Evaluation of growth performance and body proximate composition of three strains of *Oreochromis niloticus* L., (1758) under greenhouse condition

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II. ABSTRACT

Growth performance and proximate body composition of fingerling *Oreochromis niloticus* strains from different lakes (Chamo, Babogaya and Hashengie) were compared in tank culture system under greenhouse condition between April and October, 2017. Fingerlings of average weight 4.4 g were stocked at stocking density of 20 fish/m3 in tanks (1.2 m3 each) in three treatments with four replicate each. The treatment groups were fed formulated feed with 30% crude protein at a rate of 5% body weight per day. Fish samples were taken monthly from each tank for body length and weight measurement. Nutrient content of fish fillet was chemically determined following standard methods of Association of Official Analytical Chemists at the end of the experiment. Growth performance parameters (final weight, daily weight gain and specific growth rate), feed conversion ratio, body proximate composition (except carbohydrate) and survival rate were not significantly different ($p>0.05$) among the strains tested. However, the wellbeing of the fish, expressed as Fulton's condition factor was significantly higher ($p<0.05$) for the strain from Lake Hashengie compared with those from Lakes Chamo and Babogaya. Body proximate composition of the strains were well in the range reported for tilapia except for the lower crude fat content of strain from Lake Hashengie, which was reported to have the highest compared with O. niloticus strains from other lakes in the natural system. The reason for no variation in the growth performances of the three strains could be due to the culture system where culturing tanks were under greenhouse which brought the culture water temperature in the optimum range for O. niloticus growth. Despite the optimum culture water temperature, the daily growth rates of the three strains were low which might be due to breeding, and poor nutritional quality and low digestibility of feed. The feed quality also explains why strain from Lake Hashengie had lower crude fat content while has the highest crude fat in the natural system. Generally, based on the current finding, strains of *O. niloticus* either from lakes Chamo, Babogaya or Hashengie can be used for further experiment and stoking activities with feed supplementation. However, we strongly recommend further research to be conducted in this regard with standard fish feed and more strain included since this is the only study reported under greenhouse condition.

III. LIST OF ABBREVIATIONS AND ACRONYMS

AOAC	Association of Official Analytical Chemists
APHA	American Public Health Association
DO	Dissolved Oxygen
FAO	Food and Agricultural Organization
FCF	Feed Conversion Ratio
GE	Gross Energy
TNA	Total Nitrogen Ammonia

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1. INTRODUCTION

Tilapia is a group of cichlid fishes, which includes three economically important genera namely, *Tilapia, Oreochromis,* and *Sarotherodon* (Oponda *et al*., 2017). They are considered to be the most important and second most cultured fish species next to carp around the world (Abdelhamid *et al*., 2017). Hence they are alternatively called as "the aquatic chicken". It has been reported that tilapia is native to Africa but has been introduced almost to all parts of the world (Malik *et al*., 2017). The adaptability of tilapias to a wide range of environments and intensification of culture systems have resulted in a rapid expansion of tilapia farming and introduction of these fish into many subtropical and temperate regions of the world (Santos *et al.,* 2013*)*. Among tilapias, Nile tilapia (*Oreochromis niloticus*) is the most widely cultured fish (Zenebe Tadesse *et al*., 2012). It is highly recognized that systematic effort is needed to secure and further improve the genetic quality to such widely cultured fish species (Bentsen *et al*., 1998).

The growth of some species of fish has been improved by selection programs because genetic improvement through selection has the potential to improve the productivity and sustainability of cultured fish (Hulata *et al*., 1986). Selection involves developing a breeding program in which individuals or families are chosen on the basis of their value for commercially important trait(s) (Lakra, 2001). Thus, the search for tilapia strains of superior performance is becoming more and more frequent by producers, because of the increasing demands for healthy food by the world population (Santos *et al*., 2008). Number of selection experiments and testing programs that aimed to increase growth rate of tilapia have been conducted for *O. niloticus* (Hulata *et al*., 1986; Eknath *et al*., 1993; Brzeski and Doyle, 1995; Gjedrem, 1997; Bentsen *et al*., 1998; Bolivar and Newkirk, 2002; Ponzoni *et al*., 2005; Rutten *et al*., 2005; Ridha, 2006; Rezk *et al*., 2009).

In Ethiopia however, little attention is given for selection of fast growing strain and this is among the major challenges for aquaculture development (Shibru Tedla, 2016). Three studies made by Kassaye Balkew and Gjoen (2012), Zelalem Teshome (2013) and Abelneh Yimer *et al*. (2015) have been reported so far on comparative evaluation of growth for *O. niloticus* strains from different water bodies of Ethiopia in pond culture system, while *O. niloticus* is indigenous to the country, comprising above 60% of fish production from capture fisheries and has high socio-economic demand. This might probably show the limitations in strain comparison growth experiments of the particular species as these studies cannot be sufficient for a country with large number of water bodies containing their respective *O. niloticus* strains. Furthermore, all these studies were conducted in concrete pond culture system where the water temperature may not be in the range for optimum growth of the culture species. Therefore, studies should have to be conducted under favorable culture environment so that complete profile of comparative growth data will be available for the strains.

From nutritional point of view, fish fillet consists of several components such as moisture, protein, lipid, vitamins and minerals all of which contribute to the overall meat composition. Composition of fish proteins is better than the composition of proteins of other animals, which is mainly due to more favorable amino acid composition and lot of free amino acids (Buchtová *et al*., 2010). The nutrients, minerals and the omega 3 fatty acids found in fishes are heart-friendly and can make improvements in brain development and reproduction. Proximate composition of fish varies greatly from species to species and from one individual to another based on different factors. Fish body composition is reported to be affected by both exogenous and endogenous factors (Huss, 1995). Environmental conditions, level of protein in the diet and feeding rate are among the exogenous factors that affect fish body composition (Ogata and Shearer, 2000). On the other hand, endogenous factors are genetic and linked to the life stage, age, size, sex and species and govern the majority of principles that determine the composition of fish (Huss, 1995). Number of investigations on the contents of proximate composition in fish has been documented for marine and temperate fish. However, similar data on tropical fish mainly from Africa are very scarce (Zenebe Tadesse, 2010). In Ethiopia, only few studies have been conducted to evaluate comparative proximate body composition of Nile tilapia from natural water bodies (Zenebe Tadesse, 2010; Tsegay Teame *et al.* 2016). However, there is no similar study so far reported from tank culture system under greenhouse condition.

2. OBJECTIVES

2.1. General objective

- To generate scientific information on growth performance and body proximate composition of *O. niloticus* as scientific basis for aquaculture development

2.2. Specific objectives

- To compare growth performance and survival rate of strains of *O. niloticus* fingerlings obtained from parents from Lakes: Chamo, Babogaya and Hashengie under greenhouse condition
- To compare body proximate composition of strains of *O. niloticus* grown under greenhouse condition

3. RESEARCH QUESTIONS

- Is there significant difference in growth performance and survival rate among strains of *O. niloticus* obtained from Lakes Chamo, Babogaya and Hashengie grown under greenhouse condition?
- Is there significant variation in body proximate composition among strains of *O. niloticus* grown under greenhouse condition?

4. LITERATURE REVIEW

4.1. What is strain?

There is no consensus on the definition of 'strain' in aquaculture species (Ponzoni *et al*., 2012). Often the terms strain, stock and population are used interchangeably. Gunnes and Gjedrem (1978) define strain as 'a discrete breeding population from a river, river system, or a fjord leading to a river.' Based on this definition, any discrete breeding population from a hatchery may also be termed a strain for evaluation purposes (Ponzoni *et al*., 2012).

4.2. Diversity of Nile tilapia strain in Africa

From the paleo-geographic point of view, Africa has experienced severe hydro-geographic modifications since the Pleistocene (Bezault *et al*., 2011). For instance, the East African Rift valley has been subject to many tectonic disruptions of the water basins with inversion of the course of some rivers in the Nile basin, whereas the Sudano-Sahelian region experienced dramatic climatic fluctuations with alternating humid and dry phases (Beadle, 1981). By their drastic modifications on the extension and connectivity of the different water-basins, hydro-geographic modifications have undoubtedly affected the distribution of fish species and their population genetic structure in Africa (Bezault *et al*., 2011).

Genetic characterization of *O. niloticus* natural populations from the major basins (Rivers Senegal at Dagana, Niger at Selingue, Niger at Bamako, Chari at N'Jamena, Nile at Cairo, Suguta, hot springs of the Awash system at Sodore and lakes Volta, Chad, Manzalla, Tana, Koka, Zywai, Awasa, Turkana, Edward, Baringo) have been conducted by Agnèse *et al*. (1996) using allozymes and restriction fragment length polymorphism of mitochondrial DNA. Accordingly, Agnèse *et al*. (1996) have clustered these populations in three groups: One is composed of the Nile drainage (lakes Manzalla, Edward, Tana and Nile at Cairo), and the Kenyan Rift Valley populations (Lake Turkana, Lake Baringo and the Suguta River). The second major group is composed of the Ethiopian Rift Valley populations (Sodore hot springs and Lakes Koka, Awasa, Ziway) and the third group is composed of the West African populations (Senegal, Niger, Volta, Chari Rivers and Lake Chad). Furthermore, using microsatellite loci from ten natural populations (Lakes Hora, Koka, Metahara, Turkana, Nile at Lake Manzala, Senegal at Djouj Nat. Park, Niger Volta, Kou, Lake Volta and River Volta), Bezault *et al*. (2011) have identified three genetic clusters of Nile tilapia populations populations corresponding to the major biogeographic subdivisions: (1) the

Ethiopian Rift Valley ichthyofaunal province (the Awash system), (2) the Nilotic region (comprising the presently separated but previously connected Nile River and Turkana basin) and (3) the Sudano-Sahelian region (West-African basins).

4.3. Diversity of Nile tilapia strain in Ethiopia

Trewavas (1983) have made morphological analysis on seven populations of *O. niloticus* from Ethiopian water bodies (lakes Abijata, Awassa, Akaki, Chamo, Tana, Beseka and River Awash at Metehara). According to Trewavas (1983), populations of *O. niloticus* from lakes Abijata, Awassa, Akaki, Chamo and Tana are classified as to be *O. niloticus cancellatus* and the remaining population from the two water bodies (Lake Beseka and River Awash at Metehara) are assigned to *O. niloticus filoa.* Furthermore, Seifu Seyoum and Kornfield (1992) have characterized *O. niloticus* populations of Ethiopian water bodies (lakes Abijata, Awassa, Chamo, Tana, Beseka, Langano, Zewai, Akaki and River Awash at Metehara) using restriction endonuclease analysis of mitochondrial DNA. Seifu Seyoum and Kornfield (1992) have assigned populations of *O. niloticus* from lakes Abijata, Awassa, Chamo, Langano and Zewai to be *O. niloticus cancellatus* in consistent with the report by Trewavas (1983). However, there are three inconsistencies between the reports made by Trewavas (1983) and Seifu Seyoum and Kornfield (1992). The first case involves the position of the specimens from Lake Tana. Fish from Lake Tana, morphologically assigned to *O. niloticus cancellatus* by Trewavas (1983) is no more assigned as *O. niloticus cancellatus* by Seifu Seyoum and Kornfield (1992) but represents an additional, previously unrecognized taxon which is *O. niloticus tana.* Seifu Seyoum and Kornfield (1992) have reported that *O. niloticus* population from Lake Tana was found to be different from *O. niloticus cancellatus* in 19 of 29 informative endonucleases analyzed. The second inconsistency involves identification of the fish collected from Lake Beseka. *Oreochromis niloticus* from Lake Beseka were thought by Trewavas (1983) to be allied to *O. niloticus filoa,* However, analysis of mitochondrial DNA of fish from this location made by Seifu Seyoum and Kornfield (1992) showed mitochondrial DNA restriction phenotypes identical to *O. niloticus cancellatus* specimens. The final inconsistency between morphological analysis by Trewavas (1983) and endonuclease analysis of mitochondrial DNA by Seifu Seyoum and Kornfield (1992) concerns the *O. niloticus* of Akaki River. Trewavas (1983) examined five specimens of *O. niloticus* from Akaki river, assigned them to *O. niloticus cancellatus*, However, according to

Seifu Seyoum and Kornfield (1992), fish from Akaki river did not show similar mitochondrial DNA phenotypes for *O. niloticus cancellatus,* instead had phenotypic characteristic of *O. niloticus filoa* from hot springs in the Awash near Metehara. Similarly, using allozyme analysis, Agnèse *et al*. (1996) have assigned *O. niloticus* populations from the Ethiopian Rift Valley, lakes Ziway and Koka, and the Awash River as *O. niloticus cancellatus* and *O. niloticus* from Sodore hot springs as *O. niloticus filoa.* In contrary to Seifu Seyoum and Kornfield (1992), Agnèse *et al*. (1996) have assigned *O. niloticus* of Lake Tana to be *O. niloticus niloticus*. This variation might be attributable to the different techniques employed in the two studies. For instance, even though both authors use mitochondrial DNA analysis for classification of *O. niloticus* of Lake Tana, Agnèse *et al*. (1996) was able to consider small fragments of mitochondrial DNA and intrapopulation polymorphism in which Seifu Seyoum and Kornfield (1992) fails to do. Moreover, using microsatellite loci analysis, Bezault *et al*. (2011) have described *O. niloticus* populations from lakes Hora and Koka represents sub-species of *O. niloticus cancellatus* and *O. niloticus* of Lake Metahara represents sub-species *O. niloticus filoa*.

4.4. Aquaculture

Aquaculture, also known as aqua farming, in simple terms is the farming of aquatic life under controlled environment (Olatunji *et al*., 2017). It covers all forms of farming of aquatic animals and plants in freshwater, brackish and saltwater. At present, aquaculture is the fastest growing sector of alternative food production and holds great potential as a sustainable solution for world food security (Budd *et al*., 2015). Now it accounts for nearly 40 percent of the world's food fish (FAO, 2017). It has the same objective with that of agriculture which is the controlled production of food to improve food supply for our consumption, despite, in the case of aquaculture; the products are aquatic animals and plants that grow in the water.

4.4.1.World Aquaculture

Due to continuous increase in world's population, increasing demands for more proteins and the decline in capture fisheries, aquaculture production is increasing worldwide (Tiamiyu *et al*., 2016; Omole, 2017; Marzouk *et al*., 2017). With almost all farmed aquatic animals destined for human consumption, aquaculture supplied 10.42 kg of food fish for human consumption on world average in 2015, a level further up by 0.28 kg from 10.14 kg in 2014 (FAO, 2017). This shows that aquaculture has emerged as one of the most promising industries in the world with a considerable growth potential to improve human dietary standards by providing protein rich food. According to FAO (2017) report, fish harvested from aquaculture amounted to 76.6 million tons with an estimated first-sale value of US$157.9 billion in 2015. In addition to fish production, aquaculture produces considerable quantities of aquatic plants. World aquaculture production of fish and plants combined reached 106 million tons in 2015, for an estimated total value of US$162.7 billion, with farmed aquatic plants contributing 29.4 million tons (FAO, 2017). Thus, farmed fish constitutes about three-quarters of total aquaculture production by volume, and farmed aquatic plant one-quarter, but the latter's share in total aquaculture value is disproportionately low (less than 5 percent).

4.4.2.Aquaculture in Africa

Commercial aquaculture production in Africa is still comparably low (Mallya, 2007). In 2015 the contribution of African to the global aquaculture production from all inland, marine and costal aquaculture was 1.772 million tons (FAO, 2017). This accounts only 2.3% of world total aquaculture production. Of this, 1.54% is contributed by Egypt, the largest contributor to world aquaculture from Africa followed by Nigeria (0.42%). The whole Sub-Saharan Africa region excluding Nigeria contributed 0.33% to world aquaculture. During the period 2005 to 2015 the contribution of Africa to the world aquaculture production increased by 0.86% from 0.6462 million to 1.772 million tons (FAO, 2017).

4.4.3.Aquaculture in Ethiopia

Ethiopia has high potential for developing fish culture both in terms of land/water and in its climatic regime with rich biological diversity of native fish species (Shibru Tedla, 2016). According to FAO (2014) report, all year round farming of cold water species could be achieved in about 11 percent of Ethiopia's surface area, on the high central plateau above 2500 m. Wide array of fish ranging from cold water to warm water species can also be farmed in the central highlands which present favorable temperature characteristics. Furthermore, the lowlands representing about 33 percent of total area could also be suitable for the cultivation of tilapia and other warm water species. Moreover, according to the geographic information system based site suitability analysis reported by Eshete Dejen and Zemenu Mintesnot (2012), about 1.4%, 55.49%, and 43.1% of the country was found to be highly suitable, moderately suitable and marginally suitable, respectively for commercial production of Nile tilapia under pond culture system.

Despite the country's favorable environmental and socio-economic conditions, aquaculture in Ethiopia has not yet attained its full potential (Adem Mohammed and Assefa Tessema, 2017). Shibru Tedla (2016) has reported that limited research and technology output, limited transfer of scientific information and technology, poor extension services, poor policy implementation, poor coordination among stakeholders and actors, lack of trained personnel in aquaculture, lack of knowledge to manage pond fishing and processing, lack of sufficient fingerlings to supply stakeholders and lack of investment in the sector are some of the cross-sectoral challenges for aquaculture development in the country. Institutionally, National Fisheries and Aquatic Life Research Center (NFALRC)-Sebeta, the former Sebeta fish culture station built in 1975, have been engaged in fish stock enhancement operations. The station has ponds covering a total area of about two hectares and has a research, training and extension units as well as a hatchery. With stocks recruited from natural water bodies, it has maintained and propagated broodstocks of common carp (*Cyprinus carpio*), crucian carp (*Carassius carassius*) and Nile tilapia (*Oreochromis niloticus*) as well as goldfish (*Carassius auratus*). Ziway and Bahri Dar Fisheries Resource Research Centers are also fisheries institutes which are engaged in research and training activities at their respective regional states.

4.5. Tilapia aquaculture

4.5.1. Nile tilapia (*Oreochromis niloticus*)

The culture of Nile tilapia can be traced to an ancient Egyptians times dating back to over 4000 years (Shibru Tedla, 2016). It is one of the most known members of the tropical and subtropical freshwater fishes and is now globally distributed because of its importance in aquaculture (Katya *et al*., 2017). It demonstrates fast growth rate, reproduces easily with no need for special hatchery technology, consumes wide range of feed types, able to survive in poor water conditions, tolerates environmental stress and has resistance to disease (Popma and Masser, 1999).

4.5.2. Nile tilapia selection for growth

It is widely accepted that successful aquaculture development requires improved strains that are fast growing, resistant to disease and suited for culture in a variety of fish farming conditions. Ponzoni *et al.* (2007) have reported that genetic improvement is one of the most powerful and least expensive means of increasing the efficiency of aquaculture. Both traditional animal breeding and science-based quantitative genetic approaches have been used to improve tilapia phenotypes (Ansah *et al*., 2014). One common traditional approach to genetic improvement is the practice of selective breeding, which is based on the underlying principle that some significant variation in observable performance is directly heritable from parent to offspring (Ansah *et al*., 2014). According to Ponzoni *et al.* (2007), continuous genetic gain that leads to better growth is possible through selective breeding. The Genetically Improvement of Farmed Tilapia (GIFT) project, one of the most significant innovations in tilapia culture, succeeded in part because it was based upon using selective breeding of a highly diverse synthetic base population (El-Sayed, 2006). Similar principles have also been applied in a number of countries to improve strains of tilapia, of which Akosombo strain, FaST strain, Chitralada strain, GenoMar Supreme Tilapia and Red Tilapia are an examples. At the very beginning, GIFT project, collected wild Nile tilapia populations from Egypt, Ghana, Senegal and Kenya, for the reason of generality that the established farmed tilapia stocks in Asia were derived from few founder individuals (Eknath *et al*., 1993). These collections represented the first-ever direct transfers of *O. niloticus* from Africa to Asia, with all samples belonging to the sub-species *Oreochromis niloticus niloticus*, with the exception of the Kenyan samples, which belonged to the sub-species *Oreochromis niloticus vulcani* (Ansah *et al*., 2014). GIFT project, after just one generation of selection, had generated considerable interest from the tilapia production industry in Asia. Dey (2000) has reported that the adoption of GIFT strain in Bangladesh, China, Philippines, Thailand and Vietnam led to yield increment of between 24% and 61%. From Africa, Ghana stands to benefit by approximately 1% of the country's GDP ($40.71 billion) from the introduction of the GIFT strain in 2012.

4.5.3. Nutritional requirement of Nile tilapia

The feeding habits of Nile tilapia consists of a wide range of aquatic organisms depending on availability (Canonico *et al*., 2005). Although the proportion varies with stages in their life cycles, Nile tilapia feeds on a wide variety of natural feeds in natural water bodies including plankton, some aquatic macrophytes, planktonic and benthic aquatic invertebrates, detritus and organic matter (Popma and Masser, 1999; Zenebe Tadesse, 1999). In semi- natural pond-cultured tilapia, these natural food organisms account for 30-50% of overall growth (Popma and Masser, 1999). In intensive culture systems however, fish mainly depends on artificial feeds than the natural fish foods as the later do not grow in enough quantity in such systems.

5.2.1.1. Protein requirement of Nile tilapia

Protein is a major dietary nutrient that affects tilapia growth (Lovell and Limsuwan, 1986) by providing essential amino acids and energy for maintenance (Elnady *et al*., 2017). Amino acids are essential in that the fish cannot synthesize them in adequate amounts. Therefore they must be provided by the diet for producing muscle, assist with enzymatic functions and supply energy to the fish which in turn help their growth. The ability of tilapia to utilize dietary protein for growth is related to both dietary protein level and availability of non-protein energy sources (Anani and Nortey, 2017). If non-protein energy is insufficient or if the protein is of poor quality, protein will be de-aminated in the body to supply energy for metabolism (Sans *et al*., 2000). The correct level of protein required for optimum growth of Nile tilapia is controversial. Zenebe Tadesse *et al*. (2012) have reported that fish supplied with feed containing higher protein level grew better than fish groups supplied with feed containing relatively lower percent of crude protein. Similar results have also been reported by several authors (Jauncey, 1998; Mary *et al*., 2014 and Choudhary, *et al.,* 2017) where Nile tilapia resulted in fast growth and higher net fish yields when it is supplied with feed containing higher percent of crude protein. However, higher protein level may not always result in better growth. According to Bahnasawy *et al*. (2009), Nile tilapia fingerlings fed on 30% protein diet attained highest growth than fingerlings fed on 35% protein diet. This is because of the fact that each fish size has a certain protein limit after which excess protein level could not be utilized efficiently (Daudpota *et al.,* 2014). It has also been reported that dietary protein requirement of Nile tilapia change as the maturity level changes (Craig, 2009), where mature fish require less protein to support growth than fry, fingerling and juveniles (Choudhary *et al*., 2017). This is in agreement with the report of FAO (2016) in which protein requirement of Nile tilapia during first feeding larval stages is high and ranges from 45 to 50%, but decreases with increasing fish size. Tilapia fry and fingerlings, protein requirement ranges from 35 to 40%, 30-35 percent for juveniles while adult tilapia require 28 to 32 dietary protein for optimum performance.

5.2.1.2. Lipid requirement of Nile tilapia

In feed, dietary lipids serve as a source of fatty acids, phospholipids, sterols and fat-soluble vitamins necessary for proper functioning of physiological processes, maintenance of biological structure and function of cell membranes (El-Din *et al.,* 2016; Ayisi *et al*., 2017). Lipids are high in energy that supply approximately about twice the amount of energy as carbohydrates or proteins (Craig, 2009). An excess of dietary lipids, however, can cause a decrease in feed consumption and reduce the utilization of other nutrients leading to reduced growth rates and increased fat deposition (El –Kasheif *et al*., 2011). There is some uncertainty regarding the optimum lipid requirements of *O. niloticus* and variations are apparent between the various life stages. El –Kasheif *et al*. (2011) have reported that *O. niloticus* fingerlings fed on diet containing 9% supplemented lipid attained maximum final weight and show better feed utilization efficiency. In another experiment, Jauncey (2000) has suggested that to maximize protein utilization, dietary lipid concentration should be between 8% and 12% for tilapia up to 25g, and 6% to 8% for larger fish. This is within the range reported by FAO (2016) where dietary crude lipid requirement of *O. niloticus* ranges between 6–13% for fry and fingerling and 4–12% for adult.

5.2.1.3. Carbohydrate requirement of Nile tilapia

Carbohydrates are the most economical source of energy available in abundant quantities at low prices and have a protein-sparing effect in some low-protein diets (Stone *et al*., 2003). Digestibility of carbohydrate by different species appears to be dependent on the complexity of the carbohydrate as well as its dietary content with simpler carbohydrate being more easily digested while digestibility of carbohydrate generally decreases as dietary content increases (Krogdahl *et al*., 2005). Fishes are expected to have lower dietary energy requirements for the fact that they do not have to maintain a constant body temperature, use less energy in protein waste excretion and less energy requirement to maintain position in space as a result of their neutral buoyancy in water (Hancz, 2011). However, results have been reported that an increase in dietary carbohydrate content improves metabolism and growth in tilapia (Tung and Shiau, 1993; Shiau, 1997; Azaza *et al*., 2013). Wang *et al*. (2017) have suggested that 20% dietary starch is enough for normal growth of *O. niloticus.* This is within the range reported by Amirkolaie *et al*. (2006) where improved growth was observed in *O. niloticus* fed on diets with 10%-40% inclusion of starch. Furthermore, FAO (2016) recommends greater than 25% carbohydrate concentration for all stages of *O. niloticus*. However, feeding excessive dietary carbohydrates of fish may have harmful effects on growth, feed efficiency, physiological dysfunction and fat deposition by stimulating lipogenic enzymes (Tan *et al*., 2009; Tian *et al*., 2012)

4.5.4. Water quality requirement of Nile tilapia

Water quality is the totality of physical, biological and chemical parameters that affect the general condition of cultured organisms as it determines the health and growth conditions. Quality of water is, therefore, an essential factor to be considered when planning for aquaculture production (Mallya, 2007).

5.2.1.4. Temperature

Water temperature, probably the most important physical variable on aquatic ecology, is the degree or intensity of heat present in water. Water temperature affects growth, metabolism, reproduction, feed consumption, physiology and survival of *O. niloticus* (Adem Mohammed and Assefa Tessema, 2017). Popma and Masser (1999) describes lethal temperature levels for *O. niloticus* as ≤12°C and ≥42°C. According to Boussou *et al*. (2017) better growth for larval stages of *O. niloticus* have been obtained in a temperature range of 27.5 – 30.6 which is in agreement with the temperature rang (20-30) report by Mirea *et al*. (2013) for optimum growth performance and survival of *O. niloticus* in intensive culture system. In another study, Azaza *et al*. (2008) have found out that best growth and feed utilization of *O. niloticus* fry was attained at a temperature range of 26 - 30^{0}C. Similar result have also been reported by Faruk *et al*. (2012) where optimum temperature for growth of fry *O. niloticus* was 25-29°C. Studies have shown that, growth rates of *O. niloticus* increase with increasing temperature, however, when experimental temperature reaches the upper limit of the tolerance range, performance of growth decreases (Boussou *et al*., 2017). This decrease in growth could be due to the higher energy cost for maintenance metabolism and loss of appetite (Azaza *et al*. 2008). Furthermore, Boussou *et al*. (2017) suggested that high rate of gastric evacuation could also be a reason for a decrease in growth at higher temperature. According to Boussou *et al*. (2017) higher temperature accelerates the rate of passing digesta through the intestinal tract, thus significantly reducing the digestibility and assimilation of nutrients. At higher temperature, physiological processes associated with digestion and nitrogen retention function are less efficient.

5.2.1.5. Dissolved oxygen

Dissolved oxygen, besides feed and temperature, is the most important factor controlling growth (Jobling, 1994). It is necessary to glucose breakdown and energy release inside fish cells (Boyd, 1998). Dissolved oxygen content below a critical level reduces fish growth and feed utilization, increase feed conversion ratio, increase risk on potential diseases or even fish death (Sultana *et al*., 2017). Furthermore, it has been reported that low levels of dissolved oxygen may inhibit feed intake that could subsequently lead to poor growth in fish. This may be due to the reduced oxygen availability necessary to glucose breakdown and energy release inside fish cells (Boyd, 1998). It has been reported that growth pattern of *O. niloticus* is greatly influenced by low dissolved oxygen availability (Abdel-Tawwab *et al*., 2015). Adamneh Dagne *et al*. (2013) have mentioned the dissolved oxygen level for acceptable growth of *O. niloticus* ranges from 3.0 to 9.0.

5.2.1.6. pH

The pH of water is a measure of hydrogen ion that causes acidity and alkalinity on a scale of 0-14 with 7 being the neutral state (Kumar, 2012). It has been used universally to express the intensity of the acid or alkaline condition of a solution. Water pH is a crucial factor for the development, growth and survival of fish where fluctuations of pH in water causes ionic imbalance and could lead to death (Abdullah *et al*., 2017). Both alkaline (pH 8.5–10) and acidic (pH below 6.0) water causes acute physiological disturbance in fish, affecting the normal growth rate and finally becoming a potentially lethal factor for fish (Abdullah *et al*., 2017). El-Sherif and El-Feky (2009) have reported that water pH 7-8 could be more suitable for Nile tilapia culture for optimum growth performance and survival rate. This report is consistent with the report by Popma and Masser (1999) where tilapia can survive at pH ranging from 5 to 10 but they do best at a pH range from 6 to 9.

5.2.1.7. Ammonia

Ammonia is a nitrogenous compound excreted by fish through gills and faeces. In water ammonia is present in two forms: the high toxic un-ionized ammonia (NH_3) and the non-toxic ionized ammonium (NH_4^+) (Hegazi, 2011). They are in chemical equilibrium driven by temperature and pH (Parra and Yufera, 1999) where the fraction of toxic ammonia increases at elevated temperature and high values of pH (Durborow *et al.*, 1997). The sum of NH_3 and NH_4^+ is called total nitrogen ammonia (De-Silva *et al.*, 2013). Chronic ammonia exposures affect Nile tilapia in several ways. For instance it causes gill and kidney damage, decreased brain monoamines, decreased ATPase level, reduce growth rates and increased brain glutamine (Durborow *et al.*, 1997; El-Shafai *et al.*, 2004; Benli *et al.*, 2008). Un-ionized ammonia begins to depress food consumption at concentrations as low as 0.08 mg/L. Prolonged exposure (several weeks) to un-ionized ammonia concentration greater than 1 mg/L causes losses, especially among fry and juveniles in water with low DO concentration (Durborow *et al.*, 1997).

5.2.1.8. Salinity

Growth rate of *O.niloticus* is greatly influenced by different salinity levels (Iqbal *et al.*, 2012). Salt tolerance of this species depends on strains, size and prevailing environmental factors (Altum and Sarihan, 2008). Azevedo *et al.* (2015) have reported that better growth of *O. niloticus* was observed in a salinity level up to 7 ppt. Similar result has also been reported by Popma and Masser (1999) where *O. niloticus* can grow well at salinities up to 15 ppt, performing better below 5 ppt. Furthermore, this report has also been supported by Likongwe *et al.* (1996) where *O. niloticus* can grow well at salinities up to 16 ppt with optimum salinity level of 8 ppt. The best performance of *O. niloticus* cultivated in lower water-salinity levels can be related to the energy cost for the ionic regulation, which is lower when the fish is kept in an isotonic environment and this energy can be directed towards growth (Boeuf and Payan, 2001). Besides osmoregulation, the effect of water salinity on the performance of *O. niloticus* might be explained by its action upon digestive enzymes, where the exposure to different salinities might modify the water ingestion, altering the salinity of the intestinal content and affecting the activity of digestive enzymes as Moutou *et al.* (2004) have reported for sparid (*Sparus aurata*).

5. MATERIALS AND METHODS

5.1. Study area

The study was conducted at National Fisheries and Aquatic Life Research Center (NFALRC) - Sebeta, under greenhouse condition from April to October 2017. The research center is located about 24 kilometers southwest of the capital Addis Ababa, at an altitude of 2220m above sea level.

5.2. Experimental setup

The experiment was done with complete randomized design in four replica. A total of 12 tanks with water holding capacity of 1.2 m^3 (1m x 1m x 1.2m) were used. The water source for the experiment was ground water and the tank levels were maintained to $1m^3$. The tanks were continuously aerated using aerators (model- ACO-6603). One-fourth of the water in each tank was siphoned and replaced every third day to avoid tank water quality deterioration by the faeces and feed leftovers. The walls and bottom of the tanks were scraped and cleaned every 6^{th} day to minimize algal growth, in doing so hundred percent of the water was replaced with fresh ground water.

Figure 1: Photo showing the water tankers used for the experiment

5.3. Fingerling stocking

Fingerlings of *O. niloticus* were obtained from fish seed production ponds available at National Fisheries and Aquatic Life Research Center. Fingerlings were collected using two centimeter stretched mesh size seine net, from ponds reserved for *O. niloticus* parents collected from Lakes Chamo, Babogaya and Hashengie. Eighty mixed sex fingerlings from each strain were randomly distributed to culturing tanks in four replicas in the greenhouse and were acclimatized for three weeks. The average body weights of *O. niloticus* from the three strains at stocking were 4.4 gram. The stocking density was 20 fish/m^3 as recommended by several authors for *O. niloticus* growth in plastic tank (El-Sayed, 1998; Santos *et al*., 2013)

5.4. Experimental feed and feeding

Fish feed was formulated from locally available feed ingredients such as brewery waste, noug cake and wheat bran which is prepared by mixing the ingredients in pellet form. The feed was formulated based on Sebeta-1 fish diet which has 30 % crude protein (Table 1). Daily feed requirement of the fish was calculated based on 5% body weight of fish in each tank. Daily feed requirement was adjusted based on monthly weight gain calculated from monthly weight measurements. Feed was delivered into the feeding tray manually two times per day at 10 am and 4 pm. The feeding tray was made from mosquito net to avoid sinking of feeds and further allows the fish to get feed at any time of the day.

Table 1: Nutrient composition (% dry weight) of the experimental feed ingredients

Composition of feed	Proximate composition of feed ingredients		
Ingredients	Ingredient inclusion (%)	Crude protein	Crude lipid
Brewery waste	40	27.4	2.7
Noug cake	52	33	6.7
Wheat bran	8	18.5	3.6
Feed		30	4.9

5.5. Water quality measurements

Dissolved oxygen, water temperature, conductivity and pH of the experiment were measured in every other day, three times per day at 9:00am, 1:00pm and 5:00pm with Multimeter-probe. Total nitrogen ammonia was determined every two weeks using standard method (APHA, 1999). To see the diurnal changes in physico-chemical parameters, 24 hour measurement was conducted at every 2 hour intervals.

5.6. Length-weight measurements

Hundred percent of the fish from each tank were collected monthly for length-weight measurements. Total length and weight were measured using ruler and digital balance, respectively. Total length was measured to the nearest centimeter and weight to the nearest gram.

5.7. Growth parameter calculation

Growth parameters such as total weight gain, daily weight gain, specific growth rate, feed conversion ratio, Fulton's condition factor and survival rate were calculated as follows (Zenebe Tadesse *et al*., 2012; Mary, 2014)

$$\text{Average initial length (cm)} = \frac{\text{sum of individual length at the begning}}{\text{total number of individuals}}$$

$$\text{Average final length (cm)} = \frac{\text{sum of individual length at the end}}{\text{total number of individuals}}$$

$$\text{Average initial weight (g)} = \frac{\text{sum of individual weight at the begning}}{\text{total number of individuals}}$$

$$\text{Average final weight (g)} = \frac{\text{sum of individual weight at the end}}{\text{total number of individuals}}$$

Weight gain (g) = Final weight (g) – Initial weight (g)

$$\text{Daily weight gain (g/fish/day)} = \frac{\text{Average final weight} - \text{Average initial weight}}{\text{culturing period (day)}}$$

$$\text{Specific growth rate (\% per day)} = \frac{\ln \text{finalweight} - \ln \text{intial weight}}{\text{culturing period (day)}} * 100$$

$$\text{Feed conversion ratio} = \frac{\text{Feed intake (g)}}{\text{Live weight gain (g)}}$$

$$\text{Fulton condition factor} = \frac{\text{Weight}}{\text{Length}^3} * 100$$

$$\text{Survival rate (\%)} = \frac{\text{Final number of fish}}{\text{Initial number of fish}} * 100$$

5.8. Analysis of body proximate composition

Mixed sex *O. niloticus* with average body weight 49gram, 50gram and 49 gram for Babogaya, Chamo and Hashengie were selected for body proximate analysis. A fillet sample was then taken from the two sides of each fish manually using laboratory knife for the respective treatments.

Moisture content was determined by oven drying method following the procedure of AOAC (1998). Empty dishes were dried using air drying oven for 1 hour at 105^0C, transferred to desiccators (with granular silica gel), cooled for 30 minutes, and were weighed. Next, five gram of composite fresh fillet was transferred to the dried and weighed dishes. The dishes and their contents were placed in the drying oven and dried for 6 hours at 105^0C in an oven until constant weights were obtained, then the dishes and their contents were cooled in desiccators to room temperature and re-weighed. The difference in weight before and after drying expressed as a percentage of the initial weight was taken as the moisture content.

$$\text{Moisture content} = \frac{\text{Weight of wet sample} - \text{Weight of dried sample}}{\text{weight of wet sample}} \times 100$$

Crude protein was quantified by the standard micro-Kjeldahl Nitrogen method as described in AOAC (2005). Accordingly, one gram wet sample was hydrolyzed with concentrated sulfuric acid at 400°C using Behroset InKje M digestion apparatus in the presence of 1 gram catalyst Copper Sulfate until clear solution was formed. After digestion was completed, the formed clear solution was cooled for 30 minutes. The resulting solution was distilled under alkaline condition using the Behr S1 steam distillation apparatus by addition of 50 mL sodium hydroxide (40 %) and 70mL distilled water. The distillate containing ammonia was trapped in 25ml boric acid (2%) solution. The distillation process was terminated when the volume of receiving flask reached between 100 to 150 mL. Then, nitrogen content was estimated by titration of the formed ammonium borate with 0.1N HCl. Crude protein was estimated by multiplying the nitrogen content with a factor of 6.25. The result was expressed as a percentage of the original weight of the sample.

$$\% \text{ N} = \frac{\text{Normality of HCl x (Volume of HCl titrates sample } - \text{ Volume of HCl titrates blank)}}{\text{weight of sample}} \text{ x } \frac{14\text{gram}}{\text{mole}} \text{ x } 100$$

$$\text{Crude protein} = 6.25 \text{ x } \%\text{N}$$

Crude fat was determined following the procedure of AOAC (1998) by semi continuous solvent extraction method. First, empty porous cellulose extraction thimble covered with fat free cotton was oven dried at 105 °C for 1 hour, cooled in a desiccator for 30 minutes and weighed. Next, 2 gram of dried and ground sample was placed in a thimble. The thimble was placed in an extraction chamber which is suspended above a flask containing diethyl ether solvent and below the condenser. A flask containing diethyl ether solvent in the presence of boiling chips was placed inside the extraction chamber then heated at 55^0C and the solvent evaporates, moves up into the condenser where it is converted into a liquid that trickles into the extraction chamber containing the sample. At the end of the extraction process, which typically lasts for 4 hours, the thimble containing the extracted sample was oven dried at 105 °C for 1 hour, cooled in a desiccator for 30 minutes and weight was determined. Weight of fat was calculated from the difference in weight of the thimble containing the sample, before and after extraction. The crude fat in the initial sample was then calculated as percentage

Weight of fat = Weight of thimble before extraction - Weight of thimble after extraction

$$\% \text{ crude fat in dry base } = \frac{\text{weight of fat}}{\text{weight of sample}} \text{ x } 100$$

Eventually fat content in wet base was recalculated from dry base using the formula:

$$\% \text{ crude fat in wet } = \frac{\% \text{ crude fat in dry (100}-\text{Moisture content)}}{100}$$

Ash was determined as the weight of the residue after 5 g of wet sample had been ashed at 550 °C in a muffle furnace overnight. First, porcelain crucibles were oven dried at 105^0c for one hour, transferred to desiccator, cooled for 30 minutes, and was weighed. Five gram of wet sample was added to pre-weighed crucible. The crucible with the sample was heated in a muffle furnace at 550^0C overnight. Then furnace heated crucible was cooled in desiccator for 30 minutes and weighed. Finally, percentage ash content was calculated as

$$\text{Ash Content} = \frac{\text{weight of ash}}{\text{weight of sample}} \text{x} 100$$

Gross energy values (kcal/g) was calculated by overall addition of the Carbohydrate content multiplied by 4, protein content multiplied by 4 and fat content multiplied by 9, using Atwater's conversion factors. The result was expressed as kcal per 100 gram.

Gross energy value = 4 x carbohydrate content + 4 x protein content + 9 x fat content

Carbohydrate content = 100 – (moisture content + protein content + fat content + ash content)

5.9. Statistical analysis

Analyses were performed using the statistical package SPSS software (version 21). All the data were subjected to one-way analysis of variance (ANOVA) followed by a comparison of means using Tukey multiple range test at 5% significance level.

6. RESULTS

Data on physico-chemical parameters of the culture system are summarized in Table 2. All limnological parameters showed temporal variation. The minimum and maximum day time water temperature recorded during the experimental period were 22^0C and 33^0C, respectively, where the lowest was recorded in July and highest in May. Dissolved oxygen content showed an inverse relation with water temperature in which minimum (3mg/l) value was recorded in May and maximum (6.5mg/l) in July. pH also showed similar trend with dissolved oxygen where minimum pH value was recorded in May and maximum in July and September. However, conductivity of the culture system was found to follow similar trend with water temperature where minimum conductivity was recorded in July (142µS/cm) and the maximum value being in May (228µS/cm). Total nitrogen ammonia was found to be independent of physical parameters rather it was found to be dependent on fish size being maximum in October (0.48mg/l).

Diurnal changes in water temperature and dissolved oxygen is presented in Figure 1. The minimum water temperature was recorded at 6 am (22^oc) and the maximum at 6 pm (28.5^oc) of the day. On the other hand the minimum dissolved oxygen concentration was recorded at 10pm (3mg/l) and the maximum at 8am (5.1mg/l).

Table 2: Physico-chemical measurements of the culture systems in greenhouse condition (mean ± standard error)

		Months					
Parameters	Time	May	June	July	August	September	October
Water temperature (^{0}C)	9am	25.1±0.3	25±0.2	23.6±0.1	24±0.2	24.6±0.2	24.9±0.3
	1pm	28.0±0.4	27.9±0.2	25.7±0.2	25.4±0.2	25.9±0.2	26±0.2
	5pm	30.1±0.5	29.3±0.1	27.5±0.1	27.6±0.1	27.9±0.2	28.6±0.0
	Mean	27.7± 0.1	27.4±0.1	25.6±0.1	25.9± 0.1	26.1±0.1	26.5±0.2
Dissolved Oxygen (mg/l)	9am	4.1±0.1	4.5±0.1	5.6±0.2	5.1±0.2	5.4±0.4	5.5±0.0
	1pm	4.4±0.1	4.7±0.1	5.5±0.2	5.4±0.2	5.2±0.2	5.3±0.0
	5pm	4.7±0.2	4.7±0.1	5.4±0.0	5.5±0.2	5.1±0.2	5.2±0.0
	Mean	4.5±0.05	4.6±0.03	5.5±0.03	5.3±0.04	5.2±0.05	5.3±0.01
pH	Mean	5.5±1.0	6.5±1.0	8.0±1.0	7.9±1.0	8.0±1.0	7.9±1.0
Conductivity (µS/cm)	Mean	210±0.6	207±0.7	168±1.3	169 ± 0.8	171.5±1.1	175±1.1
TNA (mg/l)	Mean	0.13	0.14	0.21	0.29	0.33	0.38

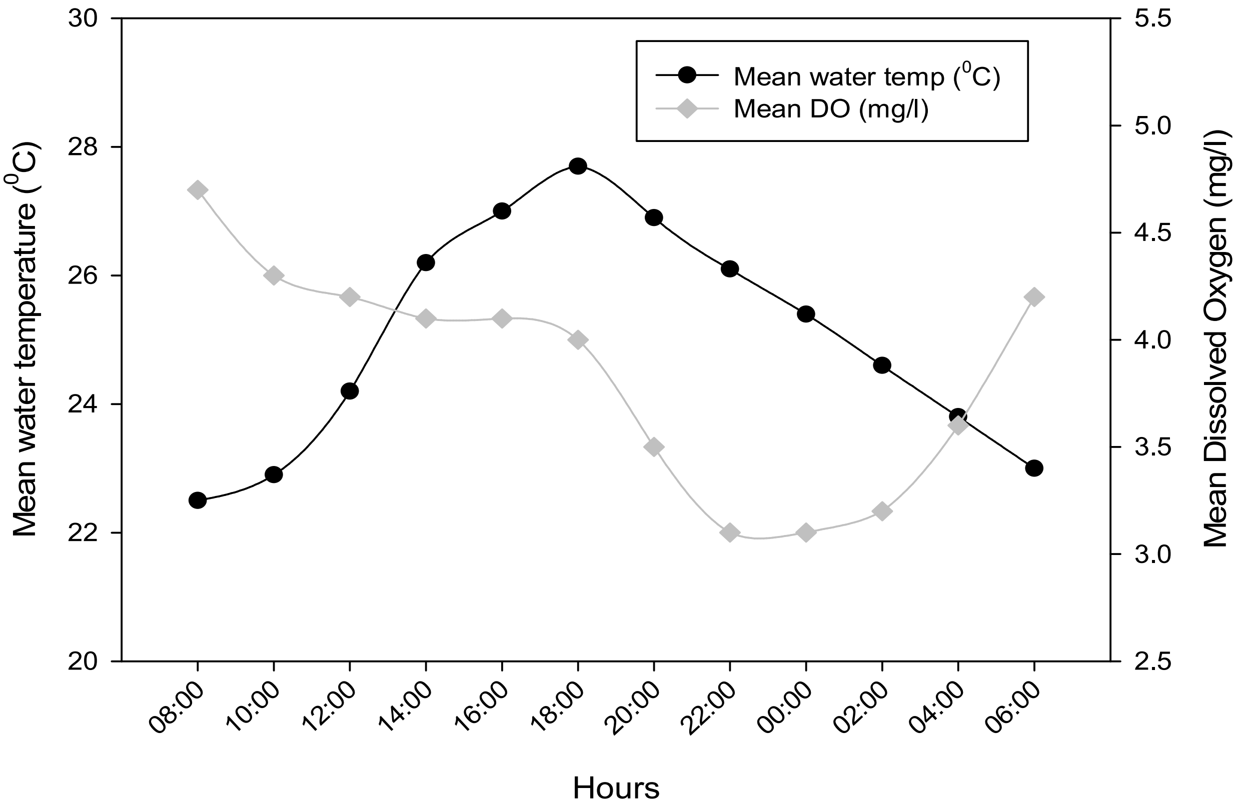


Figure 2: Diurnal water temperature and dissolved oxygen content of the tank culture system under greenhouse condition

Data for growth parameters, feed conversion ratio, Fulton's condition factor and survival rate are summarized in Table 3. Highest final weight gain was recorded in Babogaya and Chamo strains followed by Hashengie. Similar trend was obtained in daily weight gain and specific growth rate where comparatively higher values were obtained for Babogaya and Chamo strains followed by Hashengie strain. All the strains attained similar feed conversion ratio with a little lower in Babogaya strain. In terms of condition factor Hashengie stain showed better Fulton's condition factor followed by Babogaya and Chamo strains respectively. Highre survival rate was recorded in Chamo and Babogaya strains with lowest in Hashengie strain.

Table 3: Growth parameters, feed conversion ratio, Fulton's condition factor and survival rate of *O. niloticus* strains cultured in tanks under greenhouse condition (mean ± standard error)

	Strains		
Parameters	Chamo	Babogaya	Hashengie
Initial weight (g)	4.4±0.2[a]	4.4±0.2[a]	4.4±0.1[a]
Final weight (g)	37.2±2.6[a]	37.6±2.1[a]	33.3±2.8[a]
Initial length (cm)	5.6±0.07[a]	5.9±0.06[a]	5.9±0.04[a]
Final length (cm)	12.6±0.3[a]	12.6±0.2[a]	11.2±0.3[a]
Weight gain (g)	32.8±2.5[a]	33.2±2[a]	28.9±2.8[a]
Daily weight gain (g/fish/day)	0.18±0.01[a]	0.18±0.01[a]	0.16±0.02[a]
Specific growth rate (%per day)	1.1± 0.03[a]	1.1±0.02[a]	1.0±0.05[a]
Feed conversion ratio	4.7±0.14[a]	4.6±0.32[a]	4.7±0.24[a]
Fulton condition factor	1.8±0.04[a]	1.9±0.02[a]	2.2±0.05[b]
Survival rate (%)	100±0.0	100±0.0	84±3.25

Mean in the same raw with similar superscript are not significantly different ($p>0.05$)

Results on monthly change in mean total length and body weight of the three *O. niloticus* strains at different sampling periods are given in Figure 3 and 4, respectively. At the end of the experimental period total weight of the strains were found to be in the range of 22g and 68g. Change in size of the three strains was found to be variable at different sampling months. Chamo and Babogaya strains were found to have comparable mean weight and length in all the sampling periods. However, mean total length and weight of Hashengie strain was lower than the other two strains. All strains grew in a liner manner from the beginning up to the end of the experiment. As indicated in Figure 3 and Figure 4, change in length was greater than change in weight at early life stage. However, as time goes, change in weight was found to be greater than change in length, implying that fish grow predominantly in weight than in length at late life stage. Besides to this, there was no decline in weight gain of all strains at the end of the experimental period suggesting that, the maximum weights of the strains is yet to be attained.

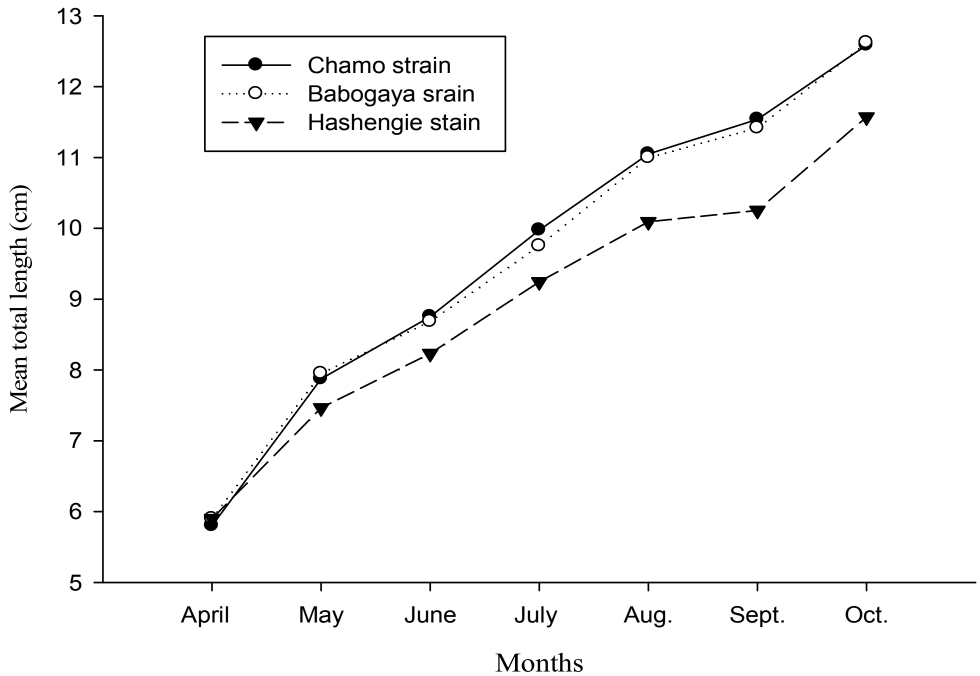


Figure 3: Monthly changes in mean total length of three *O. niloticus* strains grown in tanks under greenhouse condition months

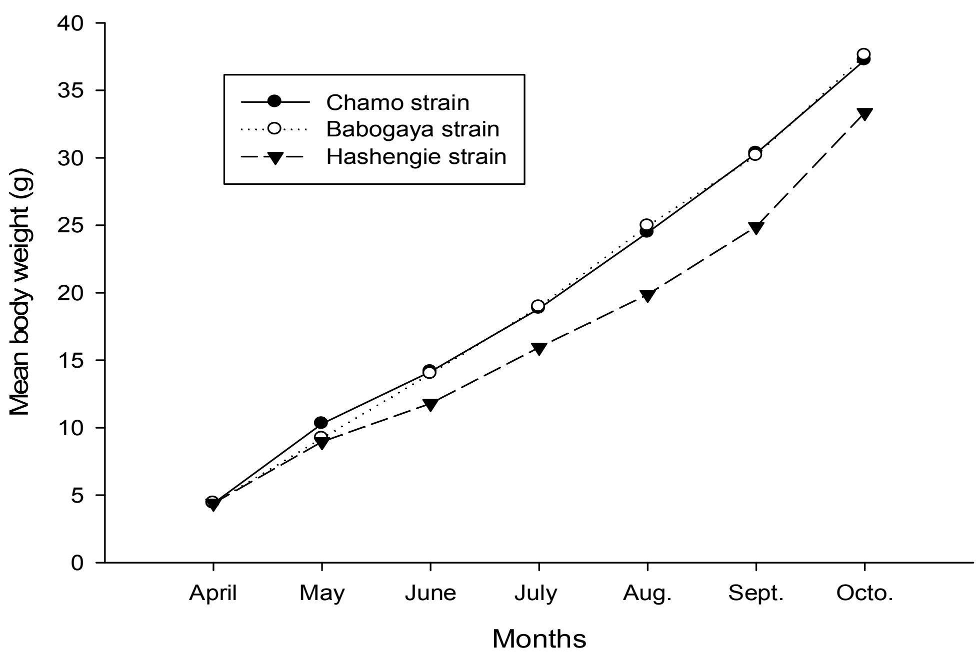
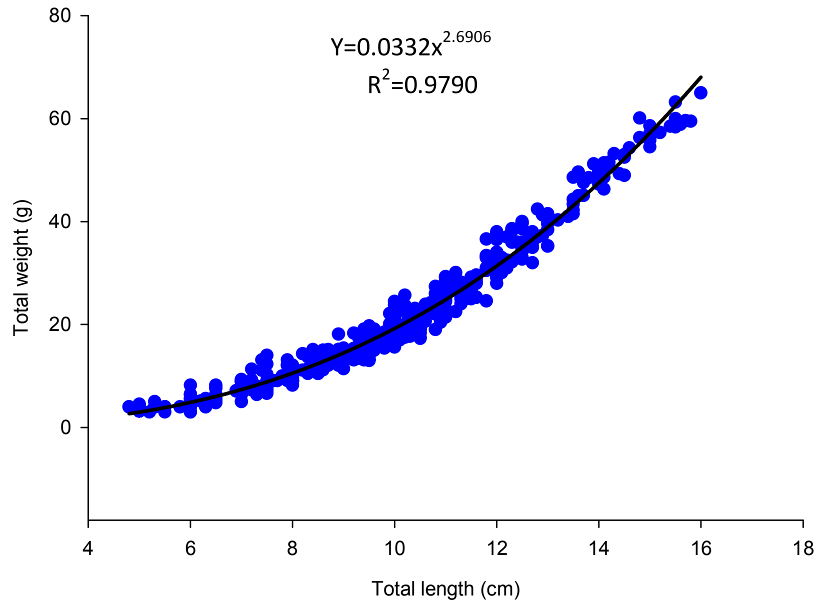


Figure 4: Monthly growth curve of mean body weight of three *O. niloticus* strains cultured in tanks under greenhouse condition

Results of length-weight relationship of strains are given in Figure 5. The strain from Hashengie shows better length-weight relation with relatively higher value of regression coefficient followed by Babogaya and Chamo strains, respectively.



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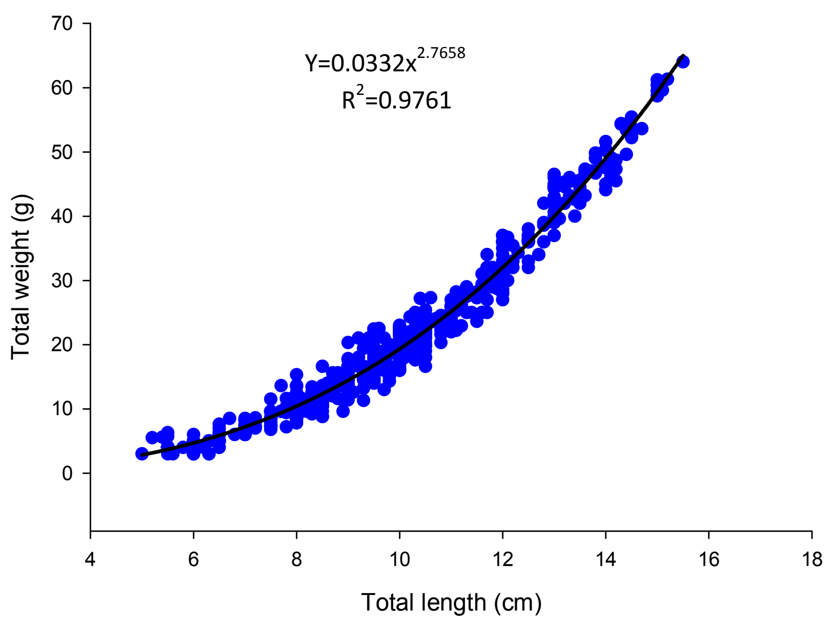

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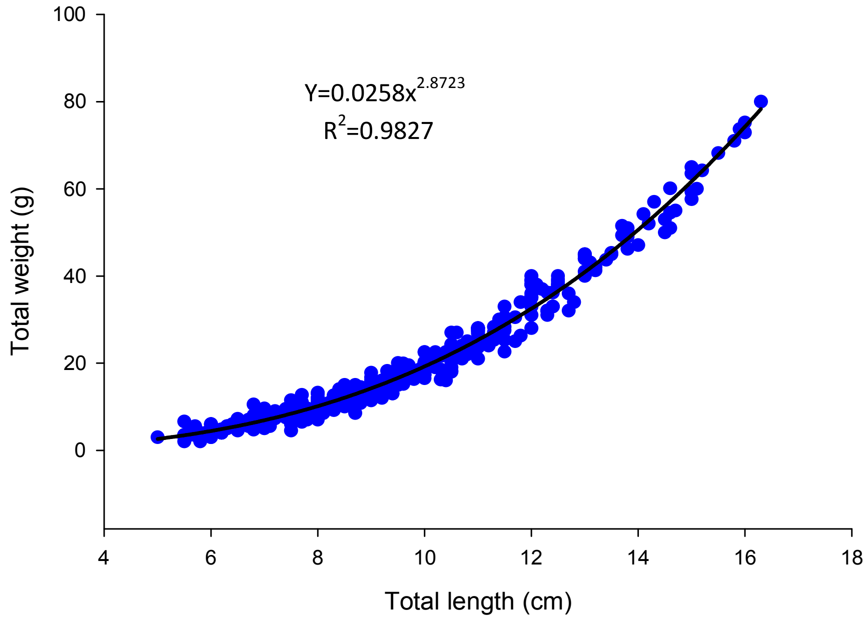

C

Figure 5: Length-weight relationships of *O. niloticus* strains (A, Chamo B, Babogaya and C, Hashengie) reared in tank culture system under greenhouse condition

A result of proximate body composition for the tested strains is presented in Table 4. All strains were found with almost similar values in all proximate parameters tested except carbohydrate.

Table 4: Percentage proximate body composition and gross energy content in kcal /100 g of Nile tilapia fillet in wet basis (mean ± standard error) (n=8)

	Parameters					
Strain	Moisture	Crude protein	Crude Fat	Ash	Carbohydrate	GE (Kcal/100g)
Chamo	78.0±0.06[a]	18.2±0.18[a]	1.53±0.0[a]	1.27±0.1[a]	1.0±0.1[a]	90.6±0.8[a]
Babogaya	78.1±0.06[a]	18.6±0.08[a]	1.26±0.1[a]	1.20±0.1[a]	0.84±0.1[a]	89.1±0.9[a]
Hashengie	77.8±0.23[a]	17.6±0.25[a]	1.20±0.1[a]	1.33±0.1[a]	2.07±0.1[b]	89.5±0.2[a]

Mean in the same column with similar superscript are not significantly different ($p>0.05$)

7. DISCUSSION

7.1. Physico-chemical parameters

In the present study growth performance and proximate body composition of fingerling *Oreochromis niloticus* strains from different Ethiopian freshwater lakes were compared in tank culture system under greenhouse condition. Water quality parameters tested during the study period remained in the acceptable range required for normal growth and physiological activities of *O. niloticus* fingerlings. Monthly variations were observed in all water quality parameters. Water temperature was found to range from 25.6±0.11^{0}C to 27.7± 0.13^{0}C where the lowest being in July and the highest in May. The variation in water temperature might be attributed to seasonal difference in atmospheric air temperature in which it was lower in July because of the seasonal rain and relatively higher in May. This is in agreement with the report by Zenebe Tadese *et al*. (2012) who stated that air temperature is relatively warmer during the dry season between February and June and declines in the wet season mainly in July and August. The temperature record of the present study is well in the optimum temperature range reported for best growth, survival rate and feed utilization of *O. niloticus* (Azaza *et al*., 2008; Faruk *et al*., 2012). Dissolved oxygen content of the culture system showed monthly variation in an inverse relation with water temperature. It was found to range from 4.5±0.05 mg/l in May to 5.5±0.03 mg/l in July. The lowest dissolved oxygen content in May might be attributed to the higher water temperature. It has been reported that water temperature affects dissolved oxygen content of a given culture water where, the higher the temperature, the lower the dissolved oxygen will be. This is in line with the report by Wetzel (1983) who pointed out that solubility of oxygen is affected non-linearly by temperature, and increase considerably in cold water. Dissolved oxygen content of the present study was in acceptable range for growth of tilapia. Adamneh Dagne *et al*. (2013) have mentioned that the dissolved oxygen level for growth of *O. niloticus* ranges from 3.0 to 9.0. pH of the culture system was also found to have similar trend with dissolved oxygen, ranging from 5.5 in May to 8 in July and September. The lowest pH value recorded in May might be attributed to the relatively higher water temperature content in that particular month. Studies have showed that pH is inversely related to water temperature in which, the higher the water temperature the lower the pH will be. pH in the present study was optimum for growth of *O. niloticus* fingerlings except the pH value recorded in May. This is comparable with the report by El-Sherif and El-Feky (2009) who reported that water pH ranging from 7-8 could be more suitable for optimum growth performance and survival rate of Nile tilapia. Similar result has also been reported by Popma and Masser (1999) where tilapia can survive and grow best at pH range from 6 to 9. The level of total nitrogen ammonia was found to increase from 0.15mg/l at the beginning of the experiment to 0.38mg/l at the end of the experiment. Similar result was reported by Mesay Eniyew *et al*. (2016) where buildup of nitrogenous compounds such as ammonia was observed in progress with time. Protein intake is reported as major factor to affect nitrogenous end products of fish (Yigit *et al*., 2005). Therefore, the increment of total nitrogen ammonia in progress with time in the present study might be attributed to higher protein intake from feed in relation to size increment of the culture strains, which in turn cause an increase in the amount of excreted nitrogenous waste, mainly total nitrogen ammonia.

In 24 hours cycle, water temperature was recorded to be higher from 2pm to 6pm of the day time and lower at night (Figure 2). The diurnal variation in water temperature could be related to sunrise and sunset cycle of the day which in turn affects the extent of solar light. Solar light is combination of different rays with their respective wavelengths and energies. Studies have showed that wavelengths and energies of solar light are inversely related in a way that when wavelength is high the energy will be low (Kumar *et al*. 2014). During the day, rays from the sun pass through the polyethylene cover of the greenhouse to the inside area. In this time rays with shorter wavelength re-bounce back to the outside environment, however, rays with higher wave length remain inside the greenhouse because their low energy content didn't enable them to penetrate the polyethylene cover again from the inside area to the external environment. In this case, these rays make the temperature of the greenhouse to be higher which in turn increase the water temperature. But, the inside area of the greenhouse becomes cold because of absence of sun light, and hence the water temperature also decreases. Moreover, dissolved oxygen content of the experimental system was found to be lower during the night time from 8pm to 4am and relatively higher in day time from 6am to 4pm (Figure 2). The low dissolved oxygen content of the culture system during the night time might be attributed to higher oxygen consumption rate of *O. niloticus* at night as it has been reported by García-Trejo *et al*. (2016). Furthermore, low dissolved oxygen content during the night time might also be attributed to respiration by phytoplankton species. The process of respiration by phytoplankton consumes oxygen to produce energy and makes dissolved oxygen content of a given water to be low.

7.2. Growth performance

Result of the present study demonstrates that relatively higher final weight gain was recorded from Babogaya and Chamo strains than Hashengie strain. However, there was no significant difference ($p>0.05$) among the strains tested. Unlike, to the present study, Abelneh Yimer *et al*. (2015) have reported that Chamo strain had statistically highest ($p<0.05$) final mean body weight than Tana and Hashengie strains in pond culture experiment. Similar result has also been reported by Zelalem Teshome (2013) where Chamo strain had significantly higher ($p<0.05$) final mean body weight than Ziway, Tana and Hashengie strains while, significantly lowest final mean body weight was attained by Hashengie strain in pond culture experiment. Furthermore, better growth rate of *O. niloticus* from Lake Chamo was reported by Demeke Admassu and Ahlgren (2000) based on otolith micro-increment analysis from the natural system. The situation of non-significant difference in the final weight gain in the present study could be related to the optimization and excluded deviation in environmental factors. For instance, while environmental temperature variation was between 18 and 48°C, temperature inside the tanks showed a variation between 23 and 28°C, which is a recommended for *O. niloticus* culture (Mirea *et al*., 2013). It has been reported that cultivation under greenhouse diminishes the effect of deviation in environmental factors and is helpful tool for water temperature control (García-Trejo *et al*., 2016)

Daily growth rate of *O. niloticus* strains in the present study was found ranging from 0.16 to 0.18 gram/day/fish. The daily growth rate of Chamo and Babogaya strains was found to be equal in proportion and was relatively higher than daily growth rate attained by Hashengie strain. However, there was no significant difference ($p>0.05$) in daily growth rate of the three strains. The relatively higher daily growth rate attained by Chamo and Babogaya strains might be attributed to better nutrient utilization efficiency from feed which in turn is affected by strain variation as it has been reported by Soltan and Hassaan (2017) where fish which convert greater part of the nutrients absorbed to body weight, may attain higher growth rate. Daily growth rate of the present study is lower than daily growth rate reported by other authors for *O. niloticus*. Adamneh Dagne *et al*. (2013) have reported daily growth rate of 0.29±0.02 gram/fish for mixed sex *O. niloticus* in pond culture system. Furthermore, Matthew *et al*. (2016) have reported daily growth rate ranging from 0.52 to 2.30 for *O. niloticus* in happas. Moreover, daily growth rate of the present study is lower than the daily growth rate reported by Abelneh Yimer *et al*. (2015) (0.23 to 0.33 g/day) and Kassaye Balkew and Gjoen (2012) (0.68 to 0.86 g/day) for *O. niloticus* in pond culture experiment. The lower daily growth rate and low weight gain for that matter, of the present study might be attributed to breeding of strains which was observed since one month beyond the starting date of the experiment. Strains of the present study was found to be sexually mature, holding egg in their mouse at a size of 7.7cm, 7.4cm and 7.7cm for Chamo, Hashengie and Babogaya strains, respectively. Similar result was noticed by Thahon *et al*. (2008) and Hafeez-ur-Rehman *et al*. (2008) that tilapia starts breeding even at three months old at a size of about 8cm onwards. The situation of early sexual maturity in the present study might affect the growth rate of the strains in a number of ways. The first probable effect is the investment of energy for gonad development and gamete production. Early sexual maturation, with heavy investments of nutrients for gonad development and gamete production, was reported to have several negative consequences for growth rate and product quality of farmed fish (Marianne *et al*., 2016). Gonad development is accompanied by endocrine, behavioral and body composition changes that lead to lower growth rate (Estebana *et al*., 2017). This is related to the low feeding rate and use of energy from diet and/or part of the body reserves for gonad development and gamete production rather than for somatic growth which is undesirable characteristic in fish farming (Turan and Guragac, 2014). Furthermore, Low daily growth rate of the present study might also be as the result of energy loses from body reserve due to mouth brooding nature of the strains. *Oreochromis niloticus* being a maternal mouth brooder to assure the survival of their offspring, hatch eggs in buccal cavity of the female and the female protects the hatched young from predators in her mouth. The female incubates the eggs in her buccal cavity and broods the fry after hatching until the yolk sac is absorbed (Kour *et al*., 2014). The process of incubating and brooding may take from one up to two weeks, depending on temperature (Kour *et al*., 2014). When eggs are fertilized and develop, the females do not feed during the mouth incubation and brooding period, which cause considerable drain on body reserves (Soltan and Hassaan, 2017). Not only this, even after fry are been released, they may swim back into mouth of the parent if there is threat. Moreover, the lower growth rate of the present study might also be attributed to the quality and digestibility of feed. Feed conversion ratio, the indicator of feed quality, was found to be higher in all the strains tested. Feed conversion ratio of the present study indicated that 4.7gram of feed was used to produce 1 gram fish flesh in Chamo and Hashengie strains. Furthermore, 4.6gram of feed was used to produce one gram additional weight in Babogaya strain. These FCR value are higher than the recommended 1.5gram of feed to produce 1gram of live weight in aquaculture (Stickney, 1979). High feed conversion ratio of the present study might indicate low quality of the feed used which was formulated from agro-industrial byproducts which could affect the growth rate. This idea is in agreement with the report by Yakubu *et al*. (2013) who pointed out that higher FCR indicates poor acceptance or utilization of diet as a result of low quality of experimental feed. Absence of natural food could also be a reason for the lower growth rate of strains in the present study. As the result of interference to the experimental system through continues change of experimental water, the amount of natural food that was to be available had it been the water was without change was avoided. Studies have reported that high yield of Nile tilapia can be achieved by higher abundance of natural food in culture system (Elnady *et al*., 2010; Zenebe Tadesse *et al*., 2012)

Specific growth rate, the percentage increase in weight of fish per day, was ranged from 1.0±0.05 to 1.1±0.03. It followed similar trend with daily growth rate where it was relatively higher in Babogaya and Chamo strains than Hashengie strain. However, there was no significant difference ($p>0.05$) in specific growth rate among the strains. Specific growth rate recorded in the present study is lower than those obtained in other studies, for the same reasons mentioned to the lower daily growth rate. For instance, Yakubu *et al*. (2013) have reported specific growth rate ranging from 1.46 to 1.64 for *O. niloticus* under controlled environment. Furthermore, Kassaye Balekew and Gjoen (2012) also found higher specific growth rate ranging from 2.41 to 2.73 for *O. niloticus* strains in pond culture system. Moreover, higher specific growth rate ranging from 2.51±0.1 to 3.50±0.1 and 2.23±0.06 to 2.43±0.04 have also been reported by Al-Hafedh (1999) and Muin *et al*. (2017), respectively for *O. niloticus.* However, specific growth rate of the present study is in agreement with Garduno-Lugo *et al*. (2003) who reported a specific growth rate of 1.04 for *O. niloticus* in controlled environment.

Feed conversion ratio (FCR) expresses the weight of feed (g or kg) used to produce 1g or 1kg of fish flesh (Yakubu *et al*., 2013). It is an important indicator of the quality of fish feed where lower FCR indicates better utilization of feed and extraction of nutrients from the feed and further converting it into flesh. Feed conversion ratio reported in the present study was ranged from 4.6 to 4.7. Significant difference ($p>0.05$) was not observed in feed conversion ratio of the tested strains. However, these values are higher than the FCR reported by other authors. Ridha (2006) has reported FCR value ranging from 1.44 ± 0.02 to 1.68 ± 0.05 in growth comparison experiment. In similar study Kassaye Balkew and Gjoen (2012) has also pointed out lower FCR value ranging from 1.72 to 1.76. Furthermore, the FCR of 4.6 to 4.7 in the present study was also higher than the acceptable recommended FCR value of 1.5 for aquaculture (Stickney, 1979). The difference in FCR value might probably be due to strain variation and different culture environment as it has been reported by Guimaraes *et al.* (2008) where efficient utilization of diet may vary even within single species because of the particular strain of fish used and the environmental factors. Feed quality and life stage of cultured fish might also be a reason for the FCR difference. Ridha (2006) has reported low FCR value attained by *O. niloticus* strains at early life stage compared to later life stage of the same strain. However, FCR reported in the present study is in close agreement with the report of Abelneh Yimer *et al*. (2015) who reported FCR value ranging from 3.6 to 4.4 for *O. niloticus* strains in pond culture system.

The length-weight relationship and condition factor are important parameters for assessing the growth pattern, health and general well-being of fish (Anani and Nunoo, 2016). The growth of fish is said to be isometric when length increases in equal proportions with body weight (Bagenal and Tesch, 1978). The regression co-efficient for isometric growth is '3' and values greater or lesser than'3' indicate positive and negative allometric growth, respectively (Ndiaye, 2015). The value of regression co-efficient "b" in the present study was ranged from 2.69 to 2.87. The regression co-efficient recorded in the present study shows negative allometric growth in all treatments, which implies that the fish becomes more slender as it increases in weight (Chakravartty, 2016). However, these values are not match deviated from the isometric value of "b" which is 3, signifying that the growth attained by the strains was close to isometric growth. The result of the present study is comparable with the findings of other researchers who worked on growth of Nile tilapia. Abelneh Yimer *et al*. (2015) have reported regression co-efficient ranging from 2.76 to 2.86 in strain comparison experiment under pond culture system. It is also in line with the report by Zenebe Tadesse (1997) who reported regression co-efficient value of 2.89 for Nile tilapia from Lake Tana under natural system. Furthermore, the regression co-efficient values of the present study is within the recommended range of 2 - 4 appropriate for fresh water fishes (Anani and Nunoo, 2016) where the value of "b" above 3 are possible in some conditions such as stress free environments (Prasad *et al*., 2007).

Condition factor is quantitative parameter estimated based on length-weight data and reflects the physiological state of a fish in relation to its welfare (Ighwela *et al*., 2011). It expresses 'condition', 'fitness' or 'wellbeing' of fish based on the hypothesis that the heavier fish of a given length is in better condition (Biswas *et al*., 2011). Poorly conditioned fishes are associated with negative allometric growth, which implies that the fish becomes more slender as it increases in weight whilst fishes with appropriate condition factor have isometric growth, which implies that the fish becomes relatively deeper bodied as it increases in length (Chakravartty, 2016). Fulton' condition factor of *O. niloticus* strains in the present study were 1.8, 1.9 and 2.2 for Chamo, Babogaya and Hashengie, respectively. Hashengie strain, the strain with the relatively lower growth rate, attains significantly higher ($p<0.05$) condition factor than the other strains tested. This is in comparable with the report by Ridha (2006) and Kassaye Balakew and Gjoen (2013) who stated similar result where strain with lower growth rate attains higher value of Fulton's condition factor. The low Fulton's condition factor of Chamo and Babogaya strains of the present study might be related to the high breeding rate of the two strains which was observed during the experiment. This is in line with finding by Zenebe Tadesse (1997) who reported low condition factor during the peak breeding time for *O. niloticus* from Lake Tana. Fulton's condition factor of *O. niloticus* in all the treatments of the present study were greater than 1, indicating that the strains from all the treatments were in good condition and healthy during the entire period of the experiment. This is in agreement with the report of Shahabuddin *et al*. (2015) who suggested a condition factor higher than 1. 0 indicates good fish health condition. The condition factor obtained in the present study is in agreement with the report by Anani and Nunoo (2016) who found out condition factor ranging from 1.39 to 2.01 for *O. niloticus*. Furthermore, condition factor of the present study is in close agreement with condition factors reported from natural lakes of Ethiopia. For instance, Gashaw Tesfaye and Zenebe Tadesse (2008) have pointed out condition factor of 1.87, 1.81 and 1.84 for *O. niloticus* from Lake Koka, Ziway and Langeno, respectively. Furthermore, similar condition factor ranging from 1.47 to 2.29 for female and 1.44 to 2.37 for male *O. niloticus* have also been reported by Zenebe Tadesse (1997) from Lake Tana. However, unlike the present study, relatively higher value of condition factor (2.35) was reported from natural system of Lake Chamo by Yirgaw Teferi and Demeke Admasu (2002). The variation in condition factor might be attributed to difference in environmental conditions. This is in agreement with the finding of Gashaw Tesfaye and Zenebe Tadesse (2002) who pointed out that difference in environmental condition could be possible attributes for condition factor variation.

In terms of survival, relatively higher survival rate of 100% was recorded in Babogaya and Chamo strains while the lower survival rate of 84.0% was obtained in Hashengie strain. There was no significant (P>0.05) difference in survival rate among the strains tested. The lowest survival rate obtained in Hashengie strain might be attributed to the mortality rate recorded in that strain during the third month of the experimental period. Generally, the survival rates were relatively higher as it ranged from 84% to 100%. This is in consistent with the report by Ridha (2006) and Kassaye Balkew and Gjoen (2012) who reported better survival rate in strain comparison experiment of *O. niloticus*. Higher survival rate obtained in the present study could be attributed to the favorable environmental conditions for survival of *O. niloticus* throughout the experimental period. This is in agreement with the finding of El-Sherif and El-Feky (2009) who indicated that higher (100%) survival rates could be linked to favorable ecological conditions.

7.3. Body proximate composition

Moisture content among the strains of *O. niloticus* in the present study ranged from 77.8±0.23 to 78.1±0.06. The results showed that there was no significant difference (P>0.05) in the moisture content of the tested strains. The percentage range in moisture content of the strains in the present study is within the acceptable moisture level required for fish (60%-80%) (Adewumi *et al*., 2014). The moisture content of the present study is also close to the results of Muchiri *et al*. (2015) who reported moisture content ranging from 77.25 ± 0.38 to 78.98 ± 1.05 for *O. niloticus*. Moreover, moisture content of the present study is in close agreement with the findings of Garduno-Lugo (2003) and El-Hawarry (2012) who reported 79.1% and 79.09±1.02% of moisture content for *O. niloticus,* respectively.

Percentage crude protein content of *O. niloticus* stains in the present study ranged from 17.6±0.25 to 18.6±0.08. Babogaya strain had relatively higher crude protein content than the other two strains. However, there was no significant difference (p>0.05) in crude protein content in all the tested strains. Crude protein content of *O. niloticus* of the present study is in the range of permissible protein limit (15-28%) for fish and fisheries products (USDA, 2010). Moreover, percentage crude protein content of the present study is in agreement with crude protein content reported by other authors in controlled environment. For instance, Muchiri *et al.* (2015) have reported crude protein content ranging from 18.47 ± 0.34 to 18.96 ± 0.37 for *O. niloticus* grown in earthen pond. However, protein content of fish in the present study was found to be higher than the protein content of *O. niloticus* reported from natural water bodies. Tsegay Teame *et al*. (2016) have reported crude protein content of 16.13 ± 0.29 and 16.32 ± 0.30 for male and female *O. niloticus* from Lake Hashengie, respectively. Similar result of lower percentage crude protein content ranging from 13.3 ± 0.21 to 15.8 ± 0.21 was reported by Alemu Lemma *et al*. (2013) for *O. niloticus* from Lake Ziway. Furthermore, lower crude protein content (13.66±2.19) of *O. niloticus* was reported by Olopade *et al*. (2016) from Oyan Lake, Nigeria. The variation in crude protein content might be attributed to diet difference where, in this experiment strains were fed on formulated feed with relatively higher crude protein content. This is in agreement with the report by Muchiri *et al*. (2015) who stated that proximate body composition of fish is dependent on composition of the feed. Furthermore, it is clearly stated by Opiyo *et al*. (2014) that protein content of feed affects directly the protein content of fish fillet. Moreover, Al-Hafedh (1999) has reported that body composition of *O. niloticus* was influenced significantly by the dietary protein level where fish fed on high-protein diet had higher percentage of protein than fish fed on low-protein diets.

Percentage crude fat content of fish obtained in the present study ranged from 1.20±0.1 to 1.53±0.0. Chamo strain had relatively higher percent of crude fat content followed by intermediate crude fat by Babogaya strain and relatively lower in Hashengie strain. However, there was no significant difference ($p>0.05$) in fat content between the tested strains. Crude fat content recorded in strains of the present study is in the range of fat content (0.5- 2.3%) reported for fish (Petricorena, 2014). However, unlike the present study, Zenebe Tadesse (2010) has reported high fatty acid content from *O. niloticus* of Lake Hashengie. Similar result of higher crude fat content for *O. niloticus* from Lake Hashengie was also reported by Tsegay Teame *et al*. (2016). Moreover, percentage crude fat content of the present study was lower than crude fat (2.07) content reported by Garduno-Lugo (2003) for *O. niloticus*. This might be attributed to high moisture content of the tested strains of the present study. Zmijewski *et al.*, (2016) have reported a reverse correlation between fat and water content to be common among fish species. Furthermore, FAO (2010) has pointed out an inverse relation between moisture and lipid contents in fish fillet. The lower percentage crude fat content of the present study could also be because of the higher dietary protein content. This is because of the fact that protein content in diet and protein content in fillet are directly related in a way that if the protein content in diet is high, protein content in fillet will also be high (Opiyo *et al*., 2014). High protein content in fish fillet might make the other proximate components to be low including fat content. This is in agreement with the finding of Al-Hafedh (1999) who reported that *O. niloticus* fed on high protein diet was found to have lower percentage of crude lipid content than *O. niloticus* fed on low protein diet. The lower crude fat content of the present study might also be attributed to water temperature difference where, the higher the water temperature, the lower the fat content will be. This is in agreement with the finding of Tsegay Teame *et al*. (2016) who reported significantly higher crude fat in *O. niloticus* collected from Lake Hashengie than *O. niloticus* collected from Tekeze reservoir attributed to water temperature difference between the two water bodies. When water temperature approaches upper optimum range, fish becomes more active, swims here and there and its metabolic activity becomes high, in this case energy from feed is directly used for metabolic activity. If in case the energy from feed is not sufficient for the energy requirement of the metabolic activity fish use energy from body reserve. In this situation fish first consumes body fat and starts mobilizing muscle protein only when fat-derived energy has been nearly used up. On the other hand, when water temperature reaches the lower boundary of optimum range, fish starts to increase the fat composition of biological membranes as a strategy for survival and to withstand the lower temperature (Gorgun and Akpinar, 2012). This might be because of the high energy holding capacity of fat. Moreover, composition of the experimental feed could also be a reason for the low crude fat content of the tested strains. Composition of feed in the present study, where it's components being all plant origin might affect the fat content of the fish fillet. Zenebe Tadesse (2010) have found out high fatty acid content on *O. niloticus* from Lake Hashengie than from Lakes Babogaya, Hora, Haiq and Tana which was attributed to diet composition difference between the respective water bodies where, the diet of *O. niloticus* from Lakes Babogaya, Hora, Haiq and Tana was predominantly composed of phytoplankton whereas *O. niloticus* in Hashengie mainly feeds on zooplankton. However, crude fat content of *O. niloticus* strains in the present study is higher than the fat content of 0.92±0.41 reported by El-Hawarry (2012).

Percentage ash content in the present study ranged from 1.20±0.1 to 1.33±0.1. Hashengie strain was found to have relatively higher percentage ash content while relatively lower ash content was observed in Babogaya strain. However, there was no significant difference ($p>0.05$) in ash content of the tested strains. Ash content of strains in the present study is in the range of ash (1.2-1.5%) content reported for fish (Petricorena, 2014). It is also in line with the ash content reported by other authors. For instance, Muchiri *et al*. (2015) have reported ash content ranging from 1.14 ± 0.32 to 1.41 ± 0.12 for *O. niloticus* in controlled environment. Furthermore, Younis *et al*. (2015) have also pointed out similar ash content ranging from 1.02 ±0.11 to 1.30 ±0.07 for *O. niloticus.* Moreover, ash content of the present study is in close agreement with the report of Alemu Lemma *et al*. (2013) who reported ash content ranging from 1.0 ± 0.02 to 1.14 ± 0.02 for *O. niloticus* from natural environment.

Carbohydrate content in the present study ranged from 0.84±0.1 to 2.07±0.1. Hashengie strain was found to attain significantly higher ($p<0.05$) carbohydrate content than Chamo and Babogaya strains. The significantly higher carbohydrate content in Hashengie strain might be attributed to the relatively lower other body proximate components. Carbohydrate content of the present study is in close agreement with the repot by Tsegay teame *et al*. (2016) who reported carbohydrate content ranging from 1.2±0.1 to 1.6±0.4 and 1.4±0.2 to 1.5±0.2 from Lake Hashengie and Tekeze reservoir.

Gross energy value for *O. niloticus* strains in the present study was found to range from 89.1±0.9 to 90.6±0.8. Chamo strain attained relatively higher gross energy content than the other two strains tested. However, there was no significant difference ($p>0.05$) in gross energy content among the strains. Gross energy of the present study was found to be higher than the energy content (55.9 ± 0.86 to 65.0 ± 0.86) reported by Alemu Lemma *et al*. (2013) for *O. niloticus.* This variation might be attributed to the higher protein content attained in strains of the present study. This is in agreement with the finding of Alemu Lemma *et al*. (2013) who reported higher gross energy value in female *O. niloticus* as compared to male which is attributed to relatively higher protein and fat content in females than males.

8. CONCLUSION AND RECOMMENDATIONS

- Unlike similar studies conducted in pond culture system at National Fisheries and Aquatic Life Research Center, results of the present study showed that growth parameters (weight gain, daily growth rate and specific growth rate, feed conversion ratio), survival rate and body proximate composition (except carbohydrate) of *O. niloticus* strains was not significantly different ($p>0.05$). However, strain from Lake Hashengie showed significantly higher ($p<0.05$) Fulton's condition factor compared with those from Lakes Chamo and Babogaya.

- Body proximate composition of the strains were well in the range reported for tilapia except for the lower crude fat content of strain from Lake Hashengie, which was reported to have the highest compared with *O. niloticus* strains from other lakes in the natural system.

- The reason for no variation in the growth performances of the three strains could be due to the culture system where culture tanks were under greenhouse which brought the culture water temperature in the optimum range for *O. niloticus*. Despite the optimum culture water temperature, compared to the results reported by other studies the daily growth rates of the three strains were lower which might be due to breeding and quality and low digestibility of feed. The feed quality also explains why strain from Lake Hashengie had lower crude fat content while has the highest crude fat in the natural system.

- Generally, based on the current finding, strains of *O. niloticus* either from Lakes Chamo, Babogaya or Hashengie can be used for further experiment and stoking activities with feed supplementation.

- However, we strongly recommend to conduct further research in this regard with standard fish feed and more strain since this is the only study reported under greenhouse condition.

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