proceedings of the conference on Aquaculture in the third Millennium pp 341-355. (Subasinghe, R.P., Bueno P, Phillips, M.J.; Hough, C.; McGladdery, S.E. and Arthur J.R. eds.) . NACA. Bangkok, Thailand.

Masser, M. P. (1997). *Cage Culture handling and feeding caged fish.* SRAC Publication No.164. Revised. p 1-6.

Mataka, L. and Kangombe, J. (2007). Effect of substitution of maize bran with chicken manure in semi-intensive pond culture of *Tilapia rendalli* (Boulenger). *Aquacult. Res.* **38**:940-946.

McGinty, A. (1991). Tilapia production in cages: effect of cage size and number of non caged fish. *Prog. Fish-Culture*. **53**:246-249

McGinty A. and Rakocy, J. (2005). *Cage culture.* Southern Regional Agricultural Center Extension. Service. USA.

Mohr, P.A. (1961). The geology, structure, and origin of the Bishoftu explosion craters. *Bulletin of the Geological Observatory.* Addis Ababa. **2**:65-101.

Nandlal, S., and Pickering, T., (2004). Tilapia fish farming in pacific island countries: Tilapia hatchery operation. V-1. 41p. Noumea, New Caledonia: Secretariat of the Pacific Community.

Nash C.E. (2001). The net-pen salmon farming industry in the Pacific Northwest. U.S.Dept. of comer. NOAA Tech. Memo, NMFS-NWFSC-46.

National Meteorological Service of Ethiopia (NMSE) (2010). Meteorological data of Debre Zeit Town

Odada O.E. and Olago O.D. (2002). *The East African Great Lakes: Limnology, Palaeolimnology and Biodiversity*. Kluwer academic publisher.

Ogunji, J., Toor, R.S., Schulz, C., and Kloas, W. (2008). Growth performance, nutrient utilization of tilapia *Oreochromis niloticus* fed housefly maggot (Magmeal) diets. *J. Fish.& Aqu. Sci*. **8**:141-147.

Ogunji, J. (2004). Alternative protein sources in diets for farmed tilapia. *Animalscience.com Reviews (2004) No. 13 Nutrition Abstracts and Reviews*. **74 (9):** 23-34.

Oresegum A. and Alegbeleye, W.O. (2001). Growth response and nutrient utilization of tilapia *Oreochromis niloticus* fed varying dietary level of cassava peels based on rations supplemented with di-methionine. **In:** *Proceedings of the First Symposium on Fish Nutrition and Fish Technology*. Pp. 58 – 71 (Eyo A.A. Ed.). *NIOMR.* Legos, Nigeria.

Ottolenghi, F., Silvestri, C., Giordano, P., levatelli, A. and New, M.B. (2004). *Capture-based aquaculture. The fattening of eels, groupers, tuna and yellowtails.* FAO. Rome. 308p.

Pillay, T.V. and Kutty, M.N. (2005). *Aquaculture: Principle and Practices*, 2nd Ed. Blackwell Publishing Ltd. Oxford. England.

Portz L and Liebert F (2004). Growth, nutrient utilization and parameters of mineral metabolism in Nile tilapia, *Oreochromis niloticus* (Linnaeus, 1758) fed plant based diet with graded level of microbial phytase. *J. An. Physiol. Nutr.* **88**:311-320.

Prosser, M.V., Wood, R.B, and Baxter, R.M. (1968). The Bishoftu crater lakes: A bathymetric and chemical study. *Arch.Hydrobiol*. **65**: 309-324.

Reintjens D. and Tesfaye Wudneh (1998). Fisheries management – A review of the current status and research needs in Ethiopia. *SINET: Eth. J. Sci.* **21**:231-266.

Ridler, N. and Hishamunda, N. (2001). Promotion of sustainable commercial aquaculture in Sub-Saharan Africa. Vol. 1. Policy framework. FAO Fisheries Technical Paper. No. 408/1. Rome, FAO. 67p.

Rippey, B, and Wood, R.B. (1985). Trends in major ions composition of five Bishoftu crater lakes. *SINET: Eth.J.Sci*, ***8****:9*-29.

Sevier, H.; Raae, A. and Lied, E. (2000). Growth and protein turnover in Atlantic salmon (*salmon salar* L.); the effect of dietary protein level and protein particles size. *Aquaculture*. **185**: 101 -120.

Shakouri, M., (2003). Impact of cage culture on sediment chemistry: A case study in Mjoifjordur. MSc. Final Project. Tehran, Iran.

Shahin, M., (1988). *Hydrology of the Nile basin*. International Institute for Hydraulic and Environmental Engineering. Elsevier, The Netherlands.

Shibru Tedla (1973). *Fresh Water Fishes of Ethiopia. Department of Biology*. HSIU. Addis Ababa. Ethiopia. 101pp.

Siddiqui, A.Q., Howlader M.S. and Adam A. (1988). Effect of dietary protein levels on growth, feed conversion and protein utilization in fry and young Nile tilapia, *Oreochromis niloticus. Aquaculture.* **70**:63-73.

Silva, P. Souza, V., Padua, D., Dalacorte, P. and Goncalves., D. (2000). Effect of stocking density on growth performance and fillet composition of tetra hybrid red tilapia, Israeli strain. **In:** *Tilapia Aquaculture in the 21st Century: Proceeding From 5th International symposium of Tilapia aquaculture.* 341-345pp (Fitzsimmon, K. and C. Filho, J. Eds.). Florida. USA.

Singh L.B., Pandey P.N., Mahto B., and Singh R.K. (2007). *River pollution*. A.P.H. Publishing Coopration, New Delhi. P1-25.

Sokal, R.R. and Rohlf, F.J (1981). *Biometry, the principles and practice of statistics in Biological research.* W.H. Freeman and company, San Fransisco, USA.

Sophin, P. (2001). Waste recycling and fish culture: Literature review available on www.utafoundation.org/utacambodia/MSc.99Thesis/Constoph. (January, 2011)

Solomon Hailu (2008). Effects of feed quantity on growth performance in cage culture system for production of Nile tilapia (*Oreochromis niloticus*, L., 1758) in Lake Babogaya, Ethiopia. MSc thesis. Department of Biology, AAU. Addis Ababa.

SPSS (2008). Software Program of Statistical Analysis. Version 17 Edition for Windows. SPSS, Chicago, IL, USA.

Stauffer, J.R., Boltz, S.E., and Boltz, J.M. (1988). Cold shock Susquehanna River, Pennsylvania. *N. Amer. J. Fish. Manag*. **8**:329 – 332.

Stickney, R.R. (1986). Tilapia tolerance of saline waters: a review. *Pro. Fish Cult*. **48**:161-167.

Swann, L. (1992). *A basic Overview of Aquaculture: History, water quality, type of aquaculture and production method*. Technical Bulletin Series 102.

Talling, J. (1987). The Phytoplankton of Lake Victoria (East Africa). *Arch Hydrobiol. Beih Ergebn Limnol*. **25**:229 – 256.

Tamiru Gebre (2006). Zooplankton Community Grazing Rates Study on the Natural Phytoplankton Assemblages in Lake Arsedi (Betemengist). M.Sc. Thesis, School of Graduate Studies, AAU, Addis Ababa.

Tesfaye Wudneh (2009). Overview of the fisheries and aquaculture development status- Its contribution to food security and protein supply in diet. **In:** *Issues and challenges in food security* (Abinet Girma and Dawit Abate eds.) pp 92-97. Addis Ababa, Ethiopia.

Tigist Wubshet (2010). Dynamics of the species composition and size fractionated biomass of phytoplankton in Lake Hora-Arsidi. Ethiopia. M.Sc. Thesis, School of Graduate Studies, AAU, Addis Ababa.

Trewavas, E. (1983). *Tilapiine Fishes of Genera Sarotherodon, Oreochromis and Danakiila.* Cornell University Press. Dorchester, England.

Tran-Duy, A., Schrama, J.W., van Dam, A.A. and Verreth, J.A.J. (2008). Effects of oxygen concentration and body weight on maximum feed intake, growth and hematological parameters of Nile tilapia, *Oreochromis niloticus. Aquaculture* **275**:152-162.

Ugwumba, A.A. Ugwumba, A.O. (2003). Aquaculture options and the future of fish supply in Nigeria. *The Zoologist.* **2**:96 -122.

Wetzel, R. and Likens, G. (2000). *Limnological Analysis*. 3rd ed. Springer-Verlag. New York. USA.

Whitford, L. and Schumcher, G. (1973). *A Manal of Freshwater Algae*. Sparks Press. Raleigh. N.C. 323pp.

Willen, E. (1991). Planktonic diatoms – an ecological review. *Algological Studies*. **62**:69 -106.

Wohlfarth, G.W., Hulata,. G., Halvy, A. (1990). Survival, sex ratio and growth of some tilapia species and their interspecific hybrids. *Eur. Aquacult. Soc. Spec. Publ*. **11**:329-354.

Wee, K.L. and Wang, S. (1987). Nutritive values of Leaucaena leaf meal in pelleted feed of Nile tilapia, *Oreochromis niloticus*. *Aquaculture*. **62**:97 - 108.

Wood, R.B., Prosser, M.V., and Baxtor R.M. (1984). Seasonal and comparative aspects of chemical sratification in some tropical crater lakes, Ethiopia. *Freshwater Biology*. **14**:557-573.

Wood, R.B., Prosser, M.V, and Baxter, R.M. (1976). The seasonal pattern of chemical characteristics of four of the Bishoftu crater lakes, Ethiopia. *Freshwat. Biol*.**6**: 519-530.

Wood, R.B., and Talling, J.F. (1988). Chemical and algal relationships in a salinity series of Ethiopian inland waters. *Hydrobiologia*. **158**:29–67.

Zenebe Taddesse (2010). Integrating cage fish farming system in reservoirs, ponds and temporary water bodies in Eastern Africa: The BOMOSA experience. From presentation of workshop on cage culture of fishes: Its feasibility in Ethiopia. AAU, Addis Ababa.

Zinabu Gebremariam (2002). The Ethiopian Rift Valley lakes: major threats and strategies for conservation. **In:** *Ethiopian Rift Valley Lakes*. pp. 259-271 (Tudorancea, C. and Taylor, D.W. eds.0 Backhuys Publishers, Leiden. The Netherlands.

Appendix I: One way ANOVAs for the replicates of the treatment and the control in all sampling time

Sampling week	Diet-1	Sum of Squares	df.	Mean Square	F	Sig.
2	Between Groups	51.344	2	25.672	1.279	.288
	Within groups	843.141	42	20.075		
	Total	894.486	44			
4	Between Groups	758.697	2	379.349	22.910	.000
	Within groups	695.455	42	16.558		
	Total	1454.152	44			
6	Between Groups	30.406	2	15.203	1.106	.340
	Within groups	577.327	42	13.746		
	Total	607.732	44			
8	Between Groups	34.533	2	17.267	.877	.423
	Within groups	826.667	42	19.683		
	Total	861.200	44			
10	Between Groups	116.311	2	58.156	3.567	.037
	Within groups	684.667	42	16.302		
	Total	800.978	44			
12	Between Groups	38.711	2	19.356	1.407	.256
	Within groups	577.600	42			
	Total	616.311	44			
14	Between Groups	8.933	2	4.467	.209	.813
	Within groups	899.067	42	21.406		
	Total	908.000	44			
16	Between Groups	50.800	2	25.400	1.389	.261
	Within groups	768.000	42	18.286		
	Total	818.800	44			
18	Between Groups	86.711	2	43.356	2.996	.061
	Within Groups	607.867	42	14.473		
	Total	694.578	44			
20	Between Groups	86.178	2	43.089	1.498	.235
	Within Groups	1208.400	42	28.771		
	Total	1294.578	44			
22	Between Groups	11.511	2	5.756	.220	.803
	Within Groups	1098.267	42	26.149		
	Total	1109.778	44			
24	Between Groups	92.578	2	46.289	.688	.508
	Within Groups	2823.733	42	67.232		
	Total	2916.311	44			

Sampling week	Diet-2	Sum of Squares	df.	Mean Square	F	Sig.
2	Between Groups	8.400	2	4.200	.716	.495
	Within Groups	246.400	42	5.867		
	Total	254.800	44			
4	Between Groups	151.016	2	75.508	2.901	.066
	Within Groups	1093.023	42	26.024		
	Total	1244.039	44			
6	Between Groups	14.562	2	7.281	.230	.795
	Within Groups	1329.004	42	31.643		
	Total	1343.566	44			
8	Between Groups	16.354	2	8.177	.277	.760
	Within Groups	1240.871	42	29.545		
	Total	1257.224	44			
10	Between Groups	30.533	2	15.267	.401	.672
	Within Groups	1598.267	42	38.054		
	Total	1628.800	44			
12	Between Groups	28.311	2	14.156	.576	.566
	Within Groups	1031.600	42	24.562		
	Total	1059.911	44			
14	Between Groups	23.333	2	11.667	.553	.579
	Within Groups	885.867	42	21.092		
	Total	909.200	44			
16	Between Groups	1.600	2	.800	.010	.990
	Within Groups	3351.600	42	79.800		
	Total	3353.200	44			
18	Between Groups	24.578	2	12.289	.200	.819
	Within Groups	2575.200	42	61.314		
	Total	2599.778	44			
20	Between Groups	26.133	2	13.067	.256	.775
	Within Groups	2145.067	42	51.073		
	Total	2171.200	44			
22	Between Groups	6.533	2	3.267	.043	.958
	Within Groups	3168.267	42	75.435		
	Total	3174.800	44			
24	Between Groups	27.778	2	13.889	.470	.628
	Within Groups	1241.467	42	29.559		
	Total	1269.244	44			

Sampling week	Diet-4	Sum of Squares	df.	Mean Square	F	Sig.
2	Between Groups	8.400	2	4.200	.716	.495
	Within Groups	246.400	42	5.867		
	Total	254.800	44			
4	Between Groups	151.016	2	75.508	2.901	.066
	Within Groups	1093.023	42	26.024		
	Total	1244.039	44			
6	Between Groups	14.562	2	7.281	.230	.795
	Within Groups	1329.004	42	31.643		
	Total	1343.566	44			
8	Between Groups	16.354	2	8.177	.277	.760
	Within Groups	1240.871	42	29.545		
	Total	1257.224	44			
10	Between Groups	30.533	2	15.267	.401	.672
	Within Groups	1598.267	42	38.054		
	Total	1628.800	44			
12	Between Groups	28.311	2	14.156	.576	.566
	Within Groups	1031.600	42	24.562		
	Total	1059.911	44			
14	Between Groups	23.333	2	11.667	.553	.579
	Within Groups	885.867	42	21.092		
	Total	909.200	44			
16	Between Groups	1.600	2	.800	.010	.990
	Within Groups	3351.600	42	79.800		
	Total	3353.200	44			
18	Between Groups	24.578	2	12.289	.200	.819
	Within Groups	2575.200	42	61.314		
	Total	2599.778	44			
20	Between Groups	26.133	2	13.067	.256	.775
	Within Groups	2145.067	42	51.073		
	Total	2171.200	44			
22	Between Groups	6.533	2	3.267	.043	.958
	Within Groups	3168.267	42	75.435		
	Total	3174.800	44			
24	Between Groups	2.844	2	1.422	.023	.977
	Within Groups	2580.267	42	61.435		
	Total	2583.111	44			

Sampling week	Control cage replicates	Sum of Squares	df.	Mean Square	F	Sig.
2	Between Groups	30.400	2	15.200	2.323	.110
	Within Groups	274.800	42	6.543		
	Total	305.200	44			
4	Between Groups	32.929	2	16.465	1.156	.325
	Within Groups	598.263	42	14.244		
	Total	631.192	44			
6	Between Groups	230.427	2	115.214	2.190	.125
	Within Groups	2209.529	42	52.608		
	Total	2439.956	44			
8	Between Groups	33.911	2	16.956	.281	.756
	Within Groups	2530.400	42	60.248		
	Total	2564.311	44			
10	Between Groups	340.311	2	170.156	2.184	.125
	Within Groups	3272.267	42	77.911		
	Total	3612.578	44			
12	Between Groups	744.933	2	372.467	4.080	.024
	Within Groups	3833.867	42	91.283		
	Total	4578.800	44			
14	Between Groups	494.044	2	247.022	3.352	.055
	Within Groups	3094.933	42	73.689		
	Total	3588.978	44			
16	Between Groups	179.733	2	289.867	9.744	.051
	Within Groups	1649.467	42	29.749		
	Total	1829.200	44			
18	Between Groups	79.511	2	139.756	4.561	.116
	Within Groups	1487.067	42	30.644		
	Total	1566.578	44			
20	Between Groups	135.911	2	117.956	8.063	.061
	Within Groups	714.400	42	14.629		
	Total	850.311	44			
22	Between Groups	325.511	2	162.756	9.359	.000
	Within Groups	730.400	42	17.390		
	Total	1055.911	44			
24	Between Groups	402.978	2	201.489	5.940	.005
	Within Groups	1424.667	42	33.921		
	Total	1827.644	44			

Sampling week	Diet-3	Sum of Squares	df.	Mean Square	F	Sig.
2	Between Groups	8.044	2	4.022	.617	.544
	Within groups	273.867	42	6.521		
	Total	281.911	44			
4	Between Groups	1.000	2	.500	.026	.975
	Within groups	816.363	42	19.437		
	Total	817.363	44			
6	Between Groups	71.385	2	35.693	1.310	.281
	Within groups	1144.147	42	27.242		
	Total	1215.532	44			
8	Between Groups	20.844	2	10.422	.401	.672
	Within groups	1092.400	42	26.010		
	Total	1113.244	44			
10	Between Groups	18.178	2	9.089	.243	.785
	Within groups	1568.133	42	37.337		
	Total	1586.311	44			
12	Between Groups	2.978	2	1.489	.030	.971
	Within groups	2088.933	42	49.737		
	Total	2091.911	44			
14	Between Groups	43.333	2	21.667	.291	.749
	Within groups	3126.667	42	74.444		
	Total	3170.000	44			
16	Between Groups	11.511	2	5.756	.131	.878
	Within groups	1847.067	42	43.978		
	Total	1858.578	44			
18	Between Groups	26.178	2	13.089	.504	.608
	Within Groups	1090.800	42	25.971		
	Total	1116.978	44			
20	Between Groups	.844	2	.422	.017	.983
	Within Groups	1036.133	42	24.670		
	Total	1036.978	44			
22	Between Groups	14.044	2	7.022	.421	.659
	Within Groups	700.933	42	16.689		
	Total	714.978	44			
24	Between Groups	6.533	2	3.267	.200	.820
	Within Groups	686.667	42	16.349		
	Total	693.200	44			

DECLARATION

I hereby declare that this thesis has been achieved by myself and is the result of my own investigation. It has neither been accepted nor submitted for any other degree. All the sources of information have been acknowledged.

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This work has been presented with our approval as supervisor.

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