EFFECTS OF DIFFERENT PROCESSING METHODS ON NUTRIENT COMPOSITION OF SWEET POTATO LEAF AS FEED FOR NILE TILAPIA, *OREOCHROMIS NILOTICUS* (LINNAEUS, 1758).

M.SC. THESIS

BY

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HAWASSA UNIVERSITY, HAWASSA, ETHIOPIA

OCTOBER, 2023GC

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MAJOR ADVISOR: NATARAJAN PAVANASAM (PROFESSOR)

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OCTOBER, 2023GC

ADVISOR'S APPROVAL SHEET

(Submission Sheet-1)

This is to certify that the thesis entitled "**Effects of Different Processing Methods on Nutrient Composition of Sweet Potato Leaf as feed for Nile tilapia, *Oreochromis niloticus* (Linnaeus, 1758)".** Submitted in partial fulfillment of the requirements for the Degree of Master of Science with specialization in Aquaculture and Fishery Management, and has been carried out by Tigist Seyfe Belachew ID. No. GpFiAqR/0006/14, under our supervision. Therefore, we recommend that the student has fulfilled the requirements and hence she can submit the thesis to the Department of Aquatic Sciences, Fisheries and Aquaculture (ASFA).

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EXAMINER'S APPROVAL SHEET

(Submission Sheet-2)

We, the Members of the Boards of Examiners of the final Open Defense have read and evaluated the thesis of Ms. Tigist Seyfe Belachew entitled "**Effects of Different Processing Methods on Nutrient Composition of Sweet Potato Leaf as feed for Nile tilapia, *Oreochromis niloticus* (Linnaeus, 1758)** and examined the candidate. This is therefore, to certify that the thesis has been accepted as partial fulfillment of the requirements for the Degree of Master of Science in Aquaculture and Fishery Management.

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Tigist Seyfe Belachew

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BIOGRAPHY

Tigist Seyfe Belachew was born on 11th December 1992 EC in Demeko Kebele, Berehet Woreda, North Shoa Zone of Amhara Regional State of Ethiopia. She attended her Primary education at Demeko Elementary School. After completion of her Elementary school, she attended her Secondary and Preparatory education at Meteh Bila Secondary and Preparatory school respectively. After completion of her Preparatory school education, she joined Wolaita Sodo University, College of Agriculture in October, 2010 EC and graduated with B.Sc. Degree in Animal and Range Science in January 29, 2013 EC. Soon after her graduation, she was employed by Wolaita Sodo University, College of Agriculture in the Department of Animal and Range Science and served as Graduate Assistant for nine months. She then joined the School of Graduate Studies of Hawassa University in October, 2014 EC to pursue her M.Sc. Degree in Aquaculture and Fishery Management under the regular program. She has now completed her study and ready to defend her work.

DECLARATION

I declare that the thesis entitled "**Effects of processing methods on nutrient composition of sweet potato leaf as feed for Nile tilapia**" is my own work. All the sources that I have used or quoted have been indicated and acknowledged by means of complete references. I solemnly declare that, this thesis is not submitted to any other institution or anywhere for the award of any other academic degree, diploma or certificate.

Name: Tigist Seyfe Belachew Signature: ___________________

Date of Submission: ________________________

School/Department: ________________________

ABBREVIATIONS

AD	Air Dried
ANFs	Anti-Nutritional Factors
CARE	Centre for Aquaculture Research and Education
CF	Crude Fiber
CP	Crude Protein
DGR	Daily Growth Rate
DM	Dry Matter
EE	Ether Extract
FBW	Final Body Weight
FCF	Fulton’s Condition Factor
FCR	Feed Conversion Ratio
FSPLM	Fermented Sweet Potato Leaf Meal
IBW	Initial Body Weight
NF	Naturally Fermented
NFE	Nitrogen Free Extract
PER	Protein Efficiency Ratio
RF	Rumen Fermented
SBC	Soybean Cake
SGR	Specific Growth Rate
SPL	Sweet Potato Leaf
SPLM	Sweet Potato Leaf Meal
SR	Survival Rate

SSF	Solid State Fermentation
T	Treatment
TL	Total Length
TW	Total Weight
YF	Yeast Fermented

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ABSTRACT

The use of alternative feeds aims to increase productivity and reduce the feed costs in aquaculture production. The present study was conducted to evaluate the effects of different processing methods on nutrient composition of sweet potato leaf (SPL) and its effect on growth performance, feed utilization and body composition of *O. niloticus*. Fresh sweet potato leaves were collected and processed differently, namely air dried (AD); yeast fermented (YF); rumen fluid fermented (RF) and naturally fermented (NF). Following proximate analysis five isonitrogenous and isoenergetic feed: one control diet and four processed SPL based diets were formulated by replacing 30% CP of SBC with processed sweet potato leaf CP. A total of 300 Nile tilapia fingerlings each with an average body weight of 10.55±0.19g were stocked in 15 hapas installed in the concrete ponds in triplicate and fed with 5% of their body weight three times a day for three months. The results of proximate analysis of SPL showed the highest CP (33.9%), and lowest CF (7.80%) in YF and the highest fat (8.55%) and ash (12.14%) content were recorded in RF. AD SPL showed the highest DM (93.41%) and NFE (55.87%) content. The fish was survive 100% in all treatment except in fish feed with ADSPL based diet (96.6%). Fulton's condition factor of experimental fish was greater than 1 in all treatment. SR and FCR was not affected by tested diets (P > 0.05). However, a significant difference in growth and feed utilization parameters were noticed. Fish fed with control diet showed better weight gain (61.85g), specific growth rate (1.66%/fish/day) and feed utilization efficiency than others except fish fed with yeast fermented sweet potato leaf. Therefore, it can be concluded that the yeast fermented sweet potato leaf meal can be used for *O. niloticus* feed without any adverse effects on growth performance, feed utilization and body composition.

Key words: Nile tilapia, nutrient composition, processing methods, sweet potato leaf

1. INTRODUCTION

1.1. Back ground of the study

Fish is an important source of dietary protein for humans, providing approximately 20% of the average per capita animal protein intake of about 3.3 billion people (FAO, 2020). Since the population growth, global fish production and fish price index are increasing rapidly in recent years and raised the demand for fish and fishery products, aquaculture assumed exceptional significance. Aquaculture is one of the fastest food-producing sectors in the world (FAO, 2022). The total aquaculture production in Ethiopia in 2020 was 6,000 metric tons. However, this is a small fraction of the country's potential. The inland capture fisheries and aquaculture sector in Ethiopia has been estimated to have a potential of over 45,000 metric tons (FAO, 2022).

Although several fish species are being included as candidate species for culture, still the Nile tilapia, *Oreochromis niloticus* (Linnaeus, 1758) occupies a better position in freshwater aquaculture (Abebe Amha, 2015). Yue *et al*. (2017) stated that, *O. niloticus* is widely accepted in different countries because of its cultivable characteristics such as its palatability, disease and stress tolerance, and good production potential in varied production systems. According to FAO (2018), *O. niloticus* forms the second most important species in world aquaculture next to carps contributing about 17% of the total aquaculture production. To increase its production still further, concentrations are now being focused on formulating cost effective feed.

Fish meal is one of the suitable fish feed ingredients and it is long been recognized as a main protein source in fish feed due to its high protein content, well-balanced amino acid profile, high protein digestibility, excellent palatability, vitamins, and growth factors (Prabu et al., 2018). However, the cost of fish meal is continuously increasing due to its high demand in aquaculture industry as well as its limited supply (FAO, 2010). A continuous increase of fish meal cost directly influences fish feed cost and subsequently the production cost in any aquaculture operation. Moreover, fish feed prepared out of soybean, corn gluten are also expensive and also create competition with human consumption. Nutrition research that helps to reduce the cost of fish feeds without reducing their efficacy will be crucial to the successful development and commercialization of aquaculture in Africa using cheap and easily accessible feed stuff (Asaminew Kassahun 2012).

Several attempts have been made for incorporation of leaf meal as possible alternative plant protein source in fish feed preparation (Osman, 2007; Vhanalakar and Muley, 2014; Meshram *et al.*, 2018; Ahmad *et al.*, 2019). Among leaf meals, sweet potato, *Ipomoea batatas* (Lamarck, 1793) leaf can serve as an efficient protein and energy source for the preparation of fish diets. Sweet potato leaf meal (SPLM) comprises 26-33% crude protein with the high amino acid score (Antia *et al.*, 2006; Adewolu, 2008; Abonyi *et al.*, 2012; Meshram *et al.*, 2018; Ahmad *et al.*, 2019), but the presence of high crude fiber and anti-nutritional factors (ANFs) limit its use in animal feed. Anti-nutrients present in sweet potato leaf meal (SPLM) are phytate, trypsin inhibitor, alkaloid, oxalate, tannin and cyanide (Antia *et al.*, 2006). Several attempts have been conducted to study the nutritive value of sweet potato leaf meal (Ishida *et al.*, 2000; Adewolu, 2008; Meshram *et al.*, 2018; Ahmad *et al.*, 2019) in fish and animal feed. Several methods such as moist heat treatments, water soaking, fermentation etc. have been used and documented to neutralize the ANFs from leaf meal (Meshram *et al.*, 2018; Ahmad *et al.*, 2019). Fermentation with micro-organism could be an innovative approach to minimize the ANFs concentration as well as digestion of crude fiber in SPLM (Mahesh and Mohini, 2013; Keishing *et al.*, 2015). The use of fermented leaf meal in feed of monogastric animals has been practiced in chicken (Hirabayashi *et al.*, 1998), piglets (Kiers *et al.*, 2003) and also in fish feed (Yamamoto et *al.*, 2010; Yuan *et al.*, 2013; Meshram *et al.*, 2018). Therefore, the aim of this study was to evaluate the effects of different processing methods on nutrient composition of SPL and its effect on growth performance, feed utilization and body composition of *O. niloticus*

1.2. Statement of the problem

Feed is generally the most expensive operational cost in aquaculture production where it represents over 50% of the operating cost, moreover protein itself represents about 50% of feed cost (El–Sayed, 2003). High cost of raw materials forces many aquaculture farmers in developing countries to replace or include expensive conventional feed ingredients like fish meal, soybean meal with other locally available ingredients. The replacement of ingredients and formulation of feeds affect the growth response and wellbeing of the fish. If feed selection is not taken into careful consideration, the farming effort will hardly bring any benefits to farmers due to low quality and poor production rate in addition to ANFs of the plant source feed. Sweet potato leaf has 26-33% crude protein, high amino acid, mineral and vitamin contents, and also this plant leaves can be harvested many time a year thereby making the availability easier and cheaper (Adewolu, 2008). Most of the time the leaf of sweet potato is discarded as a waste during tuber harvesting in Ethiopia, and at times it is used as animal feed. So due to its availability, less cost, less competitive to human and animal consumption, sweet potato leaf is suitable to prepare fish feed. However, the nutritive quality of sweet potato leaf is reduced by the effect of anti-nutritional factors such as phytate, trypsin inhibitor, alkaloid, oxalate, tannin and cyanide (Antia *et al.*, 2006) which affect the absorption efficiency of digestive end products in the small intestine. Further, it reduces the protein digestion and bioavailability of some minerals (Gemede and Ratta, 2014). Those ANFs can be reduced by processing methods like air drying, sun drying, soaking and fermentation by microorganisms. Thus, the present study is designed to investigate the effects of different processing methods on nutritive composition of sweet potato leaf and its effects on growth performance, feed utilization and body composition of *O. niloticus*.

1.3. Objectives of the study

1.3.1. General objective

- To evaluate the effects of different processing methods on nutritional composition of sweet potato leaf as feed for *O. niloticus*.

1.3.2. Specific objectives

- Evaluated the effects of air drying, sun drying, soaking, and fermentation on the proximate composition of sweet potato leaf.
- Compared the growth performance and feed utilization efficiency of *O. niloticus* fed with different processed sweet potato leaf based diets.
- Determined the survival rate and body composition of *O. niloticus* fed with different processed sweet potato leaf

1.4. Research questions

- Does processing methods affecting proximate composition of sweet potato leaf?
- Which processing methods of sweet potato leaves feed show better growth performance and feed utilization in *O. niloticus* fingerlings?
- Does sweet potato leaf meal affect survival rate and body composition of *O. niloticus*?

1.5. Significance of the study

The study was focused on processing methods of sweet potato leaves to improve nutritional value and reduce anti nutritional factors as suitable alternative ingredients for *O. niloticus* feed. The results of the study will bring to light the best methods of fermentation of sweet potato leaf, It will be used to replace costly fish feed. It will help in evolving cost- effective feeds for *O. niloticus* aquaculture in Ethiopia. Further, it will be used as a document for further researchers.

1.6. Scope of the study

This study addresses sweet potato leaf as fish feed for *O. niloticus*. The experiment was conducted in hapas installed in ideal concrete pond. Different processing methods of sweet potato leaf were conducted. Proximate compositions of tested and formulated feeds were estimated. The feeding efficiency, growth performance and survival rate of the fish were estimated. Water quality parameters of concrete ponds (hapa) and body composition of *O. niloticus* were analyzed.

1.7. Limitations of the study

The following are some limitations of the study

- The study used only one variety of sweet potato leaf, which may have different nutrient and anti-nutrient contents than other varieties.
- The study used only one level of substitution (30%) of soybean cake with processed sweet potato leaf, which may not reflect the optimal level for O. niloticus.
- The study did not measure the water quality parameters such as nitrite, and nitrate, which might have influenced the fish growth.
- The study did not evaluate the sensory and economic aspects of using processed sweet potato leaf as fish feed, which are important for consumer acceptance and profitability.
- The study was limited only to *O. niloticus*.

2. LITERATURE REVIEW

2.1. Dietary requirements of *O. niloticus*

2.1.1. Protein requirements

The protein requirement of *O. niloticus* decreases with age and size, with higher dietary CP concentrations required for fry (30–56%) and juvenile (30–40%) *O. niloticus*, but lower protein levels (28–30%) for larger *O. niloticus* (Al Hafedh, 1999). As with other warm water fish, *O. niloticus* requires 10 essential amino acids that need to be supplied by the diet. Essential amino acid requirements can be met by the use of a balance of both plant and animal proteins, and if necessary, by the inclusion of synthetic amino acids in the complete feed (Kamal *et al*., 2005).

2.1.2. Lipid requirements

According to Winfree and Stickney (1981) *O. niloticus* up to 2.5 g, the optimum dietary lipid concentration requirement was 5.2%, decreasing to 4.4% for fish up to 7.5 g. On the other hand, Jauncey (2000) suggested that to maximize protein utilization, dietary fat concentration should be between 8 and 12% for tilapia up to 25 g, and 6 to 8% for larger fish.

2.1.3. Carbohydrates

Fish do not have a specific requirement for carbohydrates, because amino acid and fatty acid precursors can supply the required glucose via gluconeogenesis. *O. niloticus* can effectively utilize carbohydrate levels up to 30 to 40% in the diet, which is considerably more than most cultured fish (Anderson *et al*., 1984). Fiber is usually considered indigestible, as *O. niloticus* does not possess the required enzymes for fiber digestion (although some cellulase activity from microbes has been found in the gut of *O. mossambica*) (Saha *et al*., 2006). For this reason, and to attain maximum growth, crude fiber levels in *O. niloticus* diets should probably not exceed 5% (Anderson *et al.*, 1984).

2.1.4. Vitamins and minerals

According to Lim *et al*. (2000), vitamins and minerals are essential for normal fish metabolism. Vitamin and mineral supplementation in the form of premixes may be beneficial in intensive systems, although most of these requirements are usually met naturally in extensive and semi-intensive pond cultures. The study conducted by Abelneh *et al*. (2015), shows that supplementation of formulated agro industrial by-products with vitamins and minerals resulted in better growth performance of *O. niloticus* in unfertilized ponds and also better economic return.

2.2. Water quality parameters and impact on fish feeding

Water quality is described as the totality of physical, biological and chemical characteristics which influence growth, survival and feed utilization performance of cultured fish (Alavisha *et al*., 2019). Changes in water quality parameters however, will affect growth and survival of fish species (Tahar *et al*., 2018). Adequate oxygen, proper temperature, good transparency, limited levels of metabolites and optimum levels of other environmental factors can be referred as good water quality parameters which can influence growth and survival of fish (Agano *et al*., 2017).

2.2.1. Temperature

Temperature plays a good role in feed conversion ratio (Samuel Bekele *et al.*, 2019). The effect of temperature in *O. niloticus* depends on their size, strain, type of production system, duration of exposure and environmental factors (EL-Sayed, 2006). The metabolic activities and physiological functions of fish including growth, feed conversion ratio, survival rate and productivity of aquaculture enterprise mainly rely on temperature regimes (Boyd, 1998). Controlling of temperature to optimum level is favored to obtain better production especially at younger stage because they are sensitive to stress (Azaza *et al.,* 2008). However, extreme levels of temperature, too hot or too cool will lead to stress thereby reduced growth rate (Boyd, 1998). The difference in temperature will affect the feeding rate of fish and hence the growth rate. This has been reported in a study conducted under controlled system in aquaria (Zenebe *et al*., 2003). Studies carried out indicated a direct relationship between growth and temperature where growth rate and feed intake increases with increasing temperature (Azaza *et al*., 2010; Kassaye Balkew, 2012). According to Wattanabe *et al.* (2002), *O. niloticus* tolerates temperature ranges between 10 and 40^{o}C. However the optimum temperature recommended for growth and feeding was 25 to 32 °C (Dennis *et al*., 2009).

2.2.2. pH

Water pH is a crucial factor for the development, growth and survival of fish where fluctuations of pH in water causes ionic imbalance leading to death of fish (Abdullah *et al*., 2017). Both alkaline pH (8.5–10) and acidic pH (below 6.0) causes acute physiological disturbance in fish, affecting the normal growth rate and finally a lethal factor for fish (Abdullah *et al*., 2017). El-Sherif and El-Feky (2009) have reported that water pH of 7-8 could be more suitable for *O. niloticus* culture for optimum growth performance and survival rate. Pompa and Masser (1999) reported that *O. niloticus* can survive at pH ranging from 5 to 10 but they do best at a pH range from 6 to 9. The concentration of pH in water in a certain rearing system disturbs and affects both survival and growth performance of *O. niloticus* as in other aquatic animals (White *et al*., 2014). According to Dubost *et al.* (1996), fish tries to adapt its behavior and physiology subjected to stress due to alterations in pH. It is reported that reduced pH retards the growth of *O. niloticus* although they have good resistance to gradual acidification (Reboucas *et al*., 2015). *O. niloticus* are able tolerate a wide pH range from 3.7 and 11, but best growth is achieved between pH 7and 9 (Ross, 2000), and growth is negatively affected in acidic waters (Webster and Lim, 2002). The desirable range of pH for growth of *O. niloticus* is in a range of 6.5 to 9.5 and the acceptable range is 5.5 to 10 (Stone and Thomforde, 2003).

2.2.3. Dissolved oxygen

Dissolved oxygen influences fish growth and feed intake, feed utilization and health status (Jobling, 1998). According to EL-Sayed (2006), dissolved oxygen concentration depends largely on temperature, and its concentration below critical level reduces fish growth, feed utilization, increases the risk on potential diseases or even fish death (Tran-Duy *et al.,* 2008; Boyd, 2010). When dissolved oxygen concentration increases, the food conversion ratio increase up to 90% and this facilitated the better growth potential and survival rate of fish (Bergheim *et al*., 2006). The preferred DO for optimum growth of *O. niloticus* is above 5mg/l (Riche and Garling, 2003). On the lower limit, Ross (2002) noted that dissolved oxygen of 3mg/l should be the minimum for optimum growth of tilapia. Generally, fish growth and yields are greater in ponds with higher dissolved oxygen concentration.

2.2.4. Ammonia

Ammonia is a toxic compound that can adversely affect fish health and its recommended level is below 0.05 mg/L (El-Sherif *et al*., 2004). But, when the concentration is more than 0.08 mg/L the feeding appetite reduces and growth of fish retards (Popma and Masser, 1999), and body weight declines considerably when the concentration of ammonia increases (Zeitoun *et al*., 2016). Ammonia is a nitrogenous compound excreted by fish through gills and faeces. Ammonia concentration in water causes gill and kidney damage, and reduces growth rates and increases brain glutamine (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 to unionized ammonia concentration greater than 1 mg/L causes losses, especially among fry and juveniles in water with low DO concentration (Dubost *et al*., 1996). Ammonia production is directly related to feeding and depends on the quality of feed, feeding rate, fish size and temperature (Riche and Garling, 2003). Maximum limit of ammonia concentration for aquatic organisms is 0.1 mg/l (Santhosh and Singh, 2007).

2.3. Sweet potato production

Sweet potato is an important economic crop in many countries. In terms of annual production, sweet potato ranks as the fifth most important food crop in the tropics and seventh in the world after wheat, rice, maize, potato, barley, and cassava (FAO, 2016). Ethiopia is the seventh world's biggest sweet potato producing country with the production of 1.7 million tons in 2019. The main centres of sweet potato production in Ethiopia include South Nations Nationality and Peoples Region and Oromia. Sweet potato fulfills a number of basic roles in the global food system, all of which have fundamental implications for meeting food requirements, reducing poverty, and increasing food security (El-Sheikha and Ray, 2017). The leaves have been used as forage for cattle due to their high protein and fiber content (Antia *et al*., 2006; Adewolu, 2008). Additionally, SPL can be used as fish feed because it can be harvested many times a year thereby making the availability easier and cheaper (Adewolu, 2008).

2.4. Proximate composition of sweet potato leaf

The nutrient content of sweet potato leaves varies among the varieties, harvest dates, crop years and processing methods. On dry weight basis, sweet potato leaves contain 25–37% crude protein, 42–61% nitrogen free extract, 2–5% ether extract, 23–38% total dietary fiber, 60–200 mg/100 g ascorbic acid, and 60–120 mg/100 g carotene (Sun *et al*., 2014). They also rich in calcium (230–1,958 mg/100 g), iron (2–22 mg/100 g), potassium (479–5,230 mg/100 g), and magnesium (220–910 mg/100 g).

According to Antia *et al.* (2006), the proximate composition sweet potato leaves contain crude protein, ether extract, crude fiber, ash content, nitrogen free extract and moisture content of 28.85%, 4.90%, 7.20%, 11.10%, 51.95% and 82.21% on dry matter bases, respectively. The caloric value was 351.30.Kcal. Perez and Tan (2006) also reported that the crude protein contents ranging from 26.5 to 32.5% in leaves of sweet potatos. Adewolu (2008) reported that, the leaf meal of the plant has 26-33% crude protein, high amino acid, mineral and vitamin content. The mineral composition of the leaves revealed high concentration of magnesium (340mg/100g) and phosphorus (37.28mg/100g). Calcium, iron, sodium, potassium and manganese contents were 28.44 mg/100g, 16.00 mg/100g, 4.23 mg/100g, 4.05 mg/100g, and 4.65mg/100g, respectively. The leaves however, contain very little of zinc (0.08mg/100g), complete absence of copper (0.00mg/100g), low content of vitamin A (0.67 mg/100g) and vitamin C (15.20 mg/100g) (Antia *et al*.,2006).

2.5. Anti-nutritional factor of sweet potato leaves

Anti-nutritional factors (ANFs) are chemical compounds synthesized in natural food and/or feedstuffs by the normal metabolism of species and by different mechanisms (for example inactivation of some nutrients, diminution of the digestive process or metabolic utilization of food/feed) which effect nutrition contrary to optimum nutrition (Soetan and Oyewole, 2009).

The anti-nutritional factors in plants may be classified on the basis of their chemical structure, the specific actions they bring about or their biosynthetic origin (Aletor, 1993). Although this classification does not encompass all the known groups of anti-nutritional factors, it does present the list of those frequently found in human foods and animal feedstuffs. The anti-nutritional factors may be divided into two major categories. They are: 1).Proteins (such as lectins and protease inhibitors) which are sensitive to normal processing temperatures, 2), Other substances which are stable or resistant to these temperatures and which include, among many others, polyphenolic compounds (mainly condensed tannins), non-protein amino acids and galactomannan gums (Osagie, 1998).

Sweet potato leaves contain different anti nutritional factors such as cyanide (30.24mg/100g), phytic acid (1.44mg/100g), tannin (0.21mg/100g) but exceptionally high value of oxalate (308mg/100g) (Antia *et al*., 2006).

Table 1. Adverse effects of some anti-nutrients (Gemede and Ratta, 2014)

Anti-nutrient	Effects on body
Phytates	Reduce Ca and Fe absorption
Oxalates	Reduce Ca absorption, encourage kidney stone formation
Cyanide	Respiratory inhibitors
Lectins, (hemagglutinins)	Prevent absorption of digestive end products in the small intestine
Protease inhibitors	Reduce protein digestion
Phenol compounds	Reduce bioavailability of some minerals (especially zinc), may negatively affect pH mechanism, reduce protein digestion

2.6. Methods for removing anti nutritional factors of sweet potato leaf

The presence of anti-nutritional factors such as invertase and protease inhibitors can be removed by oven or sun-drying, soaking, steaming and grinding prior to inclusion in fish feeds there by increasing the palatability (Adewolu, 2008). Fermentation with micro-organism could be an innovative approach to minimize the ANFs concentration as well as digestion of crude fiber in SPLM (Mahesh and Mohini, 2013; Keishing *et al.*, 2015).

2.6.1. Air drying

Air-drying reduces the moisture content of sweet potato peels, preserves it from adverse temperatures and even increases the nutritional content of the peels. Considering the energy value, the amino acid, vitamins and mineral content are relatively high; the air-dried sweet potato peels and sun-dried sweet potato peels can be used as energy source in animal feedstuff (Agubosi *et al.,* 2022). According to Pierre *et al*. (2020) air drying processes rapidly remove free cyanide from the cassava chips, but only 8–12% of the total cyanide is present as free cyanide. Air drying at four different temperatures showed that 29% of the bound cyanide was removed by drying at 46.5°C; smaller losses were recorded at the higher temperatures.

2.6.2. Sun drying

Sun drying is the simplest method of processing. It reduces moisture, volume and cyanide content of tuber, thereby prolonging product shelf life. Drying of SPL resulted in high losses of ascorbic acid. A similar observation has been reported by Maeda and Salunkhe (1981) for vegetables consumed in Tanzania, whereby when dried in open sunshine, cassava leaves, SPL and cowpea leaves retain only 5.5, 2.5 and 10.6% of the vitamins, respectively.

According to Mohamed *et al*. (2019), the most effective method for cyanide removal was by pounding fresh leaf and subsequent sun drying, whereby >95% cyanide will be eliminated. The mode of processing greatly influenced the cyanide content of cassava foods. So, since cyanide can be greatly reduced by suitable processing, it may not be a limiting factor in the utilization of cassava for food and feed purposes.

2.6.3. Soaking

Soaking is an attractive method for removing anti-nutrient of foods because it also reduces cooking time. Soaking also enhances release of enzymes (e.g. endogenous phytases), which are present in plant foods like almonds and other nuts and grains (Kumari, 2018). Soaking is also commonly required for fermentation, which can also be used to reduce the level of various anti-nutrients in foods (Gupta *et al.*, 2015). In legume, soaking has been found to decrease phytate, protease inhibitors, lectins, tannins and calcium oxalate.

2.6.4. Fermentation

Fermentation as a method of processing primarily enhances nutritional properties through biosynthesis of vitamins, essential amino acids and proteins by improving protein quality and fiber digestibility as well as the enhancement of micronutrient bioavailability and degradation of anti-nutritional factors (Motarjemi, 2002).

2.6.4.1. Yeast fermentation

Aside from the requirement of a sterile environment for the operation of submerged fermentation, enzymatic or acid treatment of starch is necessary when yeasts are to be used as the microbial inoculums, also recovery of the cell mass could be tedious and might involve further processes like centrifugation/ultra-filtration before separation of cell biomass could be achieved (Balagopalan *et al*., 2002). Onyimba *et al*. (2015) reported that the fermented SPLM were found to be richer in essential amino acid concentration than the non-fermented SPLM.

Fermentation with the co-culture of *Chaetomium globosum* and *Sacchromyces cerevisiae* brought about increases in crude protein (97.5%), ether extract (265.3%) and ash (12.3%) contents. There were reductions in the crude fiber (22.7%) and nitrogen free extract values (61.4%). Energy content is increased by 10.2%. And increase in the values of all the amino acids analyzed. Elemental analysis revealed increases in the values of calcium (1168.5 to 1225.5 mg/kg), phosphorus (39 to 69 mg/kg), potassium (1079 to 1170.5 mg/kg) and magnesium (60.5 to 90.5 mg/kg). The values of manganese (25 mg/kg) and zinc (2.5 mg/kg) were unaltered. Copper content decreased from 13.5 to 11 mg/kg while the content of iron decreased from 206.5 to 198.5 mg/kg (Onyimba *et al.,* 2015).

2.6.4.2. Rumen fermentation

Adeyemi *et al*. (2007) stated that, fermentation with rumen filtrate significantly increased the ether extract, protein and moisture content of cassava root meal. But, there were a decline in DM content which was associated with increased moisture content with advanced fermentation duration. The study also indicates an improvement in the crude protein value of whole cassava root meal when enriched with common farm animal wastes and fermented with bovine rumen filtrate. Crude protein level also increased (from 1.7% to 7.6%) after fermentation. Rumen fermentation process helps in production of several kinds of essential nutrients such as oligosaccharides, vitamins, and small-size peptides (Chen *et al*., 2010). Dairo *et al*. (2011), also reported that fermentation is known to improve protein levels in feed.

2.6.4.3. Natural fermentation

Natural fermentation brought about a number of desirable changes in the nutrient composition of the mixture of spent sorghum grain and sweet potato leaves. With the reduction of the fiber content and the enhancement of other nutrients like protein, nitrogen free extract, ether extract and minerals including calcium and phosphorus, the potential for using the fermented grain leaf substrate as a feed or feed supplement for livestock has increased. Where shorter fermentation time does not improve the amino acid profile, supplementation with cheap synthetic essential amino acids is recommended (Onyimba *et al*., 2010).

2.7. Sweet potato leaf as fish feed ingredient

Several trials were made to use sweet potato leaf to formulate suitable fish feeds. Experiments on *Tilapia zilli* resulted that sweet potato leaf meal could be included up to 15% in diets without compromising the growth and feed efficiency (Adewolu, 2008). According to Bake *et al*. (2013), a 10 -20% inclusion of sweet potato meal could be used as a replacement of wheat meal in practical diets for juvenile *O. niloticus.* On the other hand, a substitution of soybean meal with 20% SPLM in fish diets is recommended for *Clarias gariepinus* juvenile (Ebuka *et al*., 2023). Oludayo (2010) study showed that Sweet potato leaf meal has good potential as a protein source in diet of *C. gariepinus* up to 30% level without compromising growth.

According to Lochmann *et al*. (2013), SPLM was an effective energy source for channel catfish up to the maximum level tested (230 g/kg diet). SPLM did not enhance total phenols in catfish, but there were no apparent anti-nutritional effects of the meal on catfish growth, health or survival. On the other hand, the fermented sweet potato leaf meal can substitute 100% de-oiled rice bran in the diet of *Labeo rohita* fingerlings without any adverse effect on growth performance, feed conversion and whole body composition (Jayant, 2020).

2.8. Survival and growth of *O. niloticus* fingerlings in relation to feeds

Growth and survival of fish greatly depend on the type of feeds, its origin, formulation methods, methods of mixing of ingredients and removal of anti-nutritional elements (Ali *et al*., 2016). In fish culture, the type of diet used has direct relationship with the survival and growth of fish (Musiba *et al.,* 2014).

According to Eriegha *et al*. (2017), biochemical contents of a fish feed can limit the survival and growth performance of fish in culture systems. The nutritional imbalance and feeding below the optimum requirements can affect not only the growth performance but also causes mortality to fish (Gabriel *et al*., 2007). According to Reboucas *et al*. (2015), better performance and optimum growth of fish is expected if fish feeds contain the nutrients at the required level specific to fish species (Verster, 2017). Tewodross Abate and Abebe Getahun (2017) found that the feeding frequency and rate of feeding affect the growth performance of fish even if the species and the type of dietary parameters are the same. Reports also indicate that, the type of diets may cause retarded growth rate without altering survival rate and feed utilization efficiencies in *O. niloticus* (Kapigna *et al*., 2014). Besides nutrient contents of the feed, feeding the fish with appropriate sized feed is important as appropriate size of feeds not only will reduce the feeding efficiency of fish; it also reduces water quality through its accumulation in cultural system (Ahmad and Maqbool, 2017). If artificial feeding is resorted to, then the size of the pellet should correspond with the size of the fish (Bake *et al*., 2013). Besides the type of feeds, the protein levels in such feeds are also vital on the growth performance of *O. niloticus*.

2.9. Influence of Diets on Fish Body Compositions

The body composition of fish has direct relationship with qualitative parameters of diets (Maurice *et al*., 2018). Various studies have examined the effects of temperature, light, salinity, pH and oxygen concentration on the proximate composition of fish but these factors would seem to have very limited effects. On the other hand, endogenous factors are genetic and linked to the life stage, age, size, sex and anatomical position in the fish (Huss, 1995). These endogenous factors govern the majority of principles that determines the composition of fish (Huss, 1995). However, according to Lee *et al*. (2018), the inclusion of plant based fish diets have a variable impact on their fillet composition. Fish fillet or fish tissue consists of several biochemical constituents, such as moisture, protein, lipids, vitamins and minerals. Fish body composition is affected by both exogenous and endogenous factors (Huss, 1995). The dietary protein level in diet determines the crude protein and lipid contents in fish fillet (Kim *et al*., 2013).

3. MATERIALS AND METHODS

3.1. Description of the study area

The experiment was conducted in the Centre for Aquaculture Research and Education (CARE) Hawassa University, which is found in Sidama Region of Ethiopia at 275 km South of Addis Ababa, the capital city of Ethiopia. It is located at 7°3’3’’ N latitude and 38° 30’19’’ E longitude and situated at 1,714 meter above sea level (Figure 1). CARE is one of the Centers of Excellence in Hawassa University for Aquaculture diversification such as pond culture, recirculation system and integrated aquaculture system. The centre also provides community service for aquaculture diversification such as distributing of fish fingerlings to different districts of Sidama Regional State. It also provides free service to conduct their research activities for different M.Sc and Ph.D students registered in Hawassa University.

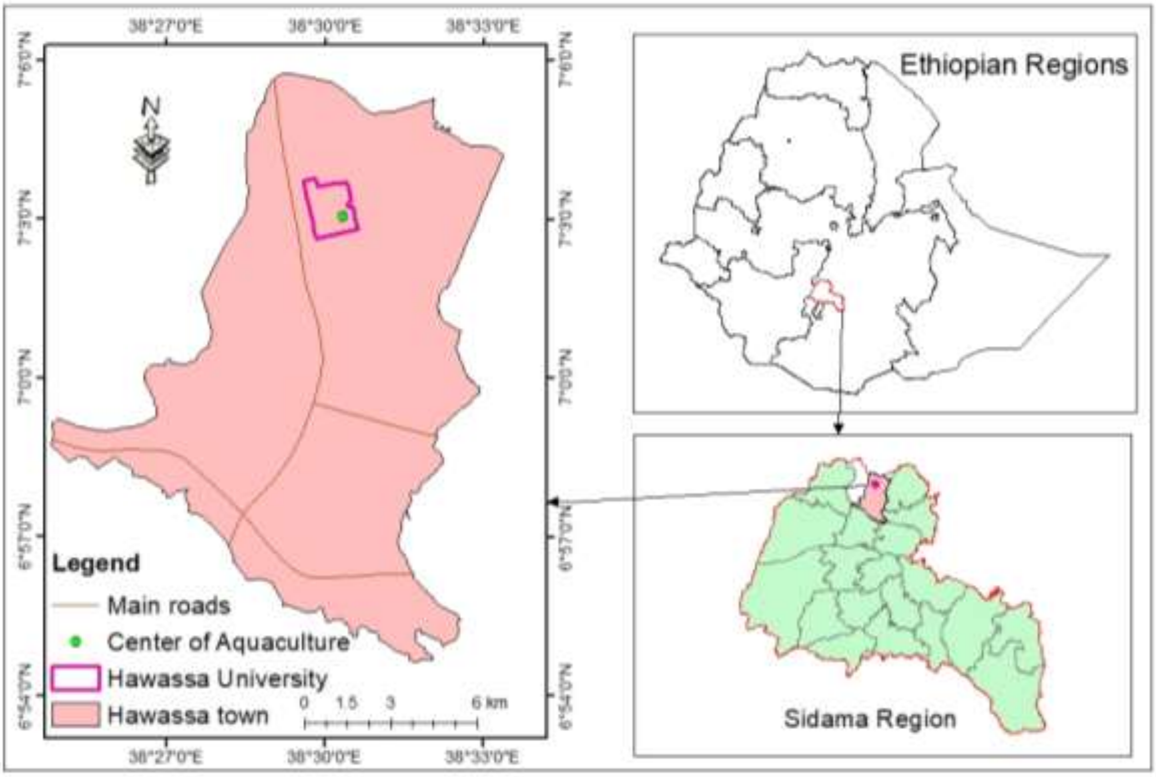

Figure 1. Location map of CARE (Developed by Wendifraw, GIS Expert, Dilla University)

3.2. Sweet potato leaf collection and processing

Fresh green sweet potato leaf was purchased from a local farmer's plot, Sidama Region Dale Woreda and transported to CARE laboratory, Hawassa University in February 2023. The leaves were handpicked and leaflets were separated from the long leaf stalk (a Figure 2). A total of 100kg fresh SPL were washed with clean water and subjected to different processing methods to increase its nutritional value. 25kg of it were air dried for five days while, the rest were pounded using wooden pestle and mortar and soaked with clean water in closed plastic bucket for three days. After soaking it was sun-dried until its water content dropped to about 50%, and composted using three fermentation methods: (1) yeast fermented (YF): 25kg of it were fermented with baker's yeast (*Sacchromyces cerevisiae*) by adding 50g yeast and 50g wheat flour per kg of SPL (El-Sayed, 2003); (2) rumen fluid fermented (RF): 25kg of SPL were fermented with fresh rumen fluid that was taken immediately from a slaughtered steer at the local abattoir and filtered with a sieve. The rumen fluid was added 20% of total weight of SPL (Adeyemi *et al*., 2007) and naturally fermented (NF): The remaining 25 kg of SPL were fermented without addition of additives. All of them were stored in covered plastic containers at room temperature separately and uniformly mixed regularly in three days to facilitate fermentation. After two weeks, the compost was sun dried until constant weight reached. Finally, the air dried and fermented SPL were ground with electric grinder and the powder was sieved with 1mm mesh sized sieve and packed in plastic bags and kept at -18^{o}C until analysis. The chemical composition of processed SPL was determined following the standard methods (AOAC, 1990) (as indicated in 3.6) in Hawassa University laboratory.

Figure 2. Separation of leaflets from the long leaf stalk (A); Dry yeast (*Sacchromyces cerevisiae*) used in sweet potato leaf fermentation (B); Rumen fluid for fermentation of sweet potato leaf (C)

3.3. Feed formulation and diet preparation

For feed formulation, soybean cake, meat and bone meal, maize flour, wheat flour and soybean oil were purchased from local market. After nutrient analysis of processed sweet potato leaf and feed ingredients, five isonitrogeneus and isoenergetic experimental diets were formulated. In all tested diets, 30% of SBC protein was replaced with processed sweet potato leaf protein (Table 2). Sodium alginate as a binder and vitamin C were added in the diet.

The formulated feed was mixed with 30% dechlorinated water to make a dough (Tewodros Abate *et al*., 2020). Pellets were produced using electric mincer pellets. The strands were cut into short pieces using grinder and sun-dried for 1 day to remove moisture. The dried pellets were screened in to three sizes using 1.8 mm and 2 mm pore size sieves small and large were prepared. The medium sized pellet was segregated with winnowing. For five treatments a total of 40 kg diet was prepared each with 8 kg of diet.

Table 2. Formulation and proximate composition of the experimental diets

Ingredient	Experimental diets				
	Control	AD	YF	RF	NF
Meat and bone meal	32	30.5	30	30	30
Soybean cake	36	26.5	28	28	29
Sweet potato leaf meal	0	14	11	12	13
Maize flour	15	12.9	13.9	12.5	11.4
Wheat flour	12.9	12	13	13.4	12.5
Sodium alginate	1	1	1	1	1
Vitamin C35%	0.1	0.1	0.1	0.1	0.1
Soybean oil	3	3	3	3	3
Total	100	100	100	100	100
Proximate composition of experimental diets (%DM, except DM)					
DM	90.39	89.56	89.76	89.76	89.69
CP	30.1	30.15	30.16	30.2	30.15
EE	9.9	9.61	9.71	9.92	9.79
Ash	10.7	10.24	10.24	10.86	10.68

NB: AD=air dried; YF=yeast fermented; RF=rumen-fluid fermented; NF=naturally fermented

3.4 Experimental design and experimental fish

The concrete ponds were washed thoroughly using clean water. 15 hapas with a size of 4.5 m^3 (2m x 1.5m x 1.5m) were tied with Eucalyptus wooden pole and the upper ends of hapas were tied up with twine. On the four lower corners of each hapa small sized stones were placed to keep the hapas in position. The concrete ponds were filled with ground water to a depth of

1.5m. A total of 300 *O. niloticus* fingerlings with an average body weight 10.55±0.19g were collected from CARE by using seine net and stocked in 15 hapas in triplicates installed in a concrete pond with a mean stocking density of 7fish/m^2. The experimental design used in this study was a completely randomized design in which treatment was assigned randomly in experimental Hapa. After one week acclimatization period by fed with control diet, fish were fed experimental diets by hand three times a day (9:00 am, 1:00 pm and 5:00 pm) with a rate of 5% of their body weight and reared for three months. All fish in each hapa were weighed biweekly to the adjusted amount of daily diet. One-third of the pond water was changed once in every three days to avoid algal clogging, feed and fecal matter. A constant water depth of 1m inside each hapa was maintained throughout the experimental period. Dead fish if any found were removed with aid of scoop net manually.

3.5. Data collection

3.5.1. Water quality parameters

Water quality parameters such as water temperature, dissolved oxygen (DO) and pH were measured once in a week (9:00am). Samples for temperature and DO measurements were taken by using (HI 9145, DO meter) while, pH was measured using a pH 3110 SET 2 model meter. Ammonia concentration was measured in the laboratory by Palin test method once in a month.

3.5.2. Growth parameter collection

The body weight of all fish was measured by using weighing balance (SF 400A, Electronic Compact Scale) to the nearest 0.1g biweekly and body length was determined using a graduated ruler to the nearest 0.1 cm. At the end of the experiment, five fish from each hapa were taken, grinded and dried at 65^{o}C for 24hrs for proximate composition analysis.

3.5.3. Determination of production parameter

The fish production performance and feed utilization efficiency parameters were calculated using the following formula.

- Weight gain = final weight (g) – initial weight (g) (Adebayo, 2004)
- Specific growth rate (SGR) = [(lnFBW (g))-(ln IBW (g))/number of trial days] X 100 (Ricker, 1975), where, FBW = Final body weight and IBW = Initial body weight
- Daily growth rate(DGR) = final weight (g) – initial weight (g)/number of trial periods (Sevier *et al*., 2000)
- Feed conversion ratio (FCR) = Dry feed fed (g)/Weight gain (g) (Mohanty, 2004)
- Protein efficiency ratio (PER) = fresh weight gain (g)/ crude protein of feed (Mohanty, 2004)
- Survival rate (%) = number of fish harvested / number of fish stocked * 100 (Ricker, 1975)
- Fulton's condition factor (FCF) = TW / TL^3 *100 (Ricker, 1975) Where, TW = total weight, TL = Total length

3.6. Proximate analysis

Proximate composition (CP, EE, CF, NFE, Ash and Moisture) of processed SPL, feed ingredients, experimental diets and fish body composition were analyzed in Hawassa University Animal Nutrition Laboratory. Moisture was obtained by drying the sample at 105°C in an oven until constant weight was achieved. Crude protein was determined by using the Microkjeldahl Digestion Method (N×6.25). Ether extract content was determined by Soxhlet-extraction. Ash content was done by combustion in muffle furnace to constant weight at 550°C. Crude fiber was determined using the acid/base digestion process. NFE was computed by taking the sum of values for crude protein, ether extract, crude fiber and moisture and subtracting this from 100. AOAC (1990) method was followed for all the analyses.

3.7. Statistical analysis

After data collection, all data were arranged and sorted in MS-Excel version 10. The basic descriptive graphs were also indicated by MS-Excel version 10 and data were presented in mean ± standard error. Statistical analyses were computed using SAS version 13software. Differences among dietary treatment means were tested using one-way analysis of variance (ANOVA) with 95% confidence interval. Test of significance of variation between means were computed using Tukey's standardized range taste α=0.05 level of significance comparision.

4. RESULTS

4.1. Water quality parameters

The main physicochemical parameter such as temperature, pH, dissolved oxygen and ammonia are presented in Table 3. The mean water temperature during the experimental period was 28.85 ^{0}C±0.15 with the minimum value 27.7^{0}C and the maximum value of 29.8^{0}C. The value however, did not show any significant difference ($P > 0.05$) between and within sampling weeks. The values of pH for all experimental weeks ranged between 7.5 and 8. There was no significant difference among and within sampling weeks ($P > 0.05$). The mean pH value of water during the experimental period was 7.77±0.1. The amount of dissolved oxygen in the experimental period ranged from 3.9mg/l to 4.5mg/l. The mean value of dissolved oxygen was 4.24±0.04 mg/l. However, the mean value of dissolved oxygen between and within weeks did not show significant difference. The ammonia level ranged from a minimum value of 0.06mg/l to a maximum of 0.12mg/l and the mean value was 0.08mg/l± 0.01. The value of total ammonia between and within months did not show significant difference.

Table 3. Water quality parameters of the experimental weeks

Parameters	**Values (Means ± SE)**
Temperature(^{o}C)	27.7-29.8(28.85 ±0.15)
Dissolved oxygen(mg/l)	3.9-4.5(4.24±0.04)
pH	7.5-8(7.77±0.1)
Ammonia(mg/l)	0.06-0.12(0.08±0.01)

4.2. Proximate composition of processed sweet potato leaf

The proximate composition of processed sweet potato leaves is presented in Table 4. The result showed that, dry matter content of RF SPL showed significantly lower value (92.33%) while in AD SPL the value was significantly higher (93.41%). Crude protein content was significantly lower in AD SPL (25.1%) and significantly higher in YF SPL (33.9%). On the other hand, the ether extract content was the lowest in AD SPL (1.76%) and highest in RF SPL (8.40%). There was significant difference between processing methods except YF SPL and NF SPL. Crude fiber content was significantly higher in AD SPL (12.98%) and significantly lower in YF SPL (7.8%). YF SPL showed the lowest ash (9.43%) content while RF SPL was showed the highest (12.14%). In terms of NFE, AD SPL showed highest value (55.87%) while in RF SPL the value was lowest (41.89%).

Table 4. Proximate composition of processed sweet potato leaf

Parameters	Processing methods			
	AD	YF	RF	NF
DM (%)	93.41±0.01^{a}	93.25±0.01^{b}	92.33±0.01^{d}	93.05±0.01^{c}
CP (%)	25.1±0.52^{d}	33.9±0.52^{a}	29.89±0.52^{b}	27.59±0.52^{c}
EE (%)	1.76±0.07^{c}	7.10±0.07^{b}	8.50±0.07^{a}	6.89±0.07^{b}
CF (%)	12.98±0.07^{a}	7.80±0.07^{d}	8.40±0.07^{c}	9.70±0.07^{b}
Ash (%)	10.68±0.01^{c}	9.43±0.01^{d}	12.14±0.01^{a}	11.80±0.01^{b}
NFE (%)	55.87±0.01^{a}	42.81±0.01^{c}	41.89±0.01^{d}	46.77±0.01^{b}

NB. The values are means ± SE and values within the same row with different letters are significantly different ($P \leq 0.05$). AD = Air dried; YF= yeast fermented; RF = rumen fermented and NF= naturally fermented.

4.3. Growth performance and feed utilization efficiency of *O. niloticus* fed with experimental diets

The growth performance parameters such as final body weight, weight gain, specific growth rate, daily growth rate and feed utilization efficiency such as feed conversion ratio and protein efficiency ratio of *O. niloticus* fed with control and different processed sweet potato leaf based diets under Hapa culture system are presented in Table 5. The result showed that there were significant differences (P < 0.05) between the fish fed with different diets.

Table 5. Growth performance and feed utilization efficiency of *O. niloticus* fed with experimental diet

Parameters	Experimental diets				
	Control	AD	YF	RF	NF
IBW (g)	10.55±0.19^{a}	10.45±0.19^{a}	10.85±0.19^{a}	10.70±0.19^{a}	10.38±0.19^{a}
FBW (g)	72.40±0.94^{a}	55.17±0.94^{c}	70.08±0.94^{a}	60.94±0.94^{b}	60.50±0.94^{b}
WG (g)	61.85±0.58^{a}	44.72±0.58^{c}	59.23±0.58^{a}	50.26±0.58^{b}	50.17±0.58^{b}
SGR	1.66±0.03^{a}	1.38±0.03^{c}	1.59±0.03^{a}	1.47±0.03^{b}	1.49±0.03^{b}
DGR	0.68±0.03^{a}	0.49±0.03^{b}	0.65±0.03^{a}	0.55±0.03^{ab}	0.55±0.03^{ab}
FCR	1.31±0.01^{d}	1.70±0.01^{a}	1.30±0.01^{e}	1.53±0.01^{c}	1.60±0.01^{b}
PER	2.05±0.01^{a}	1.50 ±0.01^{d}	1.96±0.01^{b}	1.67±0.01^{c}	1.68±0.01^{c}

N.B. The values are means ± SE and values within the same row with different letters are significantly different (P ≤ 0.05). IBW = Initial body weight, FBW = Final body weight, WG = Weight gain, SGR = Specific growth rate, DGR = Daily growth rate, FCR = feed conversion ratio, PER = protein efficiency ratio, AD=Air dried, YF=Yeast fermented, RF=rumen fermented, NF=naturally fermented

4.3.1 Growth performance of *O. niloticus* fed with experimental diets

The growth performance in terms of final body weight, weight gain, specific growth rate and daily growth rate of *O. niloticus* fed with experimental diets are presented in Table 5. The result showed that, fish fed with air dried sweet potato leaf based diet showed significantly lower final body weight (55.17g), weight gain (44.72g) and specific growth rate (1.38%/fish/day) than the fish fed with the other diets. The daily growth rate (0.49g/fish/day) of fish fed with AD SPL was significantly lower than fish fed with YF SPL and control diet but it was comparable with fish fed with RF SPL and NF SPL (P > 0.05). Fish fed with YF SPL diet showed significantly higher final body weight (70.08g), weight gain (59.23g) and specific growth rate (1.59%/fish/day) than fish fed with the other diets except the control diet. The daily growth rate (0.65g/fish/day) of fish fed with YF SPL was significantly higher than the fish fed with AD SPL and comparable with the fish fed with the other diets (P > 0.05).

4.3.2. Growth trend of *O. niloticus* fed experimental diets

The growth trend of fish fed with experimental diets are presented in Figure 3. After second week, the fish fed with control and YF SPL diet maintained the higher trend followed by RF SPL, NF SPL while the AD SPL diet had lower trend. The weight gain increments were observed in all the treatment up to the end of sampling week.

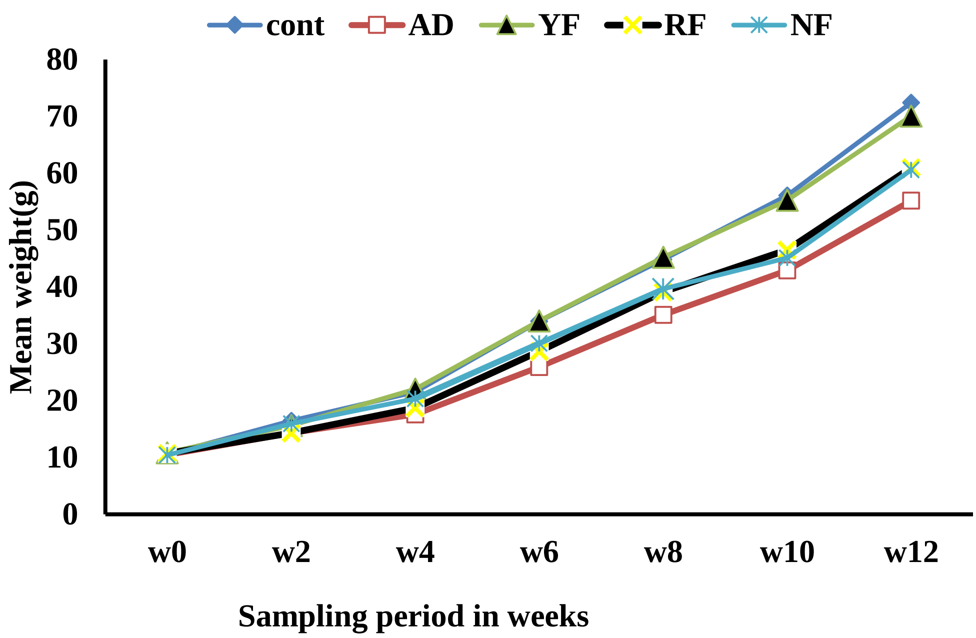

Figure 3. Growth trend of experimental fish

4.3.3. Feed conversion ratio of experimental fish

The feed conversation ratio of experimental fish fed with control and test diets are presented in Table 5. The mean value of feed conversion ratio (FCR) of fish feed with control diet was 1.31±0.001, while the FCR of fish fed with tested diets is ranged from 1.30±0.001 in YF SPL to a highest value of 1.70±0.001 in fish fed with AD SPL. The results indicated that, the fish fed with YF SPL diet showed better feed conversion ratio than the remaining treatments. The poorest FCR of fish was recorded in fed with AD SPL diet with the value of 1.70±0.001. The feed conversion ratio of *O. niloticus* fed with RF SPL and NF SPL was 1.53±0.001 and 1.60±0.001 respectively. Generally, there was significant difference ($P < 0.05$) among all treatments.

4.3.4. Protein efficiency ratio

The protein efficiency ratios (PER) of experimental diets are presented in Table 5. The highest ($P < 0.05$) mean value of protein efficiency ratio was recorded in fish fed with control diet which was 2.05±0.01. The lowest ($P < 0.05$) PER of fish was observed in fed with air dried sweet potato leaf based diet with the mean value of 1.50 ±0.01. The protein efficiency ratio of fish fed with YF SPL based diet was 1.96±0.01 which was significantly different from fish fed with other diets. There was no significant differences on protein efficiency ratios of *O. niloticus* fed with RF SPL (1.67±0.01) and NF SPL (1.68±0.01).

4.4. Fulton's condition factor

Fulton's condition factor (FCF) of fish fed with control and experimental diets ranged from 1.70±0.02 to 1.76±0.02 (Figure 4). The Fulton's condition factor of the fish fed with control diet was 1.72±0.02, while fish fed with the tested diets was ranged from a minimum value of 1.70±0.02 in YF SPL diet to the maximum value of 1.76±0.02 in NF SPL diet. The FCF of fish fed with AD SPL and RF SPL diet were 1.73±0.02 and 1.75±0.02 respectively. There was no significant difference ($P > 0.05$) among and within the treatments.

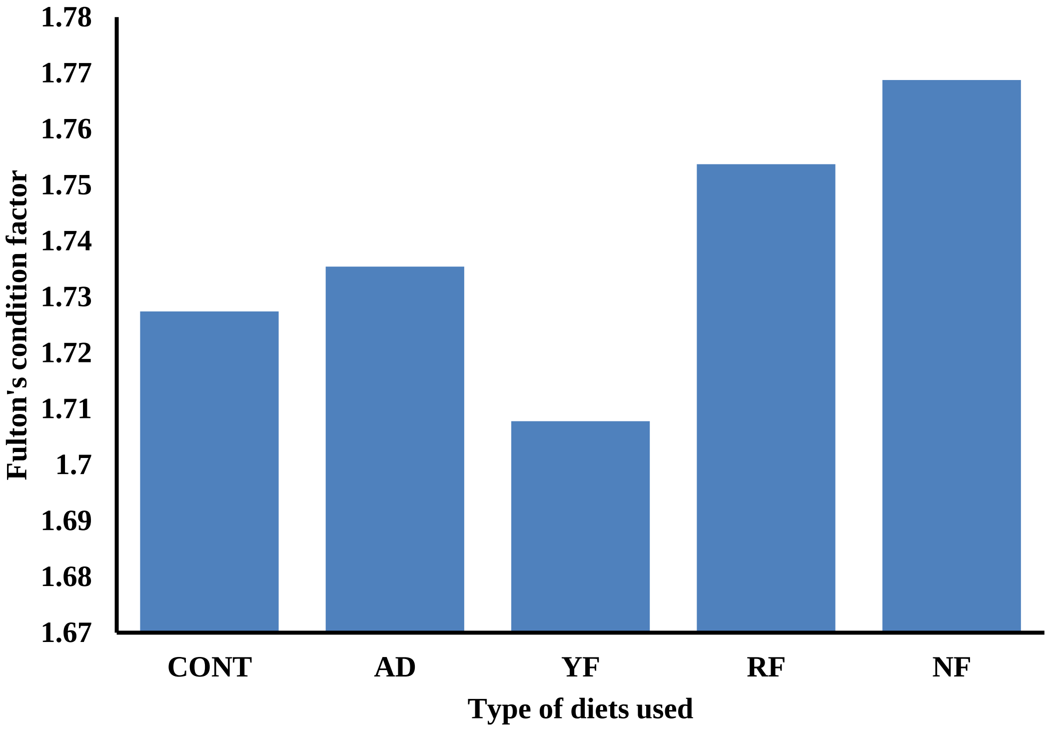

Figure 4. Average value of Fulton's condition factor of *O. niloticus*

4.5. Survival rates of experimental fish

The mean survival rates of *O. niloticus* at different processed sweet potato leaf diet was ranged from a minimum value of 96.67% to a maximum value of 100%. The low survival rate was observed in fish fed with AD SPL diet while, rest of the treatments showed higher survival rates with the value of 100 %. However, there were no significant differences among and within the treatments.

4.6. Body composition of experimental fish

The body composition of the fish fed with processed sweet potato leaf based diet and control diets are presented in Table 5. The result indicated that, the higher dry matter content of fish body was observed in fish fed with NF SPL based diet (75.24±0.19%) it was significantly higher than the fish fed with other diets. Whereas the significantly lower DM content of fish body 71.2±0.19% was seen in fish fed with RF SPL based diet than fish fed with other diet except fish fed with control diet. However, there was no significant difference in DM content of fish body that fed with AD SPL and YF SPL based diets. The crude protein content of fish body composition was significantly lower in fish fed with air dried sweet potato leaf based diet (55.40±0.21%) than the fish fed with other diets. The fish fed with YF SPL based diet showed significantly higher CP content of body composition (59.89±0.21%) than fish fed with other diets except the control diet.

The fish fed with AD SPL based diet showed significantly higher value in ether extract content of fish body composition (31.65±0.21%) than fish fed with YF SPL based diet but its value was comparable with the fish fed with the remaining diet ($P > 0.05$). The EE content of fish body composition was significantly lower in fish fed with YF SPL based diet (30.04±0.21%) than fish fed with AD SPL based diet but comparable with fish fed with other diet ($P > 0.05$).

Maximum ash content was recorded in fish fed with AD SPL based diet (17.35±0.25%). It was comparable with the ash content of fish fed with the remaining diets except the fish fed with RF SPL based diet. The minimum ash content of fish body was recorded in fish fed with RF SPL based diet (15.81±0.25%) but it was comparable with fish fed with control, YF SPL and NF SPL based diet ($P>0.05$).

Table 6. Proximate composition of *O. niloticus* fed with experimental diets

Parameters	Experimental diets				
	Control	AD	YF	RF	NF
DM (%)	71.2±0.19[c]	72.64±0.19[b]	72.7±0.19[b]	71.54±0.19[c]	75.24±0.19[a]
CP (%)	60.04±0.21[a]	55.40±0.21[c]	59.89±0.21[a]	57.14±0.21[b]	56.78±0.21[b]
EE (%)	30.25±0.26[a]	31.65±0.26[a]	30.04±0.26[b]	31.3±0.26[ab]	30.75±0.25[ab]
Ash (%)	16.15±0.25[ab]	17.35±0.25[a]	16.05±0.25[ab]	15.81±0.25[b]	16.64±0.25[ab]

N.B. Similar superscripts in the same row show no significant difference between them. AD = Air dried; YF= yeast fermented; RF = rumen fermented and NF= naturally fermented.

5. DISCUSSION

5.1 Physico-chemical parameters

Water quality parameters especially temperature, dissolved oxygen, pH, ammonia have strong influence on growth performance and feed utilization of *O. niloticus* (Gjedrem, 1997*;* Noor *et al.,* 2010)*.* Water quality is the determining factor on the success or failure of aquaculture operation (Thirupathaiah *et al*., 2012). In the present study, the total mean value of temperature (28.85 ^{O}C ± 0.15) throughout the experimental period which was within the optimum range of 25 to 32 °C for growth performance of juvenile *O. niloticus* as reported by Dennis *et al*.(2009). Moreover, the result of the temperature value of the present study is in agreement with the findings of Oben *et al.* (2015) who reported better growth performance of *O. niloticus* with a temperature range between 20°C and 29°C.

The current study showed a close relationship between temperature and growth of *O. niloticus* in that, the fish exhibited increased food intake and growth performance in relation to temperature. Similar observations were made on better feed intake and growth performance of *O. niloticus* with the increase in temperature as reported by Zenebe Tadesse *et al* (2003), Kassaye Balkew (2012), Zenebe Tadesse *et al*. (2012), Abelneh Yimer *et al*. (2015).

The oxygen value of 4.24mg/L reported in the present study falls within the range of oxygen level as reported by Ross (2000) who stated that *O. niloticus* performs better when oxygen level is greater than 3mg/L. Bhatnagar and Singh (2010) reported better survival, resistance, feed utilization and growth performance of *O. niloticus* in increased dissolved oxygen concentration of above 5mg/ l in pond culture. The results of the present study is inconsistent with the results recommended by the above author and the reason for the lower DO value in this study (4.24mg/l) may be due to decomposition of organic waste and feed remains, consequently resulting in the depletion of dissolved oxygen within the fish pond. However, Kirimi *et al*. (2016) reported that, Nile tilapia can survive even at lower dissolved oxygen levels between 0.9 and 2.98mg/l.

The desirable range of pH for pond water is between 6.5 and 9.5 and the acceptable range is between 5.5 and 10.0(Stone and Thomforde, 2003). pH value of the present experiment ranged between 7.5 and 8, and the average pH value of the experiment was 7.77. This result is in agreement with the desirable range of pH for pond reported by Stone and Thomforde (2003). Similarly,the mean pH recorded in the present study (7.77±0.1) which is within the recommended level (6.4 to 8.3) for favorable growth of fish in aquaculture as reported by (Robert *et al*., 1940). El- Sherif and El-Feky (2009) have reported that water pH of 7-8 could be more suitable for *O. niloticus* culture for optimum growth performance and survival rate.The pH value of the current study was in agreement with the above findings. The ammonia value less than 0.1 mg/l is ideal for fish culture (Boyd, 2001). Similarly, Santhosh and Singh (2007) reported that the maximum limit of ammonia concentration for aquatic organisms is 0.1 mg/l. The present result (0.08mg/l) falls within this range,

5.2. Effects of processing methods on proximate composition of sweet potato leaves

Agubosi *et al.* (2022) reported that air-dried sweet potato peels had a high metabolisable energy, moderate protein and crude fiber compared to sundried peels. Christian (2014) observed dry matter level as 88.6%, crude protein 24.9%, ether extract 1.3%, Crude fiber 12.06%, and total ash 19.3% in Sun dried Sweet potato leaf meal. The dry matter, crude protein, ether extract, and crude fiber content (93.41%, 25.1%, 1.76% and 12.98% respectively) of air dried sweet potato leaf meal in the current study were slightly higher, and the ash content (10.68%) was lower than the previous findings. The Nitrogen Free Extract value of 44.16% as reported by Oludayo (2010**)** is lower than the present study (55.87%). The resean for variations of nutrient content may be due to the different environmental conditions such as soil type, harvesting time, local varieties, crop years and processing methods. However, the proximate composition of air dried sweet potato leaf in the current study was lower in protein and higher in CF and NFE from other processing methods. This implies that air dried sweet potato leaf is less effective in protein enrichment and fiber reduction, and it is a good source of energy compared to other processing.

Fermentation of sweet potato leaves with a co-culture of *Chaetomium globosum* and *Sacchromyces cerevisiae* improved the nutrient composition of the leaves (Onyimba *et al.*, 2015). As those reports the nutrient values of crude protein, ether extract, crude fiber, ash and nitrogen free extract content of fermented sweet potato leaf were 40.20%, 8.95%, 19.40%, 17.32% and 14.13% respectively. Except nitrogen free extract, the results of the current study were lower than the previously reported value. The differences in the above values may be due to the effect of age, morphological differences of plant species, processing techniques adopted, different additive used and duration of fermentation applied. According to Jayant *et al*. (2020) the proximate composition of solid state fermentation (SSF) of sweet potato leaf with *C. globosum* (MTCC-4179) were 31.20% crude protein, 7.17% ether extract, 7.22% crude fiber and 44.11%NFE. The ether extract (7.10%) and crude fiber (7.80%) content of YF SPL in the current study was in agreement with the previous findings. The crude protein (33.9%) and NFE (48.53%) content of YF SPL in the current study was higher than the above findings. This variation may be due to difference of additive used and duration of fermentation applied. In the present study, yeast fermentation of SPL showed lower NFE content than air dried SPL and this may be due to the possible transformation of some of the carbohydrate, which could be used as carbon sources for synthesis of protein or fat (Nelson and Cox, 2017). The highest protein value of YF SPL in this study implies that yeast fermentation of sweet potato leaf is enhancing protein content and it can be used as protein source. Moreover, the lower crude fiber content in YF SPL in the current study shows that yeast fermented SPL has good nutritional value and yeast fermentation is best processing method for improving nutritional value.

The dry matter content of RF sweet potato leaf is lower (92.33%) than the other treatments. According to Adeyemi *et al*. (2007), fermentation with rumen filtrate significantly increased the moisture content of cassava root and the current study agrees with this finding. Dairo *et al*. (2011), reported that rumen fluid fermentation is known to improve protein levels in feed. The CP content of sweet potato leaves ranged from 25.5 to 29.8% in dry matter as reported by (An, 2004). The results of the current study of CP (29.8%), is in line with the maximum value of this range. From the four processing methods of SPL conducted in this study RF sweet potato leaf contained higher protein content next to the YF sweet potato leaf which was is in agreement with the study report of Genanew Abate (2023). This implies that rumen fermentation is the second effective processing method next to yeast fermentation in enriching the nutritive value of sweet potato leaf. The ether extract content (8.5%) of RF SPL in the present study was higher than Jayant *et al*. (2020) who reported that ether extract content of SSF sweet potato leaf was 7.22%. The variation may be due to local varieties and difference of processing method.

The highest ether extract content was recorded in RF sweet potato leaf (8.5%) in the present study which is in agreement with Adeyemi *et al*. (2007), who reported that fermentation with rumen filtrate significantly increased the ether extract content of cassava root meal. The crude fiber content (8.40%)of the rumen filtrate fermented SPL in the present study was the lowest next to YF sweet potato leaves (7.80%). The ash content of RF sweet potato leaves in the present study (12.14%) was higher than the ash content (10.3%) of solid state fermented sweet potato leaves as reported by (Jayant *et al*., 2020). The difference in the ash content may be due to the variation in fermenting ingredients and duration of fermentation applied.

According to Onyimba *et al*. (2010) the natural fermentation brought about a number of desirable changes such as enhancement of protein, ether extract, nitrogen free extract and reduction of fiber content of the mixture of spent sorghum grain and sweet potato leaves. These reports indicate that the crude protein, ether extract, crude fiber, ash and NFE contents of naturally fermented mixed sorghum grain and sweet potato leaves were 30.88%, 5.33%, 7.85%, 11.17% and 44.77% respectively. The protein content (27.5%) of NF sweet potato leaf in the present study was lower than the report of Onyimba *et al*. (2010). The content of ether extract (6.89%), crude fiber (9.7%) and NFE (52.57%) were higher in the current study than previous studies. The difference in the nutrient content may be due to the variation in fermenting ingredients and duration of fermentation applied. However, the ash value (11.80%) coincides with the above findings. NF showed moderate improvement in crude protein, ether extract and NFE content and reduction in crude fiber content of sweet potato leaf in the present study.

5.3. Effects of processed sweet potato leaf on growth performance, feed utilization and body composition of *O. niloticus*

Oludayo (2010) reported that, Sweet potato leaf meal has good potential as a protein source in diets of *Clarias gariepinus* up to 30% level without compromising growth. The growth and feed utilization of *O. niloticus* fed with air dried sweet potato leaf in the current study showed promising results. However, when compared to the other treatments, it was observed that it gave the lower final body weight, weight gain, specific growth rate, and feed conversion ratio. In addition, it showed lower growth trends. This means processing methods of sweet potato leaf has an effect on the growth of *O. niloticus*. This is may be due to the lower nutritive value and presence of some anti-nutritional factors in air dried sweet potato leaf. This indicated that, air drying method of sweet potato leaf is less effective in oxalate and cyanide removal and improving nutritive value (Antia *et al*., 2006). Moreover, this may be due to the relatively high fiber (cellulose) content of AD SPL since these fish lack the ability to secrete cellulase; the main cellulose-digesting enzyme (Buddington, 1980).

In the current study, the higher growth performance in terms of weight gain and specific growth rate, and higher feed utilization efficiency such as feed conversion ratio and protein efficiency ratio was observed in fish fed with YF SPL based diet. Moreover, the good attributes of growth trend curves was displayed in fish fed with YF SPL based diet. This may be due to nutritional quality such as higher CP and lower CF content of YF SPL diet. YF may also enhance the palatability and digestive qualities of sweet potato leaf. The results observed in this study are in agreement with Hassan *et al*. (2015) who report that better growth performance, feed conversion and nutrient utilization in *O. niloticus* fed with yeast fermented soybean meal than other fed groups. The similarity in weight gain, specific growth rate, daily growth rate, and protein efficiency ratio of fish fed with RF SPL and NF SPL based diet in the present study may be attributed to the similarity of nutrient content of the tested diets.

The proximate body composition of *O.niloticus* fed with air dried sweet potato leaf in the current study was 72.64% dry matter, 55.40% crude protein, 31.65% ether extract, and 17.35% ash. This is in agreement with the proximate composition of *O. niloticus* fed with socked, boiled and sundried cassava based diet (SBSDCBD) as reported by Genanew Abate (2023). However, as compared to other treatments in the current study, the proximate composition of *O. niloticus* fed with air dried sweet potato leaf based diet showed the lowest results, which may be due to the nutritive value of the test feed and growth pattern of fish on the treatments. The body composition of fish has direct relationship with qualitative parameters of diets (Maurice *et al*., 2018).

In addition, from the experimental diet the highest protein content (59.89%) of proximate body composition of *O. niloticus* was observed in fed with YF sweet potato leaf meal. This is due to the highest nutritive value of the test feed and growth pattern of fish on the treatments. The dietary protein level in diet determines the crude protein and lipid contents in fish fillet (Kim *et al*., 2013).

The proximate body composition of *O. niloticus* fed with RF SPL in the current study was 71.54% dry matter, 57.14% crude protein, 31.3% ether extract, and 15.81% ash. This is in agreement with the proximate composition of *O. niloticus* fed with 20% rumen fluid fermented water hyacinth reported by (El-Seyd, 2003). The proximate body composition especially protein and ether extract content of *O. niloticus* fed with RF SPL and NF SPL was similar in the current study. This may be attributed to the similarity of tested diet and growth pattern of fish. Lowest DM content of fish body composition were recorded in RF SPL diet. This may be due to nutrient contents of tested diet.

5.4. Fulton's condition factor and survival rate

Fulton's condition factor denotes good health status of a fish species free from nutritional imbalance, infestation, diseases or other health issues, and it is a good indicator of management practices (Gashaw Tesfaye and Zenebe Tadesse, 2008; Elias Dadebo *et al*., 2012; Agumassie Tesfahun, 2018). According to Froese (2006), Ighwella *et al*. (2011), the standard condition factor for *O. niloticus* is 1. The value of Fulton's condition factor more than 1 in the present study at all treatment indicates that, the fish were in good health condition. The survival rate was not affected by test diets of sweet potato leaf processed by different methods. The reason may be due to the reduction of toxic factor cyanide (Mohamed *et al*., 2019) and increasing of nutritive value (Jayant *et al*., 2020) in the test diet by different processing methods employed.

6. CONCLUSION AND RECOMMENDATIONS

6.1. Conclusion

In order to increase aquaculture production, it is necessary to reduce the cost of fish feed by substituting expensive feed ingredients with locally available feed staff. Substituting soybean meal protein with sweet potato leaf protein is effective way to reduce the cost of diets for *O. niloticus.* The nutritional quality of sweet potato leaf can be improved by using appropriate processing methods, while ensuring optimal fish growth and feed utilization efficiency. The present study concluded that:

Fermentation methods are better than air drying method to improve nutritional composition of sweet potato leaf. Yeast fermented sweet potato leaf followed by rumen-fluid fermented sweet potato leaf resulted in better protein content and lower fiber content than other processing methods. Processed sweet potato leaf inclusion in fish feeds did not affect the survival rate of *O. niloticus* cultured in hapas in concrete ponds. Processing methods of sweet potato leaf have beneficial impact on growth performance, feed utilization and body composition of *O. niloticus.* As a whole, in the current study there was high growth performance of fish specifically the weight gain and specific growth rate, and high feed utilization efficiency such as FCR and PER in yeast fermented sweet potato leaf and control diet. Thus, yeast fermented sweet potato leaf protein can replace 30% of soybean meal with without any change on growth performance, feed utilization and body composition of *O. niloticus*.

6.2. Recommendations

Based on the present study, the following recommendations are forwarded:

- Yeast fermentation is best method of processing to improve nutritional quality of sweet potato leaf.
- Yeast fermented sweet potato leaf can be considered as better diet for *O. niloticus* culture.
- Further research is needed to better understand the effects of processing methods on amino acid and mineral content of SPL and ANF's of sweet potato leaf.
- Further investigations should be conducted to study the rate of application of YF SPL in *O. niloticus* diet, nutrient digestibility of sweet potato leaf diet and cost benefit analysis.

REFERENCES

Abdullah, A., Ramli, R., Syafiq, M., Ridzuan, M., Murni, M., Hashim, S., Sudirwan, F., Abdullah, S., NurMansor, S., Amira, S., Zamri, M., Noor, M. and Amal, A. (2017). The presence of Vibrionaceae, Betanodavirus and Iridovirus in marine cage cultured fish: Role of fish size, water physicochemical parameters and relationships among the pathogens. *Aquaculture Reports*, 7: 57–65.

Abebe Ameha Mengistu (2015). Tilapia aquaculture business model for Ethiopia: Feasibility Study. Addis Ababa Chamber of Commerce and Sectoral Associations. Addis Ababa, Ethiopia.

Abelneh Yimer, Adamneh Dagne and ZenebeTadesse (2015). Effects of feed additives (premix) on growth performance of *Oreochromis niloticus* (L, 1758) in concrete pond, Sebeta Ethiopia. *Journal of Aquaculture*, 5: 17-35.

Abonyi, F. O., Iyi, E. O. and Machebe, N. S. (2012). Effects of feeding sweet potato (*Ipomoea batatas*) leaves on growth performance and nutrient digestibility of rabbits. *Afr. J. Biotech.*, 11(15): 3709- 3712. https://doi.org/10.5897/AJB11.3103.

Adewolu, M. A. (2008) Potentials of sweet potato (*Ipomoea batatas*) leaf meal as dietary ingredient for *Tilapia zilli* fingerlings. *Pak. J. Nutr.*, 7(3): 444–449. https://doi.org/10.3923/pjn.2008.444.449.

Adeyemi, O. A., Eruvbetine, D., Oguntona, T., Dipeolu, M. A. and Agunbiade, J. A. (2007). Enhancing the nutritional value of whole cassava root meal by rumen filtrate fermentation. *Archivos de Zootecnia,* 56: 261-264.

Agano, J., Paul, O., Raphael, K., Anyona1, N. and Gabriel, O. (2017). Effects of water physicochemical parameters on tilapia (*Oreochromis niloticus*) growth in earthen ponds in Teso North Sub-County, Busia County. *Fisheries and Aquatic Sciences*, 20: 30. https://doi.org/10.1186/s41240-017-0075-7.

Agubosi, O. C. P., Imudia, F. D. and Alagbe, J. O. (2022). Evaluation of the Nutritive Value of Air-Dried and Sun-Dried Sweet Potato (*Ipomoea Batatas*) Peels. *European journal of life safety and stability*, 14: 48 *www.ejlss.indexedresearch.org*

Agumassie Tesfahun (2018). Overview of the length weight relationship, Condition factor and Size at first Maturity of Nile tilapia *Oreochromis niloticus* on different water bodes of Ethiopia. Review. *Greener Journal of Biological Science,* 8(3):021-028.

Ahmad, Z., Deo, A. D., Kumar, S., Ranjan, A., Aklakur, M. and Sahu, N. P. (2019). Effect of replacement of de-oiled rice bran with sweet potato leaf meal on growth performance, digestive enzyme activity and body composition of *Labeo rohita* (Hamilton, 1822). *Ind. J. Fish*., 66(1): 73-80. https://doi.org/10.21077/ ijf.2019.66.1.82353-10.

Ahmed and Maqbool (2017). Effects of Dietary Protein Levels on the Growth, Feed Utilization and Haemato-Biochemical Parameters of Freshwater Fish, *Cyprinus Carpio Var*. *Specularis*. *Fisheries and Aquaculture Journal,* 8: 187. doi:10.4172/2150 3508.100 0187.

Al Hafedh, Y. S. (1999). Effects of dietary protein on growth and body composition of Nile tilapia, *Oreochromis niloticus* L. *Aquaculture Research*, 30: 385–393.

Alavaisha, E., Lyon, S. W. and Lindborg, R. (2019). Assessment of water quality across irrigation schemes: A case study of wetland agriculture impacts in Kilombero Valley, Tanzania. *Journal of Water*, 11(4): 671; https://doi.org/10.3390/w110 40671.

Aletor, V. A. (1993). Allelochemicals in plant foods and feeding stuffs. Part I. Nutritional, biochemical and physio-pathological aspects in animal production. *Veterinary and Human Toxicology*, 35(1): 57-67.

Ali, H. A., Ali, J. A., Musthafa, S. M., Kumar, M. S. A. and Naveed, S. M. (2016). Impact of formulated diets on the growth and survival of ornamental fish *Pterophyllum scalare* (Angel Fish). *Journal of Aquatic Research Development*, 7: 421. doi:10.4172/2155-9546.1000421.

An, L.V. (2004). Sweet potato leaves for growing pigs: Biomass yield, digestion and nutritive value. Doctor's dissertation. Dept. of Animal Nutrition and Management, SLU. Acta Universitatis agriculturae Suecia. Agraria vol. 470:47

Anderson, J., Jackson, A. J., Matty, A. J. and Capper, B. S. **(**1984). Effects of dietary carbohydrate and fiber on the tilapia *Oreochromis niloticus* (Linn.).J. *Aquaculture*, 37:303–314.

Antia, B. S., Akpanz, E. J., Okonl, P. A. and Umorenl, I. U. (2006). Nutritive and Anti-Nutritive Evaluation of Sweet Potatoes. *Pak. J. Nutr.*, 5(2): 166–168. https://doi.org/10.3923/pjn.2006.166.168.

AOAC (1990). Official Methods of Analysis. 15th Edn., *Association of Official Analytical Chemists*, Washington, DC., USA., pp: 600-792.

Asaminew Kassahun (2012). Utilization of locally available feedstuffs for small-scale aquaculture production in Ethiopia. (Doctoral dissertation, University of Natural Resources and Life Sciences Vienna).p:75

Azaza, M. S., Dhraief, M. N. and Kraiem, M. M. (2008). Effects of water temperature on growth and sex ratio of juvenile Nile tilapia *O. niloticus* (Linnaeus) reared in geothermal waters in southern Tunisia. *J. Therm. Biol*., 33: 98-105.

Azaza, M. S., Legendre, M., Kraiem, M. M. and Baras, E. (2010). Size-dependent effects of daily thermal fluctuations on the growth and size heterogeneity of Nile tilapia *Oreochromis niloticus*. *Journal of Fish Biology*, 76(3): 669-683.

Bake, G.G., Endo, M., Akimoto. M. and Takeuchi, T. (2013). Growth performance of Nile tilapia *Oreochromis niloticus* juveniles fed sweet potato and soy Sauce by-product meal diet in a flow through system. *Aquaculture Sci.,* 57(2):193-199.

Balagopalan, C., Padmaja. G. and George, M. (2002). Improving the nutritional value of cassava products using microbial techniques. FAO-Corporate Document Repository. *Anim. Prod. Health,* P: 95.

Benli, A. C., Koksal, G. and Ozkul, A. (2008). Sub lethal ammonia exposure of Nile tilapia (*Oreochromis niloticus* L.) kidney histology. *Chemosphere,* 72 (9):1355–1358.

Bergheim, A., Gausen, M., Næss, A., Hølland, P. M., Krogedal, P. and Crampton, V. (2006). A newly developed oxygen injection system for cage farms. *Aquacult. Eng*., 34: 40−46.

Bhatnagar, A., Singh, G. (2010). Culture fisheries in village ponds: a multi-location study in Haryana, India. *Agric Biol J. N. Am.*, 1(5):961–8.

Boyd, C. E. (1998). Water quality for pond aquaculture. *Res. Develop*., 43:1–11.

Boyd, C. E. (2001). Water quality standards: total ammonia nitrogen. The Advocate, 4:84-85.

Boyd, C. E. (2010). Dissolved oxygen concentration in pond aquaculture. https://www.researchgate.net/publication/281309202.

Buddington, R. K. (1980). Hydrolysis-resistant organic matter as a reference for measurement of fish digestion efficiency. Trans. *Am. Fish. Soc*., 109: 653– 656.

Chen, C. C., Shih, Y.C., Chiou, P. W. S. and Yu, B. (2010). Evaluating nutritional quality of single stage- and two stage-fermented soybean meals. *Asian-Australian Journal of Animal Sciences*, 23:598-606.

Christiaan Jacobus Smit (2014). Effects of Sweet Potato Forage Meals on Protein and Energy Supply, Beta-Carotene and Blood Glucose Content of Dairy Cattle Milk. M.Sc Thesis, University of South Africa. p:77

Dairo, F. A. S., Aina, A., Omoyeni, L. and Adegun, M. K. (2011). Ensiled Cassava Peel and Caged Layers' Manure Mixture as Energy Source in Broiler Starter diet. *Journal of Agricultural Science and Technology*, 1:519-524.

Dennis, P., Long, D., Thomas, M., James, L. and Rakocy, E. (2009). Tank culture of tilapia. *Southern Regional Aquaculture Center*, https://thefishsite.com/articles/tank culture-of-tilapia

Dubost, N., Masson, G. and Moreteau, J. C. (1996). Temperate freshwater fouling on floating net cages: method of evaluation, model and composition. *Aquaculture*, 143: 303–318.

Ebuka, I. A., O. Oghenebrorhie, P. H. Jnr, A. M. Lydia and Augustine, C. I. (2023). Sweet potato (*Ipomoea batatas*) leaf meal as partial replacement for soya bean meal in catfish (*Clarias gariepinus*) juvenile diet. *Livestock Research for Rural*, 35(4).

El Sheikha, A.F. and Ray, R. C. (2017). Potential impacts of bioprocessing of sweet potato: Review. *Crit Rev Food Sci & Nutr.*, 57:455–471.

Elias Dadebo, Bishaw Tadele and Kassaye Balkew (2012). The impact of gillnet selectivity on immature Nile tilapia (*Oreochromis niloticus* L.*)* in Lake Hawassa, Ethiopia. Trends in the Conservation and Utilization of Aquatic resource of Ethiopian Rift Valley. EFASA Fifth Annual Conference, Hawassa, Ethiopia. DOI:10.13140/2.1.1971.8083

El-Sayed, A.F.M. (2003). Effects of fermentation methods on the nutritive value of water hyacinth for Nile tilapia *Oreochromis niloticus* (L.) fingerlings. *J. Aquaculture*, 218: 471-478.

El-Sayed, A.F.M. (2006) Tilapia Culture. CABI Publishing, Wallingford, Oxon, UK, 294 pp.

El-Shafai, S. A., El-Gohary, F. A., Nasr, F. A., Van der Steen, N. P. and Gijzen, H. J. (2004). Chronic ammonia toxicity to duckweed fed tilapia *Oreochromis niloticus*. *J. Aquaculture*, 232: 117-127.

El-Sherif, M. S. and EL-Feky, A. M. I. (2009). Performance of Nile tilapia *Oreochromis niloticu*s fingerlings. Effect of pH. *International Journal of Agriculture & Biology*, 11: 297-300.

Eriegha, O., Ekokotu, J., and Adogbeji, P. (2017). Factors affecting feed intake in cultured fish species; A review; *Animal research international*, 14(2):2697-2709.

FAO (2010). The state of world fisheries and aquaculture, 218. Rome, Italy: Food and Agriculture Organization of the United Nations (FAO).

FAO (2016). Crop Production Data. Available at http://www.fao.org/faostat/en/#data/QC (accessed December 29, 2022).

FAO (2018). The State of World Fisheries and Aquaculture 2018. Meeting the sustainable development goals. https://creativecommons.org/licenses/byncsa/3.0/igo.

FAO (2020). The State of World Fisheries and Aquaculture 2020. *Sustainability in action*. Rome.

FAO (2022). The State of World Fisheries and Aquaculture 2022. Rome, FAO. https://doi.org/10.4060/cc0639en.

Froese, R. (2006). Condition factor and weight-length relationships: history, meta-analysis and recommendations. *J. Appl. Ichthyol.*, 22: 241-253.

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

Gashaw Tesfaye and Zenebe Tadesse (2008). Length weight relationship, Fulton condition factor and size at maturity of tilapia *Oreochromis niloticus* L.in Lake Koka, Ziway and Langano (Ethiopian Rift valley). *Ethip. J. Biol. Sci.,* 7: 139-157.

Gemede, H. F. and Ratta, N. (2014). Anti-nutritional factors in plant foods: potential health benefits and adverse effects. *International Journal of Nutrition and Food Sciences,* 3(4): 284-289.

Genanew Abate (2023). Effect of Processing Methods on the Utilization of Cassava Root Based Diets on Growth Performance of Nile tilapia, *Oreochromis niloticus L.* M.Sc., Thesis, Hawassa University. p:85.

Gjedrem, T. (1997). Selective breeding to improve aquaculture production. *J. Aquaculture.* 28:33-45.

Gupta, R. K., Gangoliya, S. S. and Singh, N. K. (2015). Reduction of phytic acid and enhancement of bioavailable micronutrients in food grains. *Journal of Food Science and Technology*, 52(2): 676–684.

Hassaan, M. S., M. A. Soltan, A. M. Abdel-Moez, (2015). Nutritive value of soybean meal after solid state fermentation with *Saccharomyces cerevisiae* for Nile tilapia, *Oreochromis niloticus. Animal Feed Science and Technology*, 201: 89–98.

Hirabayashi, M., Matsui. T. and Yano, H. (1998). Fermentation of soybean meal with *Aspergillus usamii* reduce phosphorus excretion in chicken. *Biological Trace Element Res*., 61(2): 227-234.

Huss, H.H. (1995). Quality and Quality changes in fresh fish. FAO Fisheries Technical paper No.348, Food and Agriculture Organization (FAO) of the United Nations, Rome, Italy.

Ighwela, K. A., Ahmed, A. B. and Abol-Munafi, A. B. (2011). Condition Factor as an indicator of growth and feeding intensity of Nile tilapia fingerlings (*Oreochromis niloticus*) feed on different levels of maltose. *American-Eurasian J. Agric. and Environ. Sci.*, 11 (4): 559-563.

Ishida. H., Suzuno. H., Sugiyama. N., Innami. S., Tadokoro, T. and Maekawa, A. (2000). Nutritive evaluation on chemical components of leaves, stalks and stems of sweet potatoes (*Ipomoea batataspoir*). *Food Chem*., 68(3): 359-367. https://doi.org/10.1016/S0308- 8146(99)00206-X.

Jauncey. K. (2000). Nutritional requirements. P. 327–375. *In*: M.C. M. Beveridge and B. J. McAndrew (eds.) Tilapias: Biol- ogy and Exploitation, Fish and Fisheries Series 25, *Kluwer Academic Publishers*, Dordrecht, The Netherlands.

Jayant M., N. P. Sahu, A. D. Deo, S. Gupta, C.K. Garg and R. K. Valappil (2020). Nutritional evaluation of fermented sweet potato leaf meal as a replacer of deoiled rice bran in the diet of *Labeo Rohita* Fingerlings. *J. Exp. Zool. India*, 23(1): pp. 61-70.

Jobling, M. (1998). Mythical models of gastric emptying and implications for food consumption studies. *Environ. Biol. Fishes*, 16(1-3):35- 50.

Kamal, A. H. M. M. and Mair, G. C. (2005). Salinity tolerance in superior genotypes of tilapia, *Oreochromis niloticus*, *Oreochromis mossambicus* and their hybrids. *Journal of world Aquaculture*, 247(14): 189-201.

Kapinga, I., Mlaponi, E. and kasozi, N. (2014). Effect of stocking density on the growth performance of sex reversed male Nile tilapia (*Oreochromis niloticus*) under pond conditions in Tanzania. *World Journal of Fish and Marine Sciences*, 6(2): 156–161.

Kassaye Balkew (2012). Evaluation of growth performance, feed utilization efficiency and survival rate of juvenile Nile tilapia, *O. niloticus* (Linnaeus, 1758) reared at different water temperature. *Journal of International Aquaculture*, 2(9): 59-64.

Keishing. S., Banu, T. and Umadevi, M. (2015). Effect of fermentation on the nutrient content, antioxidant and antidiabetic activities of Hawaijar, an indigenous fermented soya of Manipur, India. J. *Human Nutrit, Food Sci*., 3(3): 1066.

Kiers, J. L., Meijer, J. C., Nout, M. J. R., Rombouts, F. M., Nabuurs, M. J. A. and Van der Meulen, J. (2003). Effect of fermented soya beans on diarrhoea and feed efficiency in weaned piglets. J. *Appl. Microbiol*., 95(3): 545–552. https://doi.org/10.1046/j.1365-2672.2003.02011.x.

Kim, K. H., Lohakare, J. D., Sen, S., Ingale, S. L., Singh, N. K., Park, C. K. and Chae, B. J. (2013). Comparison of growth performance, nutrient digestibility, blood metabolites and carcass traits in Korean native and crossbred weaning piglets. *Animal Nutrition and Feed Technology*, 11(2):159–167.

Kirimi, K., Moniruzzaman, M., Kim, D., Han. S., Yun, H., Lee, S., Sungchul, C. and Bai, (2016). Effects of dietary protein levels on growth performance and body composition of juvenile parrot fish, *Oplegnathus fasciatus*. *International Aquaculture Research*, 8:239–245.

Kumari, S. (2018). The effect of soaking almonds and hazelnuts on Phytate and mineral concentrations. Doctoral dissertation, University of Otago. https://api.semanticscholar.org/CorpusID:208989709.

Lee, D. H., Lim, S. R., Han, J. J., Lee, S. W., Ra, C. S. and Kim, J. D. (2018). Effects of dietary garlic powder on growth, feed utilization and whole body composition changes in fingerling starlet sturgeon, *Acipenser ruthenus. Asian J. Anim. Sci.*, 27(9): 1303–1310.

Lim, C., Barros, M. M., Klesius, P. H. and Shoemaker, C. A. (2000).Thiamin requirement of Nile tilapia, *Oreochromi sniloticus*. p 201 *In:* Book of Abstracts. Aquaculture America, New Orleans, Louisiana. Baton Rouge, Louisiana: *World Aquaculture Society*.

Lochmann, T. Rebecca , Shahidul Islam, Harold Phillips, Zelalem Adam and Jace Everette (2013). Effects of dietary sweet potato leaf meal on the growth, non-specific immune responses, total phenols and antioxidant capacity in channel catfish (*ictalurus punctatus*). *J. Sci. Food Agric*., 93(6):1365-9.

Maeda, E. E. and Salunkhe, D. K. (1981). Retention of ascorbic acid and total carotene in solar dried vegetables. *Journal of Food Science*, 46: 1288-1290.

Mahesh, M. S. and Mohini, M. (2013). Biological treatment of crop residues for ruminant feeding: A review. *Afr. J. Biotech*., 12(27): 4221-4231.

Maurice, Y. E. O., Gopéyué, B. L. E., Mélécony Célestin, Fagbohoun Bédel, Etchian Assoi Olivier and Dabonne Soumaila (2018). Effects of modulation dietary gelatinized cornstarch protein ratio on growth performance, feed utilization, and body composition of tilapia *Oreochromis niloticus* fingerlings. *Journal of Applied Biology and Biotechnology*, 6(05):31-36.

Meshram, S., Deo, A. D., Kumar, S., Aklakur, M. and Sahu, N. P. (2018). Replacement of de oiled rice bran by soaked and fermented sweet potato leaf meal: Effect on growth performance, body composition and expression of insulin like growth factor 1 in *Labeo rohita* (Hamilton), fingerlings. *Aquaculture Res.,* 49(8): 2741-2750.

Mohamed Hawashi, Tri Widjaja and Setiyo Gunawan (2019). Solid-State Fermentation of Cassava Products for Degradation of Anti-Nutritional Value and Enrichment of Nutritional Value. https://doi.org/10.1145/3383783.3383801

Mohanty, K. (2004). Density dependent growth performance of Indian major carps in rainwater reservoir. *Journal of applied Icthyology*, 20: 123-127.

Motarjemi, Y. (2002). Impact of small scale fermentation technology on food safety in developing countries. *International Journal of Food Microbiology*, 75:213-229.

Musiba, M. J., Ngupula, G. W., Kashindy, B. B., Elison E, M., Shoko, A. P., Ndikumana, J., Ziwa, E. and Katunzi, E. F. B. (2014). Performance of locally formulated feeds for rearing of African Catfish in Tanzania. *African Crop Science Journal*, 22(4):979 – 986.

Nelson, D. L. and Cox, M. M. (2017). Lehninger Principles of Biochemistry. 7th Edition, W.H. Freeman, New York, 1328.

Noor, E. L., Deen,. I. E. and Mona, S. Z. (2010). Impact of climate change (Oxygen and Temperature) on growth and survival rate of Nile tilapia (*Oreochromis niloticus*). *Aquaculture*, 232:117-179.

Oben, B., Ernest, M. and Pius, O. (2015). Profitability of small-scale integrated fish-rice-poultry farms in Cameroon. *Journal of Agricultural Science*, **7**:232-244.

Oludayo, O. C. (2010). Growth performance and blood profile of African cat fish fed sweet potato (*Ipomoea batatas*) leaf meal. The 5th International Seminar on Tropical Animal Production, *Community Empowerment and Tropical Animal Industry*, Yogyakarta, Indonesia

Onyimba, I. A., Ogbonna, A. I., Egbere, J. O., Njila, H. L. and Ogbonna, C. I. C. (2015). Bioconversion of sweet potato leaves to animal feed. *Annual Research & Review in Biology*, 1-6.

Onyimba, I. A., Ogbonna, C. I. C. and Akueshi, C. O. (2010). Effects of Natural Fermentation on the Nutrient Composition of a Mixed Substrate of Spent Sorghum Grain and Sweet Potato Leaves. 21: 12 – 17. http://www.ajol.info/index.php/njb/index

Osagie, A.U. (1998). Nutritional quality of plant foods. 1st ed. The Post-Harvest Research Unit, UNIBEN Nigeria. pp 62.

Osman, M. A. (2007). Changes in nutrient composition, trypsin inhibitor, phytate, tannins and protein digestibility of dolichos lablab seeds [*Lablab purpuresus* (L) sweet] occurring during germination. *J. Food Technol*., 5: 294–299.

Pierre Martial Thierry Akely, Eliane Hadiowe Gnagne, Geraldine Marie Laure Tanan To Lou and Georges N'Guessan Amani (2020). Varietal influence of cassava on chemical composition and consumer acceptability of Gari, *International Journal of Food Science & Technology*, 56: 1239-1246.

Popma, T. and Masser, M. (1999). Tilapia, life history and biology. *Southern Regional Aquaculture Center*, 283: 4-8.

Prabu, E., Rajagopalsamy, C. B. T., Ahilan, B., Jegan Michael Andro, Jeevagan and Renuhade, M. (2018). Effect of dietary supplementation of biofloc meal on growth and survival of GIFT tilapia. *Indian J. Fish., 65(1): 65-70.*

Reboucas, R. T., Lima, F. R. S., Cavalcante, D. D. and Carmoesa, M. V. (2015). Tolerance of Nile tilapia juveniles to highly acidic rearing water. *Acta Scientianim Animal Sciences*, 3:227- 333.

Riche, M. and Garling, D. (2003). Fish: Feed and Nutrition. Feeding tilapia in intensive recirculating systems. http://www.hatcheryfeed.com/ hf-articles/141

Ricker, E. (1975). Computation and interpretation of biological statistics of fish population. Bull. *Fish Res. Bd. Canada*, 2: 519-529.

Robert, C. S., Grindley, and William, E. E. (1940). Fish invest servl., 4(2).

Ross, L. 2002. Environmental physiology and energetic. *Fish and Fisheries Series*, 25:89-128.

Ross, L.G. (2000). Environmental physiology and energetics. *In:* M.C.M. Beveridge and B.J. McAndrew (eds.). Tilapias: biology and exploitation, fish and fisheries. Series 25, *Kluwer Academic Publishers, Dordrecht*, 89-128.

Saha, S., Roy, R. N., Sen, S. K. and Ray, A. K. (2006). Characterization of cellulase-producing bacteria from the digestive tract of tilapia, *Oreochromis mossambica* (Peters) and grass carp, *Ctenopharyn godonidella* (Valenciennes). *Aquaculture Research*, 37: 380–388.

Samuel Bekele Mengistu, Han, A., Mulder, John, A. H., Benzie and Hans Komen (2019). A systematic literature review of the major factors causing yield gap by affecting growth, feed conversion ratio and survival rate in Nile tilapia. Review in Aquaculture. *Australian Sciences,* 5(2): 1014 – 1018.

Santhosh, B. and Singh, N. (2007). Guidelines for water quality management for fish culture in Tripura, ICAR Research Complex for NEH Region, Tripura Centre, Publication, 29.

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

Soetan, K. and Oyewole, O. (2009). The need for adequate processing to reduce the anti-nutritional factors in plants used as human foods and animal feeds- a review. *African Journal of Food Science,* 3(9): 223- 232.

Stone, N. and Thormforde, H. (2003). Understanding your fish pond water analysis report. University of Arkansas Co-operative Extension Printing services. pp. 1-4.

Sun, H., Mu, T., Xi, L., Zhang, M. and Chen, J. (2014). Sweet potato (*Ipomoea batatas* L.) leaves as nutritional and functional foods. *Food Chem.,* 156: 380–389.

Tahar, A., Kennedy, A., Richard, D., Fitzgerald, Clifford, E. and Rowan, N. (2018). Full water quality monitoring of a traditional flow-through Rainbow trout farm. *Journal of Aquaculture and Fishes*, 3: 28.

Tewodros Abate and Abebe Getahun (2017). Effect of feeding Frequency on growth performance and survival of Nile tilapia (*Oreochromis niloticus* L. 1758) in a cage culture system in Lake Hora-Arsedi, Ethiopia. *Journal of Aquaculture and Research Development*, 8 (4):479. DOI: 10. 4172/2155-9546.1000479.

Tewodros Abate, Abebe Getahun, Akewake Geremew, Gebermedihin Ambaw and John W. Recha (2020). Manual for production of Chamo strain Nile tilapia fingerlings and preparation of fish feeds from locally available material. Wageningen, the Netherlands: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS).

Thirupathaiah, M., Samatha, C.H. and Sammaiah, C. (2012). Analysis of water quality using physico-chemical parameters in lower Manair Reservoir of Karimnagar district, Andhra Pradesh. *International Journal of Environmental Sciences,* 3:172-180.

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.

Verster, N. (2017). Comparison of growth rates of tilapia species (*Oreochromis mossambicus* and *Oreochromis niloticus*) raised in a biofloc and a standard recirculating aquaculture system. Faculty of Bioscience and Engineering. M.Sc, thesis, Ghent University, Ghent, Belgium.

Vhanalakar, S. A. and Muley, D. V. (2014). Effect of dietary incorporation of *Gliricidia maculata* leaf meal on growth and feed utilization of *Cirrhinus mrigala* fingerlings. *Global J. Sci. Front. Res. Biol. Sci.,* 14(1): 1-5.

Watanabe, W.O., Losordo, T.M., Fitzimmons, K. and Hanley, K. (2002).Tilapia production systems in Americas: Technologies, Trends and Challenges. *Journal of Fish Biology,* 23: 653-673.

Webster, C. D. and Lim, C. (2002). Introduction to fish nutrition. *In:* Nutrient Requirements and Feeding of Finfish for Aquaculture, PP. 1-27. (Webster, C.D. and Lim, C. (eds). CAB *International Publishing*. USA

White, R. S., McHugh, P. A., Gloves, C. N. and Mcintosh, A. R. (2014). Multiple environmental stressors increase the realized niche breadth of a forest-dwelling fish. *Ecography,* 38(2):154-162.

Winfree, R. A. and Stickney, R. R. (1981). Effects of dietary protein and energy on growth feed conversion efficiency and body composition of *Tilapia aurea*. *J. Nutr*., 111: 1001–1012.

Yamamoto, T., Iwashita, Y., Matsunari, H., Sugita, T., Furuita, H., Akimoto, A. and Suzuki, N. (2010). Influence of fermentation conditions for soybean meal in a non-fish meal diet on the growth performance and physiological condition of rainbow trout *Oncorhynchus mykiss*. *Aquaculture*, 309(1): 173–180.

Yuan, Y. C., Lin, Y. C., Yang, H. J., Gong, Y., Gong, S. Y. and Yu, D. H. (2013). Evaluation of fermented soybean meal in the practical diets for juvenile Chinese sucker, *Myxocyprinus asiaticus*. *Aquaculture Nutrition,* 19(1): 74–83.

Yue, G., Blé, M.C., Otchoumou, K.S., Dabonne,S., Alla,L.Y. and Etchian, O.A. (2017). Digestibility and growth performance in fingerlings of tilapia *Oreochromis niloticus* fed with diet containing high-carbohydrate ingredients. *Int. J. Fish. and Aquatic Studies*, 5(4): 171-175.

Zeitoun, M. M., EL-Azrak, K. E. D. M., Zaki, M. A., Nemat-Allah, B. R. and Mehana, E.-S.E. (2016). Effects of ammonia toxicity on growth performance, cortisol, glucose and hematological response of Nile Tilapia (*Oreochromis niloticus*). *Aceh Journal of Animal Science,* 1(1): 21-28.

Zenebe Tadesse, Abeba Welde Gebriel, Mulugeta Jovani, Fikadu Tefera and Fasil Degefu, (2012). Effect of supplementary feeding of agro industrial by products on the growth performance of Nile tilapia (*Oreochromis niloticus*) in concrete ponds, *Ethiopia. J.Biol.Sci.*, 11(1):29-41.

Zenebe Tadesse, Boberg, M., Sonesten, L. and Ahlgren, G. (2003). Effects of algal diets on the growth and fatty acid content of the cichlid fish *O. niloticus* L. *Aquatic Ecol*., 37: 169-182.

APPENDICES

Appendix I: Processing of experimental ingredients to improve nutritional quality for fish feed.

A Indicates washing and pounding of SPL, B soaking, C fermentation, D drying, E grinding, F sieving, G packing for nutrient analysis

Appendix II. Feed preparation and data collection

A pelleting of diet, B sieving of diet, C measuring of water quality, D and E measuring body weight of fish, F measuring body length