UNIVERSITY OF CAPE COAST

GROWTH PERFORMANCE OF NILE TILAPIA *(OREOCHROMIS NILOTICUS*) FED ON *IPOMOEA AQUATICA*

BY

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DISCLAIMER

This is to state that the comparator commercial feed used in this study was for academic purposes only. The researcher had no support whatsoever from the commercial entity. The mention of the product in this work is in no way an advertisement, an endorsement or otherwise of the product.

DECLARATION

Candidate's Declaration

I hereby declare that this thesis is the result of my own original research and that no part of it has been presented for another degree in this university or elsewhere.

Candidate's Signature..... Date: 16/11/2018

Name..... Agtanor Setumte Kwame Enuameh

Supervisors' Declaration

We hereby declare that the preparation and presentation of the thesis were supervised in accordance with the guidelines on supervision of thesis laid down by the University of Cape Coast.

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ABSTRACT

Feed is one of the major costs of aquaculture operations, constituting between 30-70% of the total operating budget depending on the intensity of the operation. To this end, research into cheaper feed constituents (especially of the more expensive fishmeal) has been ongoing for decades. The potential of *Ipomoea aquatica* (water spinach) as an alternative to commercial feed (Raanan) in the intensive culture of *Oreochromis niloticus* was evaluated in a concrete tank system behind the Faculty of Science Complex of the University of Cape Coast from 4th April to 1st October, 2016. Raanan Commercial Feed (Raanan), Dry Whole *Ipomoea* (Dry) and Fresh Leaf *Ipomoea* (Fresh) were the diet types used whereas the Control was not fed. Growth data were taken on a bi-weekly basis and used to determine the growth performance and survival of the studied *Oreochromis niloticus*. Raanan fed fish had significantly higher protein (28.801 ± 0.292) and lipid content (3.437 ± 0.183) than Dry (20.095 ± 0.07 & 0.832 ± 0.481, respectively). In terms of growth parameters, Ranaan again had significantly ($p < 0.05$) higher values in every category: Specific Growth Rate (SGR) of 1.617 ± 0.035 followed by No Feed with 0.466 ± 0.076; Absolute Growth Rate (AGR) of 0.570 ± 0.002 with No Feed having 0.024 ± 0.011 and Percentage Weight Gain (PWG) of 2252% ± 164 while No Feed had the second highest weight gain of 150.6% ± 36.7. Terminal survival did not vary significantly across treatments with Dry having 88.89 ± 7.35%, Raanan and No Feed treatments recording 83.33 ± 4.81% and Fresh having the lowest of 69.44 ± 10% respectively. Raanan had a significantly higher Condition Factor (CF) 1.601 than any of the treatments as shown: Fresh (1.4977), Dry (1.4853) and No Feed 1.4645 which did vary significantly. The Length-Weight Relationship of all the treatments showed isometric growth. There were significant differences in the ANOVA results of the carcass proximate analysis of fingerlings and adults. In conclusion, the two forms of *Ipomoea aquatica* tested in this study did not result in good growth performance of *O. niloticus* while the Raanan commercial feed proved its efficacy as a commercial feed of choice. Some recommendations were then made.

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DEDICATION

Dedicated to the memories of Mrs. Doreene Arthur-Morrison and Mrs. Peace Kudu.

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CHAPTER ONE

INTRODUCTION

This chapter provides detailed information on the background of the study, statement of the problem, the significance of the study, the general and specific objectives of the study, the delimitations and limitations of the study and the organization of the study.

Background of the Study

Feeding the World – Capture Fisheries vs Aquaculture

Food with a balanced nutritional profile is a necessity for human existence and fish (be they farmed or captured) continues to be one of the most-traded food commodities worldwide with more than half of fish exports by value originating in developing countries (SOFIA, 2016). The current world population of 6.91 billion consumes about 118 million metric tonnes of fisheries products a year. By 2050, the world would need about 156 million metric tonnes each year (an additional 34 million metric tonnes per year) to feed a predicted 9.15 billion persons (Boyd and Li, 2012). A worrying trend is that capture fisheries are not projected to increase and aquaculture must single-handedly supply the entire future increase in demand for fisheries produce (SOFIA, 2016). Furthermore, assuming that freshwater and marine aquaculture grow at the same rate, freshwater aquaculture needs to increase to around 54 million metric tonnes per year by 2050 (Boyd and Li, 2012).

Multiple Positives from Finfish Culture

Fish is one of the most important sources of animal protein, accounting for about 17 percent at the global level, but exceeding 50 percent in many

least-developed countries. It also provides other valuable nutrients such as the long-chain omega-3 fatty acids docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA) – important for optimal neurodevelopment in children and for improving cardiovascular health. There is convincing evidence of beneficial health outcomes from fish consumption for reducing the risk of death from coronary heart disease and improving neurodevelopment in infants and young children, when the mother consumes fish before and during pregnancy (SOFIA, 2016).

"*...Tell me what you eat and I will tell you what you are...*" is a saying very applicable to the farmed fish aspect of the aquaculture industry (Toppe, 2012). As is the norm in most parts of Asia and Africa, fish is a critical part of the diet in Bangladesh, complementing local staple foods, such as rice. It is a vital source of high-quality protein aside contributing to nutrition security and provides many micronutrients essential to good health. Bangladeshis have a saying that sums things up very well: "*We are made of rice and fish*" (World Fish Center, 2011).

***Oreochromis niloticus* ("Aquatic Chicken")**

Known as the *Miracle fish* and believed to have originated from Israel *Oreochromis* spp. have spread all over the world and are the most common fish species cultured globally. *O. niloticus* (Nile tilapia) has garnered a lot of praise (leading to it being termed "aquatic chicken") as it is a fish with numerous positives such as good flesh taste, provider of omega-3-fatty acids which are very healthy for human growth, resistance to many fish diseases and is hardy in tough environments (Stickney, 2000).This fish species accepts artificial feed in the early stages of its development after being hatched, has a

high survival rate and grows very fast (El-Sayed, 2006 cited in Abdel-Tawwab *et al*., 2010).

Fishmeal in Aquaculture Feeds

Feed is one of the major costs of aquaculture operations, typically making up between 30% to 60% of the total operating budget, depending on the intensity of the operation (Lucas and Southgate, 2012). For intensive culture of tilapia, which is currently the most reliable way of producing the tonnages required to "feed the world", feed constitutes 60-70% of total production cost (Borski *et al.*, 2011). In aquaculture in Sub-Saharan Africa, feed has been estimated to represent 60-65 percent of variable costs and 45-63 percent of total costs (Hishamunda and Manning, 2002 - cited in Kassam, 2013). However, as with the majority of finfish species produced within intensive farming systems, the development of commercial aquafeeds or complete formulated diets for these species has usually been based upon the use of fishmeal as the main source of dietary protein; the nutritional characteristics of fishmeal protein approximating almost exactly to the nutritional requirements of cultured finfish (Tacon, 1993). New and Wijskstrom (FAO, 2002) write in depth about it.

Plant-Based Fishmeal Replacers

Due to the rising cost of fish feeds to the aquaculture industry, extensive research is being carried out into the production of alternative replacements. Several plant based feeds have been experimented as substitutes for fishmeal (El Sayed and Tacon, 1997; Stickney, 2000; Madalla, 2008; Abarike, 2011; Anani, 2015). Plant based replacers experimented for *O.niloticus* include plant oilseeds; such as soybean meal, cotton seed milk and

cake, groundnuts and sunflower that had diverse effects on *O. niloticus* (El Sayed and Tacon, 1997). Legumes and cereal by-products also serve as replacers. Some aquatic plants such as *Azolla pinnata*, *Azolla microphylla*, and *Lemna* spp. (duckweed) have been explored as meal substitutes for *O. niloticus* with diverse outcomes (El Sayed and Tacon, 1997).

The Aquatic Macrophyte *Ipomoea aquatica*

Ipomoea aquatica(Forsk) is an aquatic macrophyte of global distribution throughout the tropics of the old world (Snyder *et al*., 1981; Austin, 2007) with a plethora of uses ranging from the ethnomedical and medicinal (Prasad *et al*., 2008; Doka, Tigani and Yagi, 2014) to the phytoremediatory, bioaccumulatory (Trang and Brix, 2014) and finally the nutritional – to animals such as rabbits (Samkol *et al.*, 2006), fish (Tanduyan and Bontia, 2001; Mandal *et al*., 2010; Sen, 2010; Ganzon-Naret, 2015), pigs (Chhay *et al*., 2007) and humans (Snyder *et al.*, 1981; Baysa *et al*., 2006; Mandal *et al*., 2008; Samkol, 2009).

Problem Statement

One major constraint in intensive aquaculture production has to do with the high cost of feeding and attempts have been made to come up with solutions. This project seeks to determine the effectiveness of the aquatic macrophyte *Ipomoea aquatica* as a cheap source of nutrients for organic farming of *O. niloticus.* Also, about 60 – 70% of total production costs of tilapia goes into feeding (Lucas and Southgate, 2012). This is what makes the final cost of tilapia quite expensive and any successful attempt at reducing the feeding cost through a less expensive replacement of Fish Meal (FM) will have very positive ramifications on the cost of tilapia production globally.

Aside reduced costs to the aquaculture industry, production of the macrophyte could serve as a form of income generation and serve to alleviate poverty among populations in Africa and eventually globally.

Significance of the Study

Globally, one major issue is that of poverty and its alleviation. The poor across the world are usually so disadvantaged that they are unable to provide for their families the appropriate nutrient-rich diets necessary for optimum growth and development. Aquaculture can play a very important role in poverty alleviation as it could affect variables such as income generation, consumption of nutritionally more complete diets especially through the improved supply of fish. In this regard, this project on *Ipomoea aquatica* (which is readily available) as a cost-effective feed material could be groundbreaking as it would result in financially cost-effective feeding of cultured fish and will hopefully reduce the vast investment needed to feed fish (Stevenson and Irz, 2009; Kawarazuka and Béné , 2010; Kassam, 2013).

General Objective

To evaluate the potential of *Ipomoea aquatica* as an alternative to commercial intensive culture feed (Raanan) in the culture of *Oreochromis niloticus.*

Specific Objectives

1. To compare the nutritional composition of the *Ipomoea aquatica* and Raanan commercial feed used for the experiment.

2. To compare the growth performance of *Oreochromis niloticus* fed with:

    a. dry powdered whole plant *Ipomoea aquatica*

    b. fresh *Ipomoea aquatica* leaves

    c. commercial Raanan feed.

    The control treatment were not fed.

3. To determine the nutritional composition (via proximate analysis) of the carcasses of *Oreochromis niloticus* before and after the conclusion of the study.

4. To assess the survival of *O. niloticus* fed on *I. aquatica* as compared with Raanan fed fish.

Delimitation

The objective of the study was not to formulate a feed, but to test a raw aquatic plant (*Ipomoea aquatica*) ingredient that seemed to have caused comparably good growth of the *O. niloticus* in its natural setting as observed by an aquaculture enthusiast in one of the suburbs of Cape Coast. The leaves of the fresh *Ipomoea* plant without the stem were fed to the fish as it was realized earlier in the study they were unable to feed on the stem that was fibrous in nature. The comparator feeds were the powdered dry whole plant, no feed at all and the Raanan Commercial Feed – the "gold standard".

Hypothesis

The null hypothesis of this study is, “fish fed on the two *Ipomoea* derived diets will not exhibit growth comparable to that of the Raanan Commercial feed”.

Organization of the Study

The study is structured into six chapters as follows: Chapter one introduces the study and covers areas such as, background of the study, justification of the study & significance of the study, general & specific objectives of the study, delimitation of the study and the hypothesis of the study. Chapter two touches on some literature pertaining to certain aspects of the study. Chapter three focuses on the methodology that was used for the study, explains the procedures used to gather the relevant data for the study and the analyses of the data. In Chapter four, the results obtained is presented while Chapter five interprets the findings of this study with reference to relevant literature and previous findings from similar works on the same or related species. Finally, Chapter six delves into the conclusion and recommendations.

CHAPTER TWO

LITERATURE REVIEW

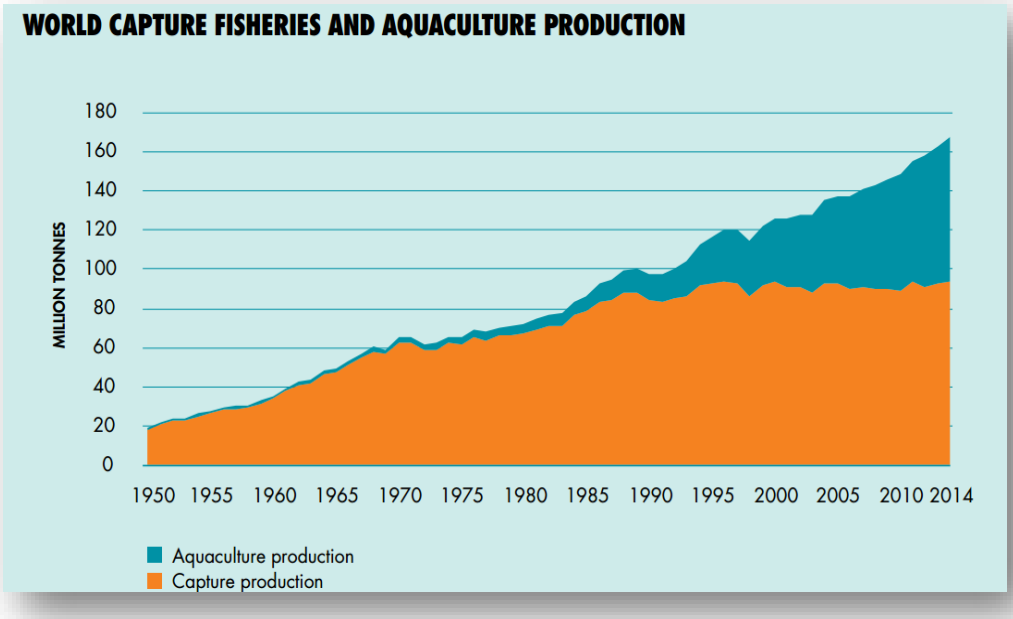
Introduction

In this chapter, some literature pertinent to the study will be reviewed.

State of Fisheries and Aquaculture

The seemingly inexhaustible oceans have proved to be finite after all. Even utilizing the most sophisticated and efficient fishing gear, landings of wild fish have levelled off since the mid-1980s, and many stocks of fish are fished so heavily (the small pelagics) that their future is threatened. Paradoxically, the world's appetite for fish continues to increase particularly in the rapidly urbanizing populations of the developing world. Aquaculture has risen to the challenge of meeting this increased demand admirably and has grown consistently by an average of 8% for the last two decades and continues to grow globally (Delgado *et al.*, 2003). In Ghana for instance, overfishing in our waters has resulted in Ghana's fisheries generating far lower returns than expected. The Fisheries and Coastal Management Capacity Building Support Project - a five-year partnership initiative between the United States Agency for International Development (USAID) and the Department of Fisheries and Aquatic Sciences (DFAS) of the University of Cape Coast (UCC) - is geared towards sustainable exploitation of marine fisheries of Ghana (DFAS, 2015a, 2015b).

The 2016 State of the World Fisheries and Aquaculture Report (SOFIA) - a flagship biennial publication of the Food and Agriculture Organization (FAO) - graphically (as seen in Figure 1) shows the almost constant capture fisheries production as against the increasing aquaculture



production.

Figure 1: State of the World Fisheries and Aquaculture Report. (Source – FAO, 2016).

Historical Note - Africa

The Third International Symposium on Tilapia in Aquaculture (ISTA 3) was held in La Côte D'Ivoire in 1996. In the preface, the editors (Pullin, R.S.V., J. Lazard, M. Legendre, J.B. Amon Kothias and D. Pauly) state the fact that it was the largest such meeting on tilapia to be held in Africa since earlier meetings in Nazareth in 1983 and Bangkok in 1987. At the time of the conference, even though Africa was known as being the "home of tilapias", it was yet to benefit from tilapia farming as have other regions. However,

African aquaculture research and development were producing promising results despite the economic difficulties under which much of these have been undertaken. Of the 64 papers and 17 abstracts of poster papers published in the report, 20 were contributed by African participants. The editors were thus hopeful that the culture of tilapias will increase both for internal use within Africa and for export to the rest of the world.

Three years on, the situation in terms of Africa benefiting more from tilapia culture had not changed much and Coche, Moehl and Sagua in 1999 wrote a section titled "Africa Regional Aquaculture Review" in the Food and Agriculture Organizations Aquaculture Newsletter (FAN, 1999) in which they traced the evolution of aquaculture in Africa since its introduction five decades earlier. In conclusion, they stated unequivocally that,

"For decades aquaculture in Africa has been vacillating between crests and troughs of various waves of development with the same constraints identified time and again: lack of seed, feed, credit and extension support. All of these constraints relate to the underlying lack of policy. If there is political will to establish workable policies, solutions to these other issues will be forthcoming".

After decades of work from the Food and Agriculture Organization (FAO), development partners, the private sector and other concerned stakeholders, aquaculture production from Africa has increased but it could get better; more needs to be done.

Aquaculture in Ghana – A Historical Note

Fish farming started when fishponds were built in 1953 by the former Department of Fisheries in the northern part of Ghana. These were to serve as hatcheries to support the culture-based reservoir fishery development programme of the colonial administration and as a way of supplementing the national demand for fish and increasing livelihood opportunities. Thus fishing skills were taught in communities living near small reservoirs, which were not traditionally used for fishing. After gaining independence in 1957 the national government adopted a policy to develop fishponds within all irrigation schemes in the country. State-owned irrigation facilities were to be developed, as far as it was technically possible, under a policy of converting 5 percent of the scheme into fish farms. Ironically, the Northern Regions were the start point but they have fallen far behind the other regions and currently rather contribute least to collated production figures (Personal Communication in 2013 at Ashaiman Aquaculture Demonstration Centre; Anani, 2015; FAO, 2018a).

Thereafter, a massive Government promotion of the industry followed with the construction of about 2 000 ponds in the early 1980s, though without much success. Of recent, however, a rapid increase in production has resulted in the introduction of numerous floating cages in Volta Lake and Volta River. The recent participation of foreign commercial investors in the sector has drastically and positively altered the face of fish farming in the country. Though fish farming is a fairly new business activity in Ghana, its practice is becoming widespread, especially in the Ashanti, Central, Eastern, Volta and Western regions of the country (FAO, 2018b).

By 2013, the government of President John Mahama with Hon. Shirley Ayitey as Minister for the Ministry of Fisheries and Aquaculture Development (MOFAD) had secured support from donors to the tune of $83 million to implement the much-touted National Aquaculture Development Plan (NADP) which had as its main objective the target of increasing productivity from 10,200 tonnes in 2010 to 100,000 tonnes in 2016, boosting the market share of farmed fish to 30 percent (MoFA/FC, 2012 cited in Kassam, 2013). Those ambitious targets were not met due to a plethora of reasons with fish feed issues being a major limiting factor.

Commercial Feed Formulation and Manufacture

Extrusion processing technology has become of major importance in the production of modern feeds used in intensive aquaculture. Extrusion is a process where the feed is subject to mixing, shearing and heating under high pressure before the extrudate finally is forced through a die. The feed constituents undergo transformations during the processing that can be beneficial if the nutritional value is improved, but detrimental if nutrients are destroyed or become resistant to digestion (Halver & Hardy, 2012). Knowing that feed cost comprises 40-60% of the variable cost in aquaculture worldwide, feed quality should be as high as possible to ensure a good feeding economy. In this context, bioavailability of the nutrients and the physical quality of the feed are both of great importance (Halver & Hardy, 2012).

Investigation of physical quality of commercial feed pellets (i.e. particle hardness, durability, sinking velocity and water absorption) has unveiled variation in quality (Chen *et al.*, 1999). Physical quality is affected by several variables, among which formulation and extruder parameters are

recognized as having great influence. Research by the Institute of Aquaculture Research in Norway (Sorenson, Date Unknown) have proven that differences in chemical composition and the pre-processing history of the ingredients affects the physical quality of the feed, either directly or indirectly through interactions with extrusion parameters.

Fish as an Invaluable Food

Consumption of fish has unique nutritional and health benefits and is considered a key element of a healthy diet. FAN (2012) trumpets this news as the headline on its cover which says, “Eat more fish, a healthy alternative. Farmed fish, a good choice”. The newsletter then enumerates just what makes fish that great a dietary source. That write-up is captured in the ensuing paragraph.

Increased attention has been given to fish as a source of essential nutrients in our diets, not only as a source of high value proteins, but more importantly also as a unique source of micronutrients and essential omega-3 fatty acids (eicosapentaenoic acid or EPA + docosahexaenoic acid or DHA). The fatty acid DHA and iodine are essential for the development of the brain and neural system in children, and are almost exclusively found in foods from the aquatic environment. It is therefore particularly important to secure a minimum consumption of fish among pregnant and lactating women and young children to assure optimal development of the brain (Toppe, 2012). Fish consumption is also known to have health benefits among adult population; it is estimated that fish consumption reduces the risk of dying of coronary heart diseases by 36 percent (Toppe, 2012) due to the long chained omega-3 fatty acids mainly found in fish and fishery products. The unique nutritional

composition of fish derives not only from fatty acids, amino acids, micronutrients (vitamins, minerals), but also other less known nutrients such as taurine and choline. Fish is an excellent source of protein, but what makes fish a really unique food is all the additional nutrients that can be found in significant amounts (Toppe, 2012).

Nutrition and Mental Health

Still on the health benefits of eating fish, the United Kingdom (UK) All Party Parliamentary Food and Health Forum (FHF) in 2007 published a document titled: The Links between diet and behaviour – The Influence of Nutrition on Mental Health. The Executive Summary and Recommendations of a 44- page document; the Report of an inquiry held by the Associate Parliamentary Food and Health Forum in the UK paints a picture of hope and healing for the approximately 450 million people suffering from mental disorders globally (WHO, 2001).

Nutrition is usually taken to be important for physical health, but mental health – brain health in its widest sense – must be considered as equally important. A diet lacking essential nutrients or containing too many ingredients that are detrimental in excess is likely to have adverse consequences for brain function and thus mental health and behaviour. It is widely agreed that a balanced diet is required to support physical health – and there is good scientific evidence suggesting that the Mediterranean diet is a good model (FHF, 2007).

The Mediterranean Diet, sometimes referred to as the 'Greek Mediterranean Diet' or 'Mediterranean Diet Plan,' incorporates the traditional

healthy living habits of people from countries bordering the Mediterranean Sea, including France, Greece, Italy and Spain (Haas, Bellows, Ganster and Moore, 2014; National Health Service - NHS, 2017). It is likely that a balanced diet of this kind is also beneficial for the healthy functioning of the brain. It is now established that certain essential fatty acids (EFAs) especially Arachidonic Acid (AA) and Docosahexaenoic Acid (DHA) form an important part of the cellular structure of the brain and in maintaining its normal functions. No nutrient works in isolation; a deficiency in one leads to sub-optimal functioning of others. The lack of certain nutrients, however, may be associated with a range of mental and behavioural disorders as this report describes. A deficiency of omega-3 EFAs is associated with certain mental and behavioural disorders, such as Attention Deficit Hyperactivity Disorder (ADHD), depression, dementia, dyspraxia, greater impulsivity and aggressive behaviour, but the association is still only partly understood (FHF, 2007).

Recommendations by FHF (2007)

Nineteen recommendations were made after the inquiry, the core ones being increased research and the implementation of a policy of increased oily fish intake for children in school as part of breakfast and lunch feeding programme and for prisoners and those in mental institutions.

Three recommendations were made:

1. The Scientific Advisory Committee on Nutrition (SACN) should be asked to define further the optimum intake of omega-3 polyunsaturated fatty acids (PUFAs) in different stages of life, especially for pregnant women and children.

2. We also recommend that in the meantime, on a precautionary basis, the FSA should reconsider its advice to pregnant women about fish consumption, with a view to encouraging them to eat two portions of oily fish, or the equivalent in omega-3 PUFAs, a week (rather than that people should eat two portions of fish a week, of which one should be oily).

3. We also recommend that the Food Standards Agency (FSA) continues to monitor closely levels of mercury, dioxin and dioxin-like polychlorinated biphenyl (PCB) in the different species of oily fish available in the UK.

The other sixteen recommendations are also very enlightening reading and have far-reaching implications for health in not only the United Kingdom but globally.

On *Oreochromis niloticus*.

Apart from being cultured in earthen ponds and cages, *O. niloticus* also happens to be one of the most common fish used in aquaponics. These are tropical fish and need warm water and they are very tolerant to crowded environment in a tank. They are omnivorous and their young are not devoured by their parents because they skip the planktonic phase. These fish grow fast and they are least fastidious about their surroundings. By the time they reach 3-5 years of age, they would be weighing about 2.72 kg (Cook, 2013).

***O. niloticus* Feed Research - Ghana.**

Four *O. niloticus* feed related researches carried out in Ghana are touched on in the ensuing paragraphs.

Abarike (2011) determined the Growth performance of fry and fingerlings of *Oreochromis niloticus* fed on different agro-industrial by-products. The study was conducted at the Aquaculture Research and Development Centre at Akosombo (ARDEC) to observe the growth performance of fry and fingerlings of *O. niloticus*; and also assess the cost-effectiveness of the different dietary treatments. In experiment 1, four isonitrogenous (36% crude protein) and isoenergetic (gross energy 18 MJ/kg) diets were formulated to contain agro-industrial by-products including: wheat bran (diet 1), pito mash (diet 2), rice bran (diet 3) and groundnut bran (diet 4) and fed to fry of *O. niloticus* (average initial weight 0.11 ± 0.01 g) stocked at 50 m^{-3} in out-door hapas for 8 weeks. In experiment 2, four isonitrogenous (30% crude protein) and isoenergetic (gross energy 18 MJ/kg) diets were formulated from the same by-products as in experiment 1 and fed to *O. niloticus* fingerlings (average initial weight 7 ± 0.23 g) stocked at 20 m^{-3} for 24 weeks.

Growth performance was similar ($P > 0.05$) for fry *O. niloticus* among all treatments. However, incidence cost was highest for diet 4 and lowest for diet 2. Fish fed on diet 2 had the highest ($P < 0.05$) profit index and those fed on diet 4 had the lowest. Growth performance in fingerlings was highest ($P < 0.05$) in diet 1 and least in the control. Whiles incidence cost was highest ($P < 0.05$) for fish fed diet 4 and lowest ($P < 0.05$) for fish fed diet 2. In conclusion, the growth performances were similar ($P > 0.05$) for fry of *O. niloticus* among all treatments. For *O. niloticus* fingerlings, diet 1 produced the fastest growth. Diet 2 was the most cost-effective diet. From this study, diets 1 and 2 for rearing of *O. niloticus* were recommended for feeding.

Abarike *et al.* (2013) looked at the nutritional quality and economic feasibility of the agro-industrials Wheat Bran (WB), Pito Mash (PM), Rice Bran (RB) and Groundnut Bran (GB) in a 30% Crude Protein diet as feed for fingerling production of *O. niloticus* grown in out-door hapas in Akosombo, Ghana over a period of 24 weeks. At the end of the experimental period, the fish fed on WB had the fastest growth and the highest average weight gain (80.80g ± 3.48) followed by RB (67.93g ± 4.19) and PM (57.33g ± 4.30) with GB having the slowest growth (44.30g ± 5.41). Economically, the most cost effective diet was the PM diet.

Three widely-available agro-industrials namely soybean meal (SBM), copra (CM) and palm kernel meals (PKM) were assessed as potential replacers for fishmeal in *O. niloticus* diets in terms of their digestibility and effects on growth and nutrient utilization (Obirikorang *et al.*, 2015). Apparent digestibility coefficients (ADC) were determined using chromic oxide as an inert marker in the test diets which were formulated to contain 30% of each of the test ingredients by weight and 70% of a fishmeal-based reference diet. The test ingredients were found to partially replace fishmeal in *O. niloticus* diets without considerably compromising diet digestibility and carcass traits although higher dietary levels of copra and palm kernel meals were found to have a deleterious effect on fish growth due to their high fibre and low dry matter digestibilities.

Anani's 2015 study (also carried out at ARDEC) utilized six commonly used ingredients in five major pond fish farming Regions (Ashanti, Brong-Ahafo, Central, Volta and Western) in Ghana. Farm-made diets were prepared and evaluated against two commonly used commercial diets for *O.*

niloticus. In all, five diets namely *A* (farm-made diet supplemented with vitamin-mineral premixes, lysine and methionine), *B* (farm-made diet without supplements), *C* (commercial tilapia diet, *Coppens*), *D* (commercial tilapia diet, *Raanan*) and *E* (mixture of *B* and *Raanan* in a ratio of 1:1) were tested in two studies: firstly, a growth study carried out in hapas over a 140-day period and secondly, a digestibility study carried out for 20 days.

After the culture period, the final mean weights of *O. niloticus* were 140.3 ± 23.4, 131.0 ± 24.4, 148.3 ± 25.4, 187.6 ± 42.1 and 140.7 ± 28.5 g for *A*, *B*, *C*, *D* and *E* respectively. There was no significant difference ($p > 0.05$) in specific growth rates among all the dietary treatments. Apparent nutrient digestibility coefficients were high (> 60 %) in all the dietary treatments. In terms of cost-effectiveness, the farm-made diets were more profitable than the commercial ones. Anani's results thus indicated that nutritionally balanced farm-made fish diet is cost-effective and will boost growth of aquaculture in rural areas where semi-intensive pond aquaculture is mainly practised in Ghana.

Feeding *O. niloticus*

It was recently demonstrated that appetite in *O. niloticus* returns four hours after satiation feeding with a pelleted diet (Riche *et al*., 2004a as cited in Riche *et al.*, 2004b). The higher quality, consistency and availability of pelleted feeds may reduce the need for frequent feedings. Fish fed three meals had significantly higher gross energy and lipid and lower crude protein contents than fish in the other treatments ($p<0.05$). Energy retention in fish fed three times daily (84.7%) was significantly higher than in fish fed five times

(49.4%). Feeding juvenile tilapia nutrient dense pelleted feeds obviates the need for frequent feedings (Riche *et al*., 2004b).

The Tilapia Market

Tilapia remains a popular product in the retail sector in the United States of America, the largest market for this species, with countries in Asia (frozen product) and Central America (fresh product) the main suppliers. Demand in Europe for this species remains limited and imports declined slightly in 2015. Tilapia production is expanding in Asia, South America and Africa with a growing volume of supply entering domestic markets in the major producing countries. However, in 2015, China, a major producer, experienced rather sluggish production and reduced processing, reflecting a slow market.
Overall, due to steady supply, import prices declined in most markets. (SOFIA, 2016).

Larger tilapia skin provides gelatin as well as leather for use in clothing, shoes, handbags, wallets, belts and other items (SOFIA, 2016). The distribution of frozen aquaculture products has also expanded dramatically, facilitated by increased volumes and much-reduced transportation costs. One example is the success of frozen whole tilapia from Asia, which has gained access to new markets in all regions of the world (SOFIA, 2016).

Ipomoea aquatica

Background

Hasan and Chakrabati (2009) write extensively on the most common and important floating macrophytes namely *Eichhornia crassipes* (Water

hyacinth), *Lemna* spp. (Duckweed) and *Azolla* spp. *Ipomoea* (water spinach) is mentioned in the section which deals with other miscellaneous floating macrophytes, namely water lettuce (*Pistia*), water fern (*Salvinia* spp.) and water chestnut (*Trapa* spp.) and these are said to be self-growing plants that are commonly found in the shallow stagnant waters of tropical and sub-tropical countries. Water spinach (*Ipomoea aquatica*) is a floating plant that roots in marshy soil at the internodes (Edwards, 1980 & Gothberg, 2008).

I. aquatica is native to India, South East Asia, and South China and is commonly eaten as a vegetable (Edwards, 1980). Hasan and Chakrabati (2009) state that little work has been done on it and its fellow miscellaneous floating macrophytes when it comes to their use as aquafeed.

Importance of Water in Aquaculture

Water is recognized as one of the key limiting resources for the new millennium. Areas with once abundant water reserves are now forced to take a close look at rationing, while water-stressed areas are being forced to get by with less and less water. Diminishing supplies and increased demand mean that water use and re-use is a critical issue. It is now clearly imperative that water use be optimized. One form of optimization is to *integrate irrigation* and *aquaculture* (IIA) and to develop synergy from this marriage (Moehl, 1999). With the increasing incidences of water shortage in Ghana, it is in our best interest to prepare for times of water shortage by starting to practice any of the forms of IIA – two will be touched on in the ensuing paragraph – rice-fish culture and poultry-fish culture.

The Chinese National Project Framework (2007) of a global initiative by the FAO concerning *Conservation and Adaptive Management of Globally Important Agricultural Heritage Systems (GIAHS)* states that rice-fish culture is believed to have originated from China and was being practiced as far back as 1700 years ago as relics excavated in 1978 in Mian County, Shanxi Province have proven. One rice field model contained 18 sculptured pottery miniatures of aquatic plants and animals with the animals being frogs, eels, spiral shells, crucian carp, grass carp, common carp, and turtles. Halwart and Gupta (2004) wrote comprehensively on it and it is a global phenomenon being practiced in places like Bangladesh, Madagascar, Thailand, Vietnam (Akegbejo-Samsons, 2010; Bosma *et al.*, 2012). In Ghana, rice is the most important cereal food crop after maize (Amanor-Boadu, 2012), thus implementing rice fish culture should, in my view, have a high impact socio-economically. Obodai *et al*., in 2009 carried out a study on Integrated Poultry-Fish production in the Bontango Irrigation Project which has several barrow pits with positive results thus proving that poultry-fish production is a viable IIA option in Ghana.

CHAPTER THREE

MATERIALS AND METHODS

Study Site and Experimental Setup

This study was carried out in a concrete tank system with 4 individual unconnected tanks behind the Faculty of Science Complex of the University of Cape Coast and close to the Botanical Garden (North - 05°06.987'; West – 001°17.677'). Each of the tanks was 3.77 m × 3.77 m wide and 0.77 m deep. Three of the tanks were used for the experiment – two for testing the effects of the feeds on *Oreochromis niloticus,* while the third was used for growing the *Ipomoea aquatica* as shown in Plate 1 below. The fourth tank was not used.

Plate 1: A picture of the study site.

Study Components

Ipomoea aquatica

The Dry *Ipomoea aquatica* whole plant *(I. aquatica)* used throughout the study was harvested into sacks from a wetland in the Ghana National Association of Teachers (GNAT) Hostel area at Eyifua (North - 05°08.907'; West – 001°16.821') in the Cape Coast North District of the Central Region of Ghana (Plate 2).

Plate 2: Site from which *I. aquatica* was harvested throughout the study.

The whole plant (i.e. stem and leaves minus the roots) were sun-dried for about a week on black plastic polythene sheeting on the concrete rooftop of my home at Kwaprow (North – 05°07.655'; W – 001°17.852') also in the Cape Coast North District of Cape Coast Region (Plate 3), bagged and milled using a Brook Crompton Series 2000 mill produced by Glen Creston Ltd. at the Technology Village, School of Agriculture, University of Cape Coast to give the Dry whole plant *Ipomoea* pictured in Plate 4.

Plate 3: Drying the freshly harvested *Ipomoea* (left) and the dried *Ipomoea* (right).

Plate 4: The bagged dried *Ipomoea* and the milled powder.

A map showing the study site, sampling site and drying location is found below.

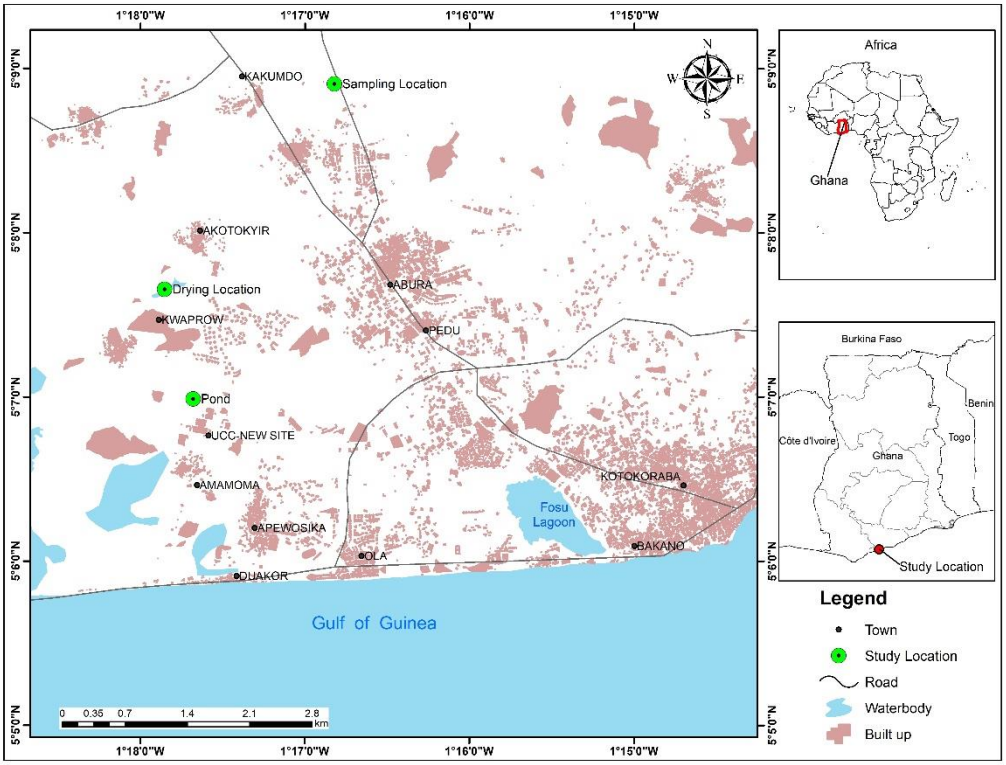


Figure 2: Map showing the location of the pond, the drying location and the sampling location.

Aquaponics of *Ipomoea aquatica*

The whole plant of *Ipomoea aquatica* does not stay fresh for more than a day and starts decomposing from the second and is spoilt by the third day. Firstly, some Styrofoam used in packaging fridges was obtained and square holes spaced evenly apart cut in them. Whole plant *Ipomoea* of approximately the same length (about 20 cm) were cut and tied together as a bundle with nylon twine. The bundles were then pushed through the square holes so the lower portion was in contact with the water of the pond (Plate 5 Left) – this was done so rooting of the *Ipomoea* would only happen at that lower portion of the whole plant as seen in Plate 5 Right.

Plate 5: Lifting up the styrofoam in which the *Ipomoea* is growing and holding two bunches of *Ipomoea* with rooting at the base.

Pest Infestation

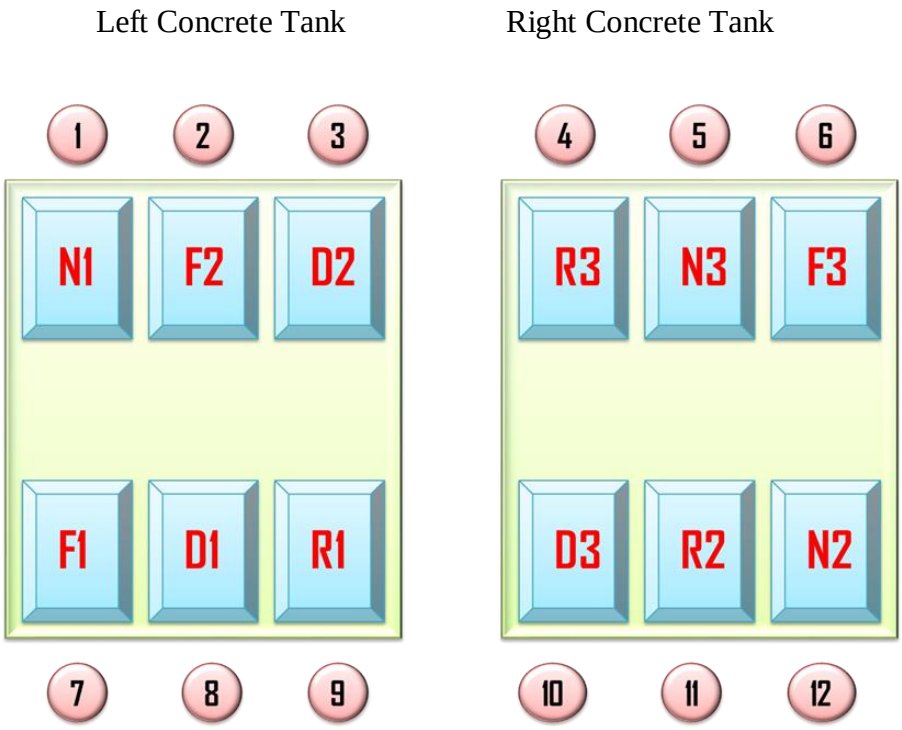
During the latter months of the study, there was trouble with pests and the havoc they caused to the initially beautifully growing plants is contrastingly seen in Plates 6 and 7.

Plate 6: A view of the growing fresh *Ipomoea* devoid of pests.

Plate 7: Two views of the growing *Ipomoea* suffering from a pest infestation.

Culturing of *Oreochromis niloticus* fingerlings

The *Oreochromis niloticus* were cultured in 1 metre cubed hapas with a stocking density of 12 fish per hapa. Four treatments were evaluated – the control which was given no feed (N), the commercial feed Raanan (R), fresh *Ipomoea* leaves (F) and dry whole plant *Ipomoea* (D). Each treatment was in triplicate with three hapas being used, thus 12 hapas were used for the experiment. The placements of the hapas in the two concrete tanks were randomized to cancel out any impacts on the treatments due to "positioning effect" and this is shown in the Figure 3 below.



Where:

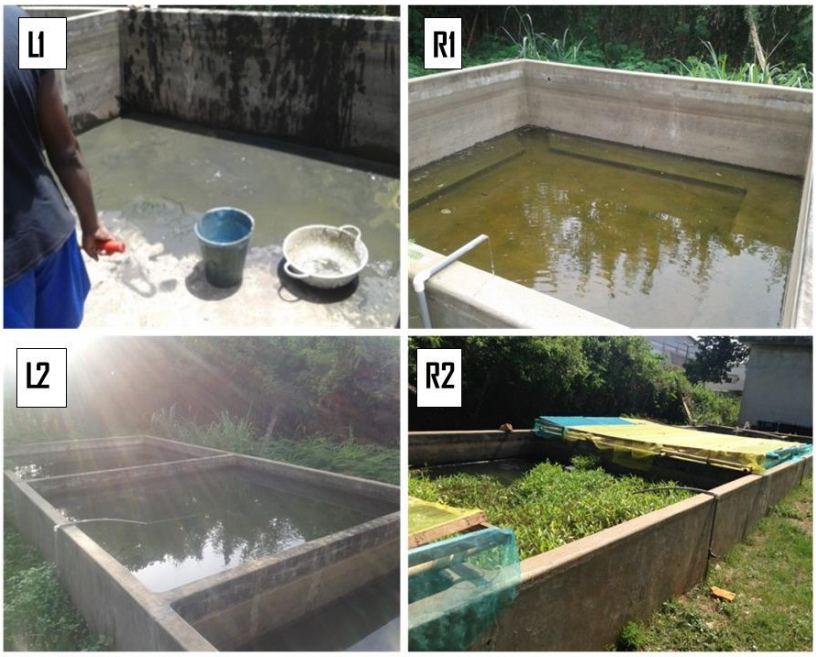
N – No Feed; F – Fresh *Ipomoea*; D – Dry *Ipomoea* and R – Raanan Feed

Figure 3: Arrangement of hapas in concrete tanks during experiment.

Two hundred fingerlings of *O. niloticus* of average mass 5 g and average length 6 cm were obtained from Ainoo-Ansah Farms, Okyereko near Winneba on 27th February, 2016 for the study and conditioned in one hapa till the start of the experiment. The study covered a period of six months from 4th April to 1st October, 2016.

Preparation of Concrete Tanks

Protective covers made of wood with mosquito netting were constructed by a carpenter to prevent silk cotton from the trees in the Botanical Garden of the University of Cape Coast and other "foreign materials" such as leaves from entering the pond.



Biochemical Composition (Proximate Analysis)

Proximate analysis of the two treatments of *Ipomoea aquatica* (fresh

Plate 8: L1 - Cleaning the tanks. R1 & L2 - filling them with water and L4 – the tanks after they had been covered with the protective covers – the *Ipomoea* is seen here growing in the middle tank.

leaves and dry whole plant), the Raanan Commercial feed and the fingerling and adult carcasses at the beginning and end of the experimental period were carried out at the School of Agriculture Laboratory at the Technology Village of the University of Cape Coast using the Association of Official Analytical Chemists - AOAC (1995) Procedure. The results of the statistical analysis carried out are presented in Appendix A.

Moisture Determination

Procedure

Porcelain crucibles were washed, dried and weighed. About 10 g of the fresh samples were put into the clean oven-dried crucibles and weighed. The crucibles containing the sample were spread over the base of the oven to ensure equal distribution of heat. They were then kept in a thermostatically controlled oven at 105°C for 48 hours. At the end of the period the samples were removed, cooled in a desiccator and weighed. Each sample was done three times.

The moisture content was then calculated as the percentage water loss by the sample.

Water Loss = Fresh Weight – Dry Weight

$$\text{Percentage Water Loss} = \frac{\text{Water Loss}}{\text{Fresh Weight}} \times 100$$

Protein Determination

Determination of Total Nitrogen (Micro-Kjedahl Method) by Distillation (Sulphuric Acid – Hydrogen Peroxide Digestion)

Procedure

The digestion mixture comprises 350 ml of hydrogen peroxide, 0.42g of selenium powder, 14g Lithium Sulphate and 420 ml sulphuric acid. The digestion procedure as outlined in FAO Laboratory Manual 2008 states that 0.2g of the oven-dried ground sample was weighed into a 100 ml Kjeldahl flask and 4.4ml of the digestion reagent was added and the samples digested at 360^{o}C for two hours.

Blank digestions (digestion of the digestion mixture without a sample) were carried out in the same way. After the digestion, the digests were transferred quantitatively into 50 ml volumetric flasks and made up to the volume.

A steam distillation apparatus was set up and steam passed through it for about 20 minutes. After flushing out the apparatus, a 100 ml conical flask containing 5ml of boric acid indicator solution was placed under the condenser of the distillation apparatus. An aliquot of the sample digest was transferred to the reaction chamber through the trap funnel. Exactly 10 ml of alkali mixture was added to commence distillation immediately and about 50 ml of the distillate were collected. The distillate was titrated against 1/140 molar (M) HCl from green to the initial colour of the indicator (wine red). Digestion blanks were treated the same way and subtracted from the sample titre value.

Calculations

$$N\ (\%) = \frac{(S - B) \times M \times 14.007 \times 100}{\text{Sample Weight(mg)}}$$

Where:

M = Molality of Acid

S = Sample titre value

B = Blank titre value

Then: Protein = %N *6.25

Crude Fat/Lipid (Ether Extract) Determination with Reagent (Petroleum Spirit)

Procedure

About 15g of the milled samples were weighed into a 50 ×10 mm soxhlet extraction thimble. This was transferred to a 50ml capacity soxhlet extractor. A clean dry 250 ml round bottom flask was weighed. About 150 ml Petroleum spirit was added and connected to the soxhlet extractor and extraction was done for 6 hours using a heating mantle as a source of heat. After the 6 hours the flask was removed and placed in an oven at 60°C for 2 hours. The round bottom flask was removed, cooled in a desiccator and weighed.

The percentage fat/oil was calculated as follows:

$$\text{Crude Fat}\ (\%) = \frac{W\ (g) \times 100}{\text{Sample (g)}}$$

Where W = Weight of Oil

Ash Determination

The dried samples were heated gently in an oven at 105°C for about an hour and then transferred to a furnace at a temperature of 550°C overnight. The heating continued until all the carbon particles were burnt away. The ash in the dish was removed from the furnace, cooled in a desiccator and weighed. The ash content was then calculated as a percentage of the original sample.

Crude Fibre Determination

Reagents – Preparation of Stock Solutions

a) Exactly 25% Sodium hydroxide solution: Exactly 12.5 g NaOH were dissolved in 700 ml distilled water in a 1000 ml volumetric flask and diluted to volume.

b) Twenty-five percent Sulphuric acid solution: Exactly 12.5 g conc. Sulphuric acid were added to a volumetric flask containing 400 ml distilled water and diluted to volume.

Procedure

About 0.50 g of the sample was weighed and placed in a boiling flask. Hundred ml of 1.25% sulphuric acid solution was added and boiled for 30 mins. After the boiling, filtration was done in a numbered sintered glass crucible. The residue was transferred back into the boiling flask and 100 ml of the 1.25% sodium hydroxide solution were added and boiled for 30 minutes. Filtration continued after the boiling and the residue was washed with boiling water and methanol.

The crucible was dried in an oven at 105°C overnight, weighed and then placed in a furnace at 500°C for about 3 hours. The crucible was then finally slowly cooled to room temperature in a desiccator and weighed.

Calculation

$$\% \text{ Crude fibre} = \frac{\text{Weight loss through ashing x } 100}{\text{Sample weight}}$$

Nitrogen Free Extract (NFE)

Consists of carbohydrates, sugars, starches, and a major portion of the hemicellulose in feeds.

% NFE= %DM - (%EE + %CP + %CF + %Ash)

Where: DM - Dry Matter; EE- Ether Extract; CP- Crude Protein & CF- Crude Fibre.

Carbohydrate Determination

Reagent

Glucose Solution

Stock solution: (1 ml is equivalent to 0.25 mg glucose). Exactly 0.250 g D-glucose (dried in a vacuum oven at 70°C over P_2O_5) was dissolved in water and diluted to 1 litre. Working standards: a range from 0 – 20 ml stock solution was pipetted into 50 ml flasks such that 2 ml of each standard gave a range from 0 - 0.20 mg glucose and was diluted to volume.

Anthrone Reagent

Exactly 760 ml concentrated H_2SO_4 was added carefully to 330 ml of water in a boiling flask and kept cool while mixing. One gram of anthrone and 1 g of thiourea were added and dissolved using a magnetic stirrer. The solution was transferred to a dark bottle and left for 2 hours before use. It was stored at 1°C.

Procedure

Extraction

Exactly 50 mg of the milled sample was weighed into a 50 ml conical flask. Thirty ml of distilled water was added and a glass bubble placed in neck to simmer gently on a hot plate for 2 hours. It was topped up to 30 ml periodically and allowed to cool slightly, then filtered through a No.44 Whatman paper into a 50 ml volumetric flask and diluted to volume when cool. The extract was prepared shortly before colour development. A blank was prepared by taking it through the same procedure.

Colour Development

Two ml of each standard were pipetted into a set of boiling tubes and 2 ml of the extract and water blank were also pipetted into boiling tubes. Standards and samples were treated the same way. About 10 ml of anthrone solution were added rapidly to mix and the tubes immersed in running tap water or ice bath. The tubes were placed in a beaker of boiling water in a dark fume cupboard and boiled for 10 minutes. The tubes were then placed in cold water and allowed to cool, preferably in the dark. The optical density was measured at 625 nm or with a red filter using water as a reference. A calibration graph was prepared from the standards and used to obtain mg

glucose in the sample aliquot. The blank determination was treated the same way and subtraction done where necessary.

$$\text{Soluble carbohydrates (\%)} = \frac{\text{C (mg)} \times \text{extract volume (ml)}}{10 \times \text{aliquot (ml)} \times \text{sample wt (g)}}$$

Where C = carbohydrate concentration from the calibration graph

Feeding and Feeding Rate.

The fish were fed three times a day: i.e. Between 0800hGMT – 0900hGMT ; 1200hGMT – 1300hGMT and 1600hGMT – 1700hGMT during the experimental period. The Raanan and Whole Plant Dry *Ipomoea* were weighed into plastic containers for the feeding while the Fresh *Ipomoea* leaves were harvested from the middle tank where they were being maintained through aquaponics and weighed before feeding (as shown in Plate 9).

Plate 9: Harvesting and weighing fresh *Ipomoea* leaves.

Feeding Rate Table and Determination

The feeding ration used by Tropo Farms (Table 1) - which is the largest fish farm involved in cage culture on the Volta Lake (obtained from a friend who had worked there) was adopted. The fish were thus given a daily ration depending on their average mass during the bi-weekly sampling.

Table 1**:** *Sample feed sheet for fish from fingerling stage to market size using an estimated 6 month cycle after Tropo Farms.*

State of Development	Unit (g) of fish Weight range	Ration
Fingerling	3-10	10%
Fingerling	10-30	8%
Fingerling	30-80	6%
Adult	80-140	4%
Adult	140-200	4%
Adult	200-350	3%

Bi-weekly Sampling

All the fish in each treatment hapa were sampled on a bi-weekly basis and the weight determined to the nearest 0.01 g using a Scout Pro (SPU) 402 electronic balance to measure the Body Weight (BW) of the fish. The standard and total length (SL and TL) were also taken to the nearest 0.1cm using a measuring board.

To avoid stressing the fish during the sampling the anaesthetic Tricaine Methane-sulphonate (otherwise known as MS-222) was used after Trushenski *et al*. (2013). About 0.62 g of MS-222 powder was dissolved in about 3 litres of tapwater in a bowl and the fish from each hapa scooped with a plastic scoop and anaesthesized. After a few minutes in the MS-222-treated water, the fish specimens stopped struggling and the weight and lengths were then

determined. Two bowls were used, one with water containing the MS-222 and the other with fresh water in which the fish were placed immediately after weighing and measuring so they could recover from the anaesthetic. After all the fish from a hapa had been measured and weighed, the fish were returned to their hapa and the same procedure carried out for the other hapas.

Plate 10: Two fish from the Raanan treatment sedated at the end of the experiment.

Fish Growth Indicators

Absolute Growth Rate (AGR)

The Absolute Growth Rate is defined as the increment of weight over a known time interval (Hopkins, 1992). That is:

$$AGR = \frac{W2 - W1}{T2 - T1}$$

Where: AGR is the Absolute Growth Rate, W2 and W1 are final and initial weights respectively and T2 and T1 are final and initial time in days, respectively.

The Absolute Growth Rate was again estimated using a regression analysis (Semi-log analysis). Here, the natural logarithms of the calculated mean weight in grams was plotted against number of weeks of culture. Therefore, the antilog of the gradient of the regression equation was recorded as the Absolute Growth Rate of the experimental fish.

Specific Growth Rate (SGR)

Wootton (1998) defined Specific Growth Rate (SGR) as:

$$SGR = \frac{\ln W2 - \ln W1}{(T2 - T1)} \times 100$$

Where: W2 and W1 are final and initial weights respectively and T2 and T1 are the final and initial times respectively.

Condition Factor

The condition factor (K) is used to compare the state of well-being or fatness of fish. Fulton's condition factor (Bagenal, 1978) is given by:

$$K = \frac{W}{L^3} \times 100$$

Where: W is the final weight in grams and L is the final length in centimetres.

Survival Rate

This is a ratio of the total number of surviving fishes to the total number of fishes stocked from the beginning of the experiment expressed in percentage after Obirikorang *et al*. (2015).

That is:

$$SR = \frac{N2}{N1} \times 100$$ (Obirikorang *et al*., 2015)

Where: SR is the Survival Rate, N1 is the total number of stocked fish and N2 is the total number of fish surviving.

Analyses

The Absolute Growth Rate, Specific Growth Rate, Growth Efficiency and Condition Factor of the fish were used to monitor fish growth. One-way Analysis of variance (ANOVA) was used to determine whether there were any significant differences in the means calculated for the above growth indicators at P = 0.05 using the Minitab 17 Statistical Package.

Thus, the change in body weight was considered as a function of growth. The individual weights and total and standard lengths (TL for Total Length and SL for Standard Length) of fish sampled from each hapa were recorded. The mean weights and mean lengths were then determined by Minitab 17 with their respective Standard Errors (SE) and other Descriptive Statistics such as Standard Deviation (StDev) and Maximum and Minimum Values.

CHAPTER FOUR

RESULTS

Introduction

The results include proximate analysis of the diet types used for the experiment, growth and survival of fingerlings of *O. niloticus* fed on the three diet types, that is, Raanan Commercial Feed (Raanan), Dry Whole *Ipomoea* (Dry), Fresh Leaf *Ipomoea* (Fresh) and the No Feed/ Control for the experimental period of 28 weeks (195 days). Carcass analysis of the juveniles of *O. niloticus* at the start of the study and the adults after the end of the research period was also carried out.

Proximate Analysis of Diets

Figure 4 shows the results of proximate analysis of the three diet types (i.e. Raanan, Dry and Fresh) and control used for the feeding experiment. The results indicate that in terms of moisture content; the whole sun-dried powdered *Ipomoea aquatica* (Dry) had a higher value (13.897 ± 0.050) than Raanan (9.208 ± 0.022). Ash content of Raanan (8.004 ± 0.065) was significantly lower than that of Dry (13.569 ± 0.096). With regard to protein, Raanan had a significantly higher protein content (28.801 ± 0.292) than Dry (20.095 ± 0.07). Raanan also had richer lipids (3.437± 0.183) compared to Dry which was 0.832 ± 0.481.

[1] Carbohydrate (CHO) was determined for the Fresh while Nitrogen Free Extract (NFE) was determined for the Dry and Ranaan, thus the values obtained cannot be compared.

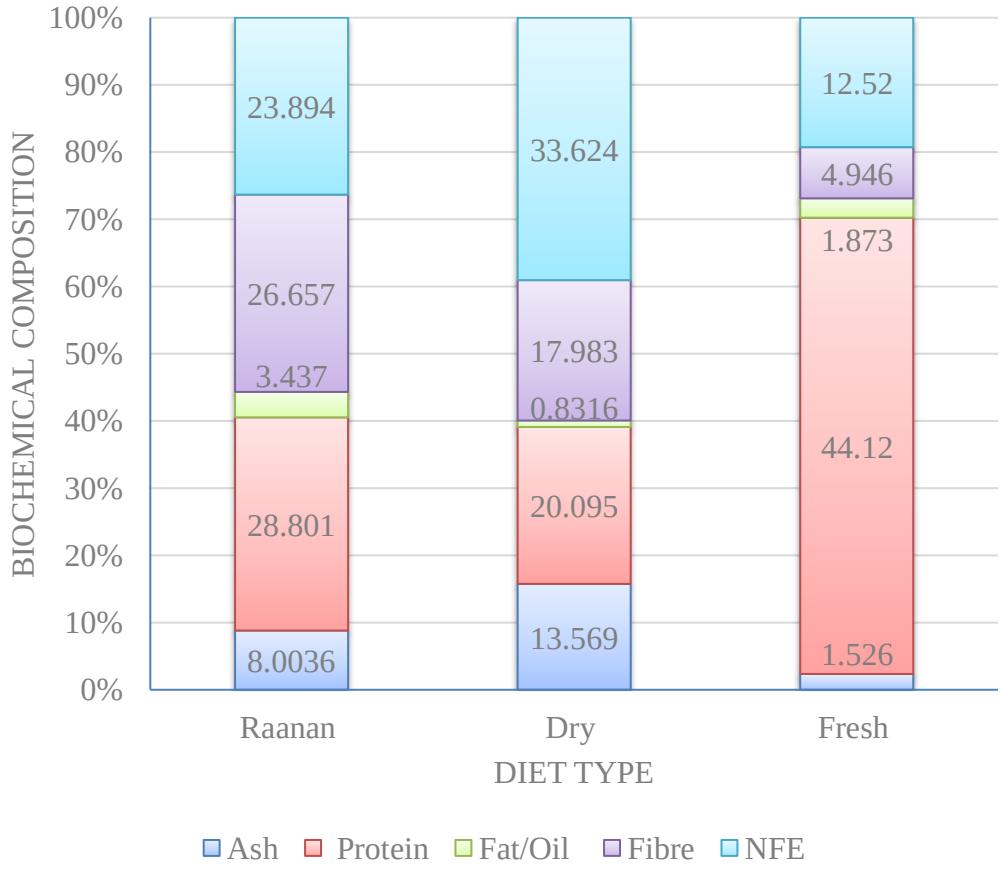


Figure 4: Proximate analysis of Raanan, Dry and Fresh *Ipomoea* utilized in the feed experiment.

Growth Parameters

Figure 5 shows the Specific Growth Rate (SGR) of the fish fed on the various diet types. SGR differed significantly in all the feed treatments. Fish fed on Raanan had a significantly higher ($p < 0.05$) SGR of 1.617 ± 0.035

[1] CHO determination on page 34

followed by the No Feed treatment (0.466 ± 0.076). Fish fed on dry *Ipomoea aquatica* had the significantly lowest ($p < 0.05$) SGR of 0.157 ± 0.014.

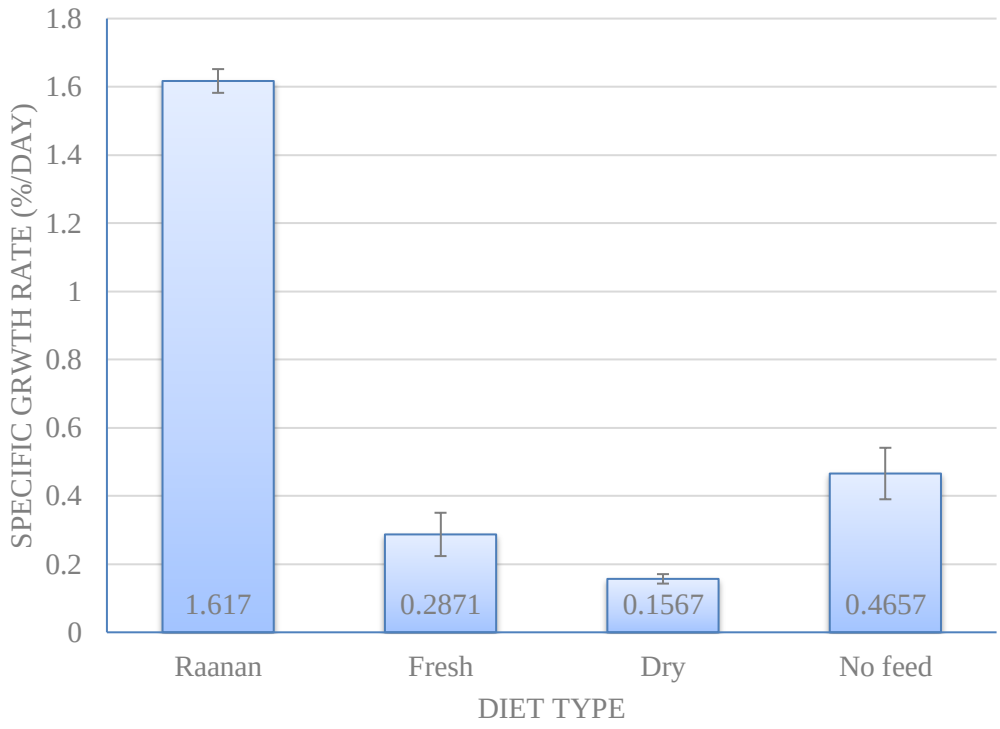


Figure 5: Specific Growth Rate (SGR) for fingerlings of *O. niloticus* fed for 28 weeks (vertical bars represent standard errors)

Figure 6 illustrates the Absolute Growth Rate (AGR) of the various diet treatments. The AGR followed the same pattern as SGR, whereby fish fed on Raanan had a significantly higher ($p < 0.05$) AGR (0.570 ± 0.002) followed by the No Feed treatment (0.024 ± 0.011) and then the Dry *Ipomoea* (0.024 ± 0.014). Fish fed on Fresh *Ipomoea* had the lowest AGR (0.021 ± 0.005). The differences between the Fresh, Dry and No Feed AGRs were not significant.

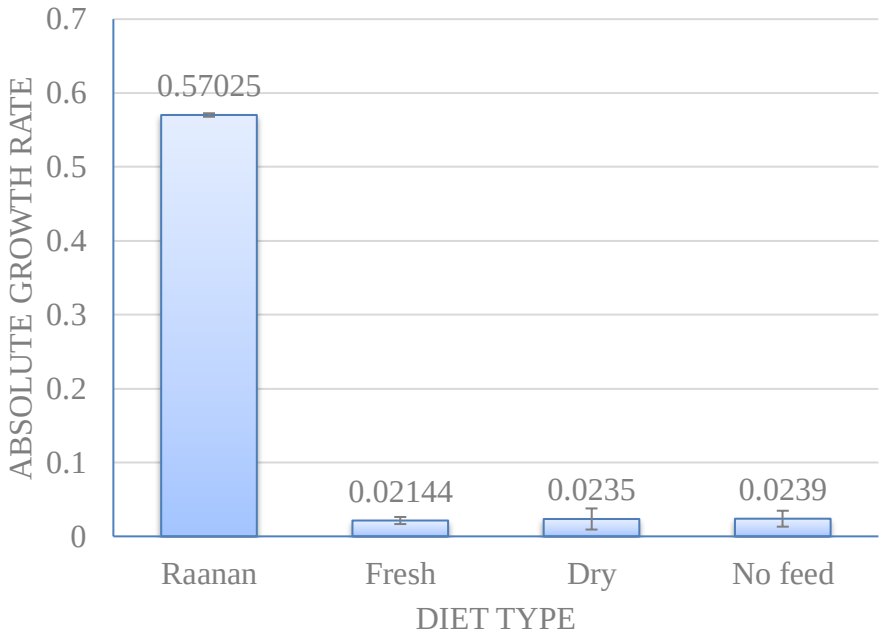


Figure 6: Absolute Growth Rate (AGR) for fingerlings of *O. niloticus* fed on the various diets for 28 weeks (vertical bars represent standard errors)

Figure 7 illustrates the Percentage Weight Gain (PWG) for *O. niloticus* fed on the various diet treatments. The analysis, once again, showed that Raanan-fed fish had significantly ($p < 0.05$) overwhelming percentage weight gain of 2252% ± 164. Ironically, the No Feed treatment managed the second highest weight gain of 150.6% ± 36.7. Here again, fish fed on fresh *Ipomoea aquatica* recorded the lowest weight gain of 77.9% ± 23.1 which was not significantly different from that of the No Feed treatment and Dry *Ipomoea aquatica* (109.8% ± 70.4).

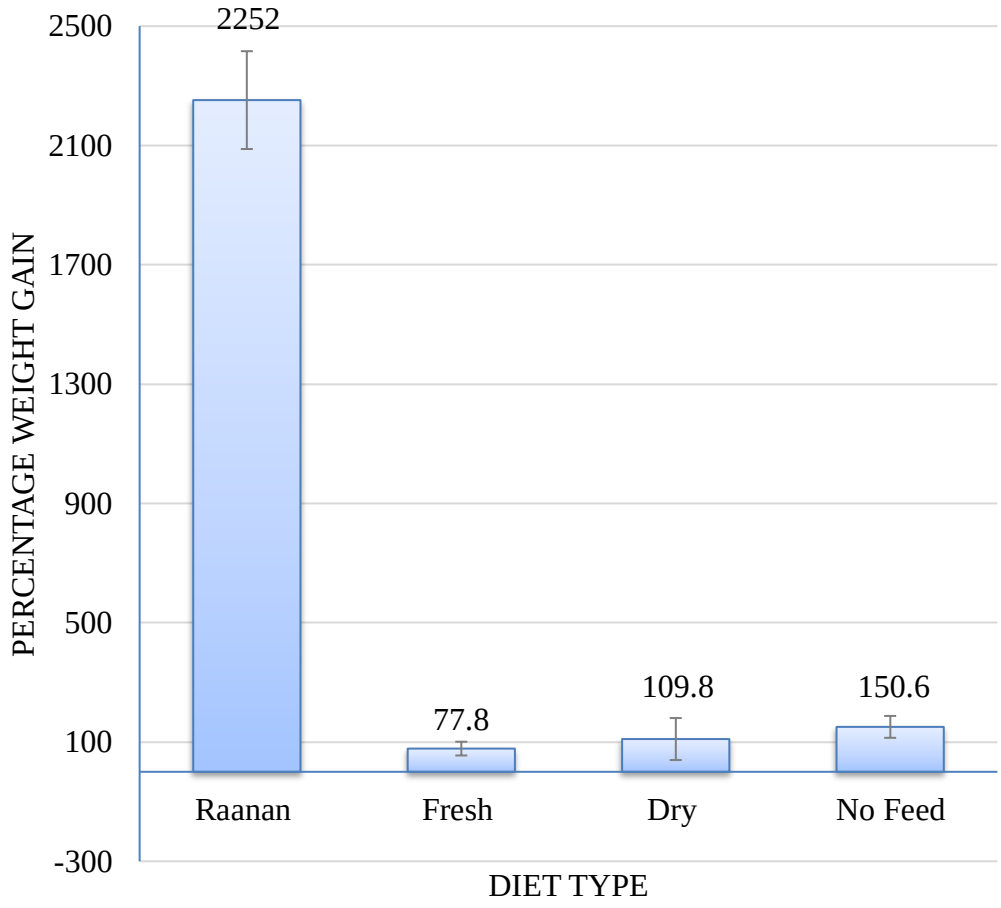


Figure 7: Percentage Weight Gain (PWG) for *O. niloticus* fed on the various diet types

Growth Curves

Figure 8 illustrates the bi-weekly weight gain of *O. niloticus* fed on the various feed treatments for the 28 weeks period. At the start of the experiment, all treatment means were not significantly different (they were all approximately 5 grams). Generally, the weight gain in fish fed on Raanan was significantly different on the biweekly basis except on week 14, 16, 18 and then on week 20 and 22 indicating a progressive increase in weight over the experimental period. Also, the biweekly weight gains for fish fed on Raanan were visibly and significantly higher than those of the other feed treatments.

The growth curves of the other treatments seemed jammed together in Figure 8 and it was difficult seeing any differences, therefore, the data for the other three (3) feed treatments were plotted differently on a magnified axis as shown in Figure 9. Here again, generally, there were no significant differences among the weight gains over the 28 weeks' period. However, a careful analysis of the data showed that at the early stages of the experiment i.e. from week 4 up to week 10, the weight gains in fish with no feed were significantly smaller than all the other treatments.

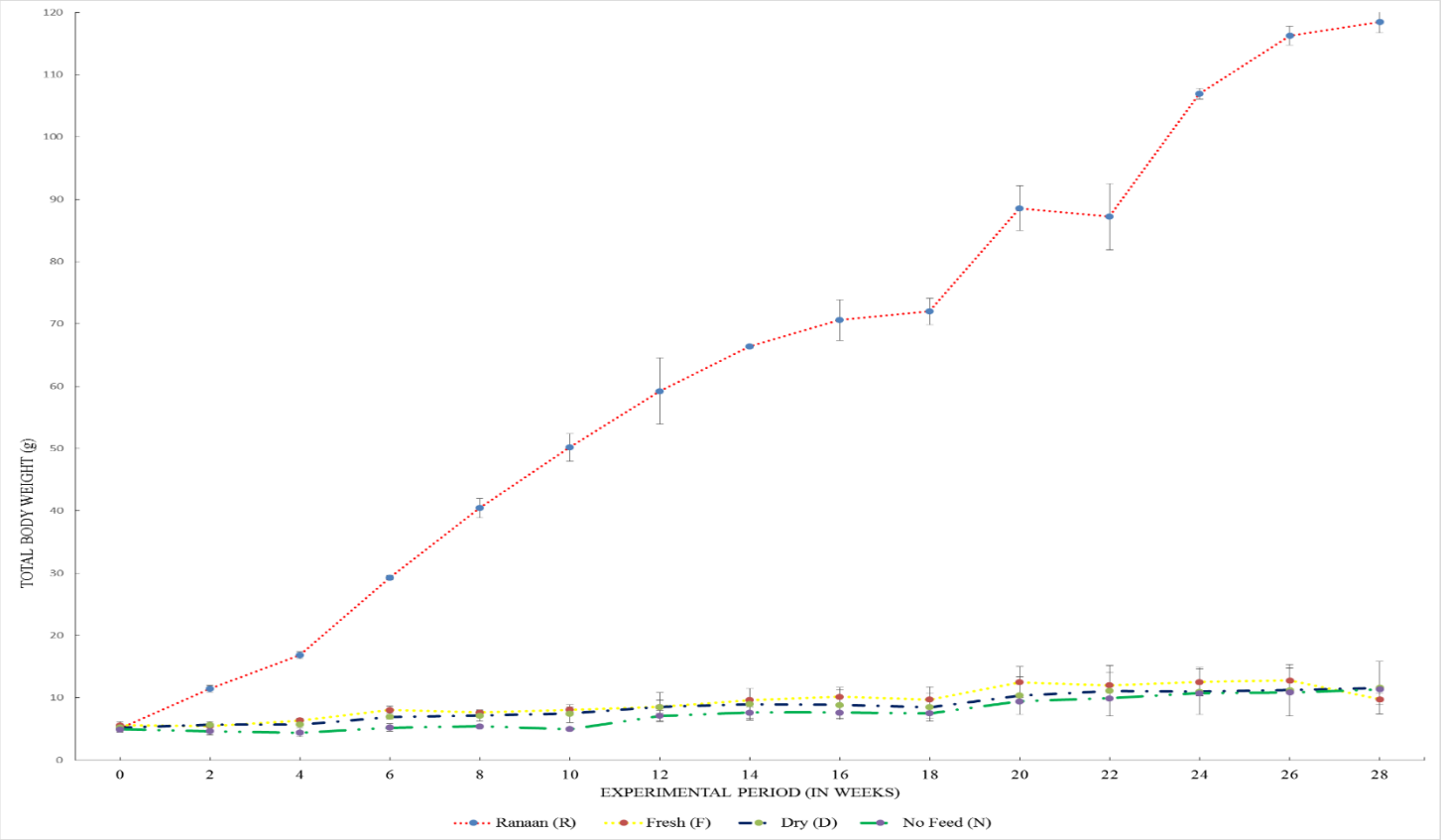


Figure 8: Growth curves (all) for fingerlings of *O. niloticus* fed for 28 weeks (vertical bars represent standard errors)

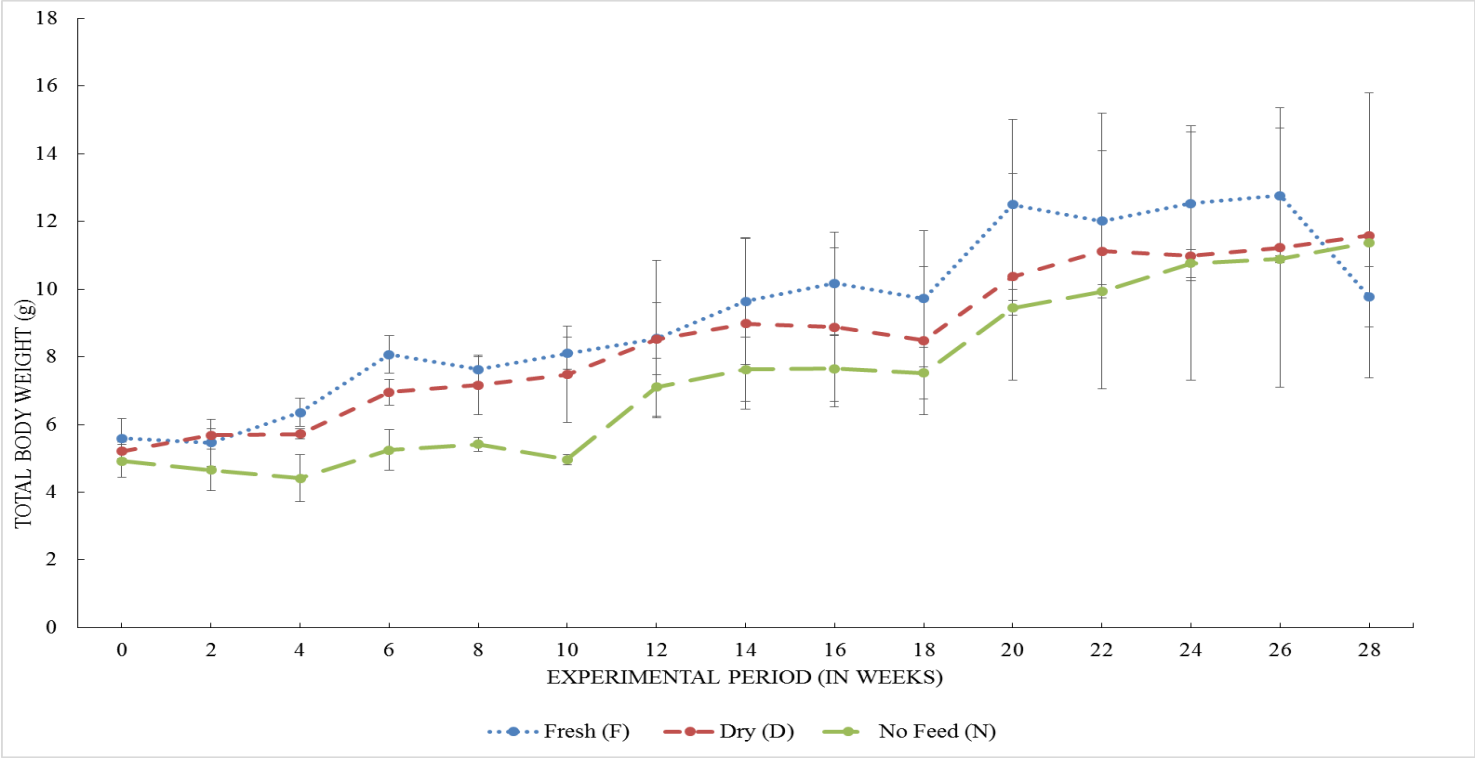


Figure 9: Growth curves (F, D and N) for fingerlings of *O. niloticus* fed for 28 weeks (vertical bars represent standard errors)

Survival

Figure 20 illustrates bi-weekly instantaneous survival rates over the experimental period. From the graph, fish fed on Dry *Ipomoea* recorded an impressive 100% survival rate from the start of the experiment (week 2) to week 16 before it declined to 94.45% and then again steadily declined to 88.89% from the 24th to the 28th week of the experiment. Fish fed on Raanan recorded 100% survival for the first 6 weeks of the experiment before declining to 91.67% in weeks 8 and 10 then again to 88.89% in weeks 12 and 14. Survival was then constantly at 83.33% till the end of the experiment. The fish fed with fresh *Ipomoea* recorded 97.22% survival rate on the 4th and 6th weeks before declining to 94.4% in the 8th week and then 91.67% on the 10th week. Survival rate continued to decline to the lowest value of 72% at the end of the experimental period. The fish which were not fed recorded 100% survival up till the 4th week of the experiment before declining to 97.22% in the sixth week. A constant survival rate of 95.84% was recorded from the 8th week through to the 18th week and then declined to 94.44% in the 20th week. Subsequently, the value declined to 91.67% in the 22nd to 26th week before finally reaching 88.89% in the 28th week.

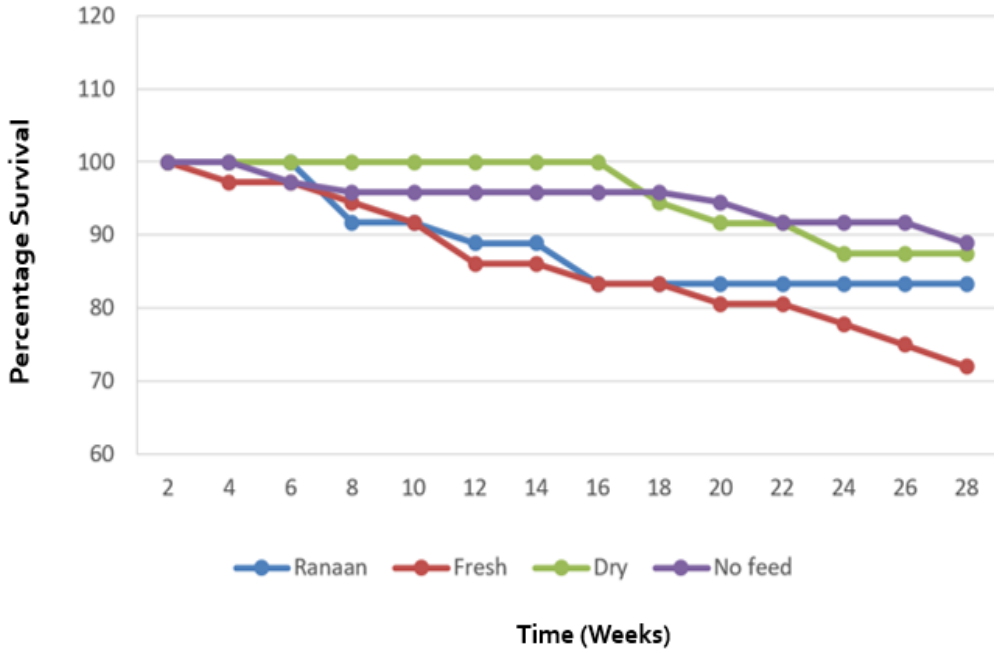


Figure 10: Instantaneous Survival Rate of *O. niloticus* fed on the various diet types over the 28-week experimental period

Figure 11 shows the terminal survival rate of *O. niloticus* fed on different feed treatments. Generally, the survival rate at the end of the 28 weeks experimental period was not significantly different among the various feed treatments. Nonetheless, fish fed on dry *Ipomoea aquatica* recorded the highest survival rates of 88.89 ± 7.35%, closely followed by the Raanan and No Feed treatments each of which recorded 83.33 ± 4.81% survival rate. Fresh *Ipomoea aquatica* recorded the lowest survival of 69.44 ± 10%.

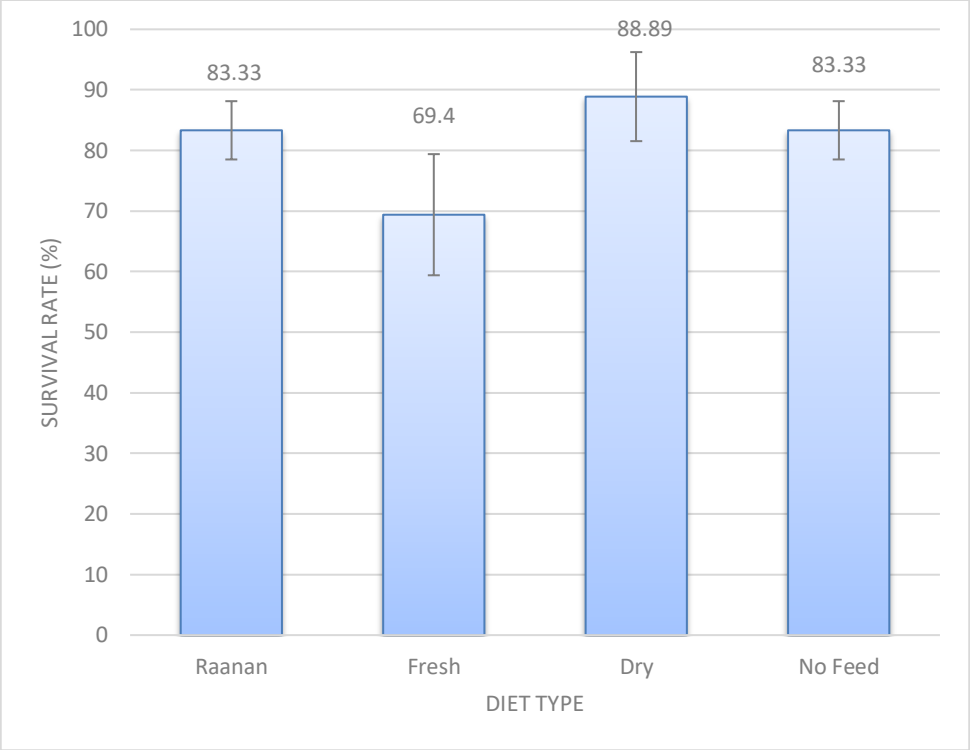


Figure 11: Terminal Survival Rate of the various diet types over the 28 week experimental period

Condition Factor

Condition factor (CF) of *O. niloticus* fed on the different feed treatments are shown in Figure 12. Fish fed on Raanan had a significantly higher condition index ($p < 0.05$) CF of 1.601±0.0200, followed by the fish fed on Fresh *Ipomoea aquatica* which had a CF of 1.4977±0.0197. Fish subjected to the No Feed treatment recorded the lowest CF of 1.4645±0.0292 although this was not significantly different from fish fed on Fresh and Dry *Ipomoea aquatica.*

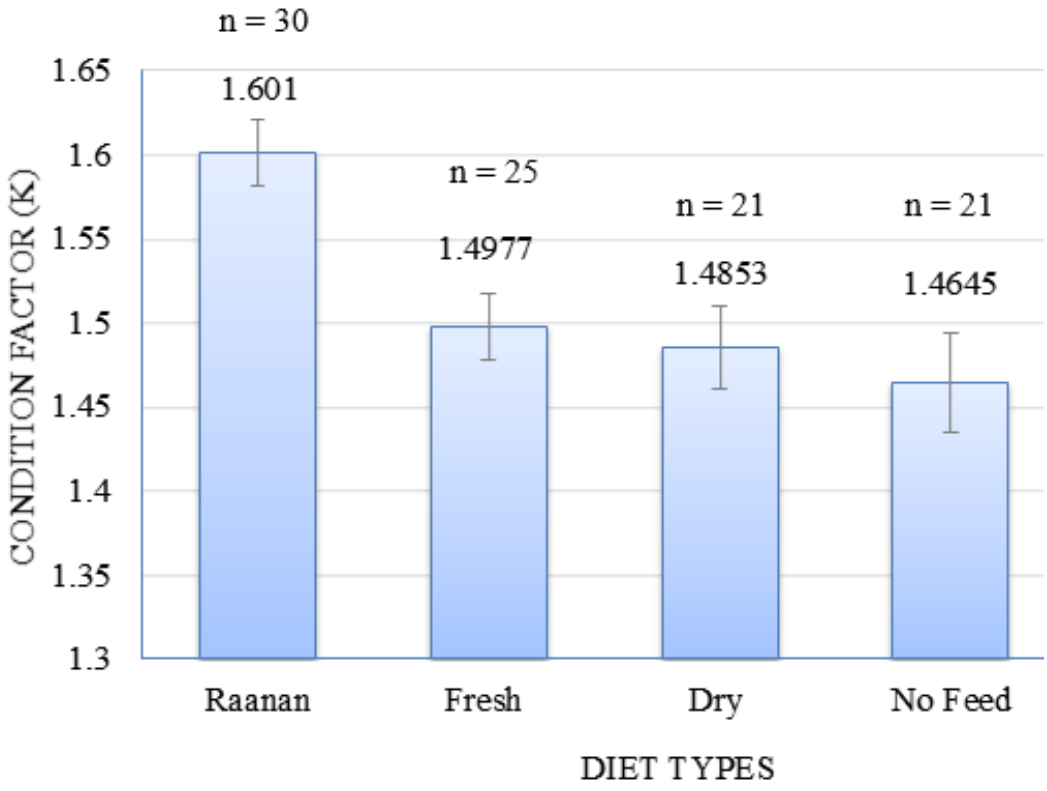


Figure 12: Condition Factor (K) of *O. niloticus* fed on the various diet types for 28 weeks

Length Weight Relationship

Length-Weight relationship of *O. niloticus* fed on Raanan for 28 weeks is shown in Figure 13. There was a significant strong positive relationship (R^2= 0.975, $p < 0.05$) between the length and the body weight of the fish. The slope value (b = 3.124) which is not significantly different ($p > 0.05$, t = 1.319) from the theoretical value of 3 indicating that length and body weight of the fish were growing at equal proportions (isometric growth).

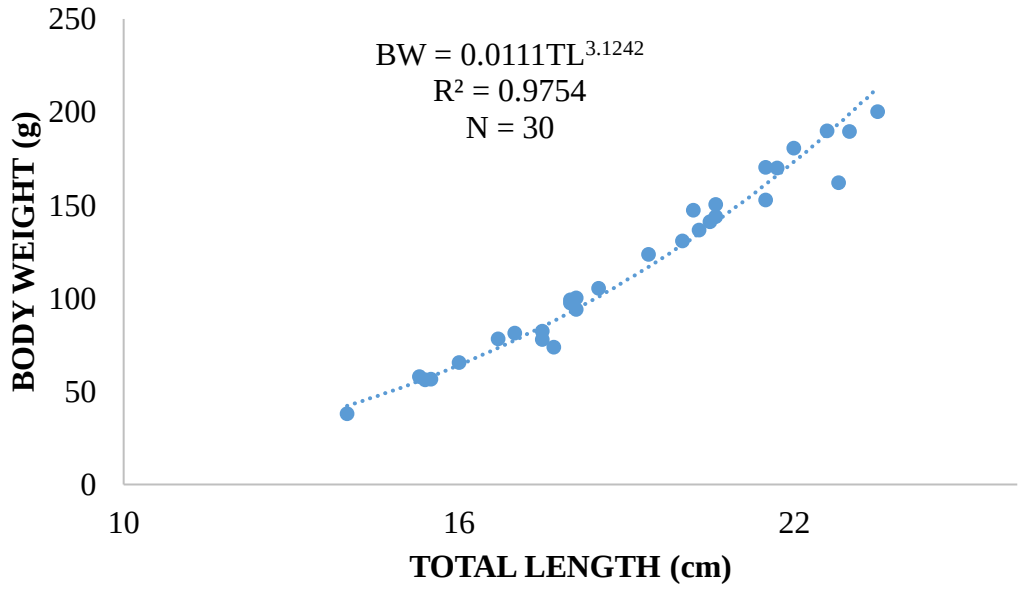


Figure 13: Length-Weight Relationship (LWR) of *O. niloticus* fed on Raanan Feed

Figure 14 shows the Length-Weight Relationship of *O. niloticus* fed on Fresh *Ipomoea aquatica*. Here again, the coefficient of determination (R^2) of the regression analysis indicated a strong relationship ($R^2 = 0.974$, $p < 0.05$) between the total length and the body weight of the fish. The slope ($b = 3.040$) which is not significantly different ($p < 0.05$, $t = 0.388$) from 3 showed that the total length and the body weight of the fish were growing at the same rate thus they were growing isometrically.

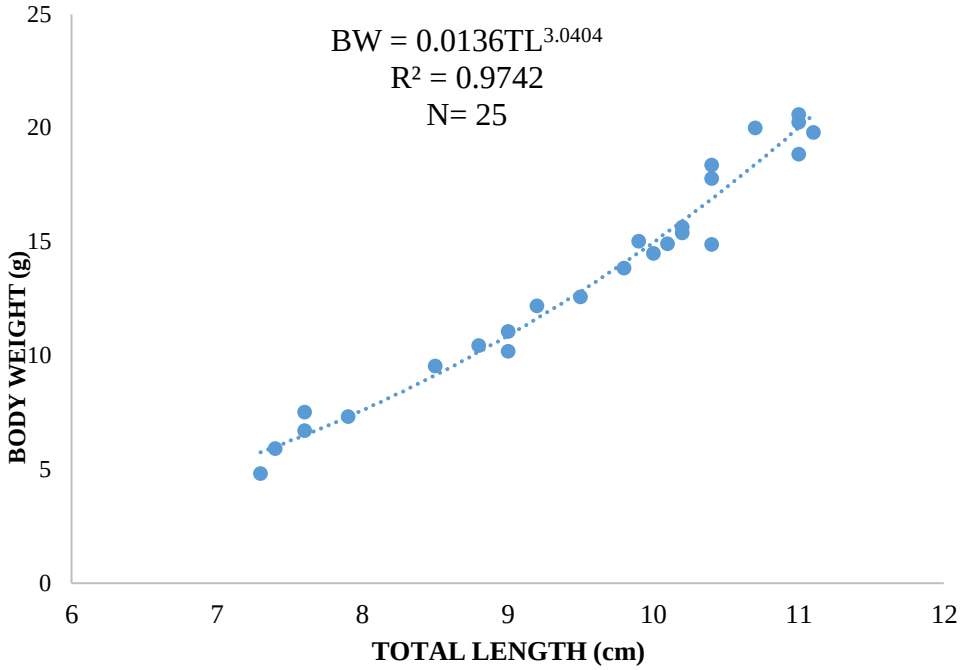


Figure 14: Length-Weight Relationship (LWR) of *O. niloticus* on Fresh *Ipomoea aquatica*

Length-Weight Relationship of *O. niloticus* fed on Dry *Ipomoea aquatica* for the 28-week period is shown in Figure 15. There is a strong relationship (R^2= 0.972, $p < 0.05$) between the length and the body weight of the fish as depicted by the high R^2 value. The b value (3.072) which was not significantly different (t = 0.336) indicated an isometric growth.

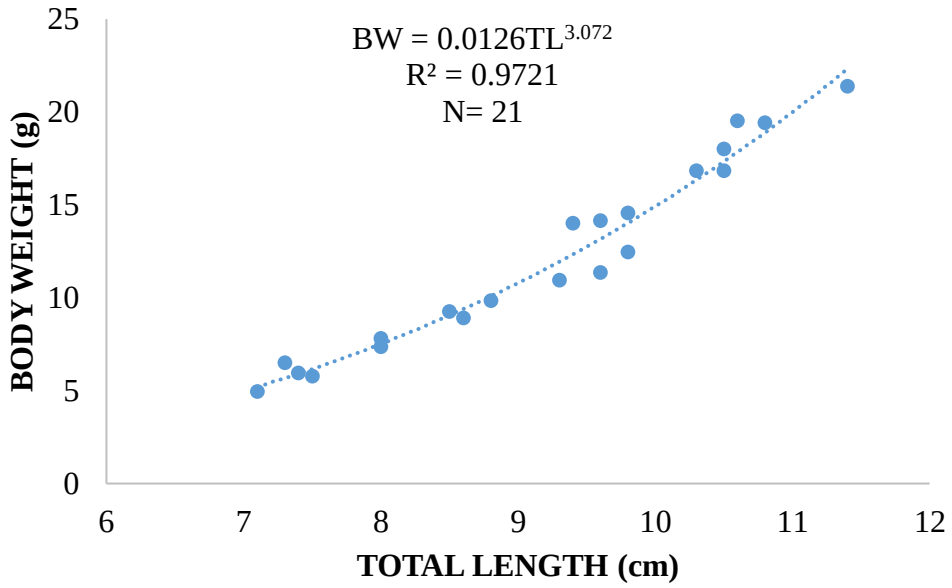


Figure 15: Length-Weight Relationship (LWR) of *O. niloticus* fed on Dry *Ipomoea aquatica*

Length-Weight relationship of *O. niloticus* for the treatment No Feed for the 28-week experimental period is shown in Figure 16. There was a significantly strong positive relationship (R^2= 0.8757, $p < 0.05$) between the length and the body weight of the fish. The slope value (b = 3.042) which is not significantly different ($p< 0.05$, t = 0.160) from the theoretical value of 3 indicated that length and body weight of the fish were growing at equal proportions, thus isometrically.

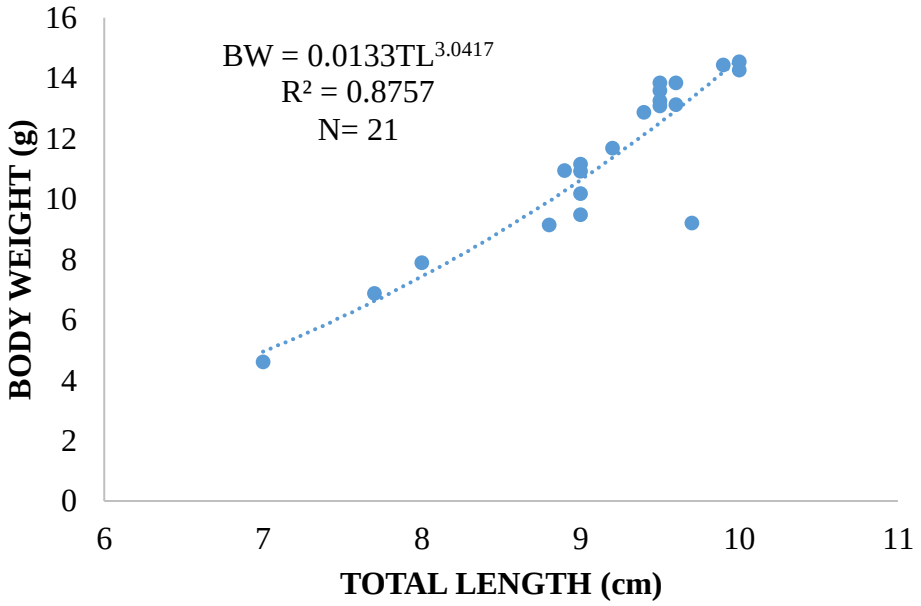


Figure 16: Length-Weight Relationship (LWR) of *O. niloticus* which received No Feed.

Carcass Analysis

Figure 17 shows the carcass analysis of the conditioned fingerlings before the commencement of the feeding trial.

NB: Fibre value so small (0.039) it does not reflect in the graph even though it is in the legend. Thus, the value of 5.233 is for the ash content.

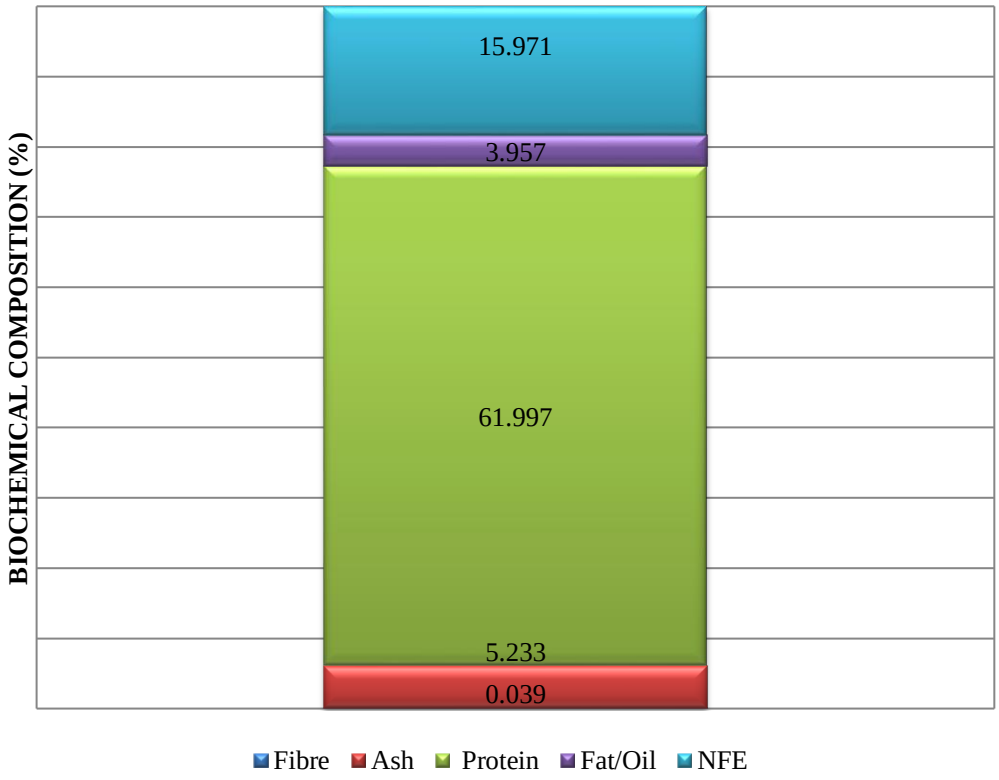


Figure 17: Carcass analysis of fingerlings of *O. niloticus* before the start of the experiment

Figure 18 shows the carcass analysis of fish fed on the various diet types after the experiment. The analysis reveals that protein levels were not significantly different in all the feed treatments except in the fresh *Ipomoea aquatica* that had a significantly lower ($p < 0.05$) protein (66.731 ± 0.171). The

lipid content was significantly lower ($p < 0.05$) in fish fed on fresh (3.717 ± 0.079) and dry *Ipomoea aquatica* (4.689 ± 0.067) and those with No Feed (5.995 ± 0.014) than those fed on Raanan (7.722 ± 0.124). Like the dry matter content, the moisture content of the fish fed on the various diet types was not significantly different. Ash content on the other hand, was significantly lower ($p < 0.05$) in fish fed on Raanan (3.208 ± 0.101) than of the other feed treatments.

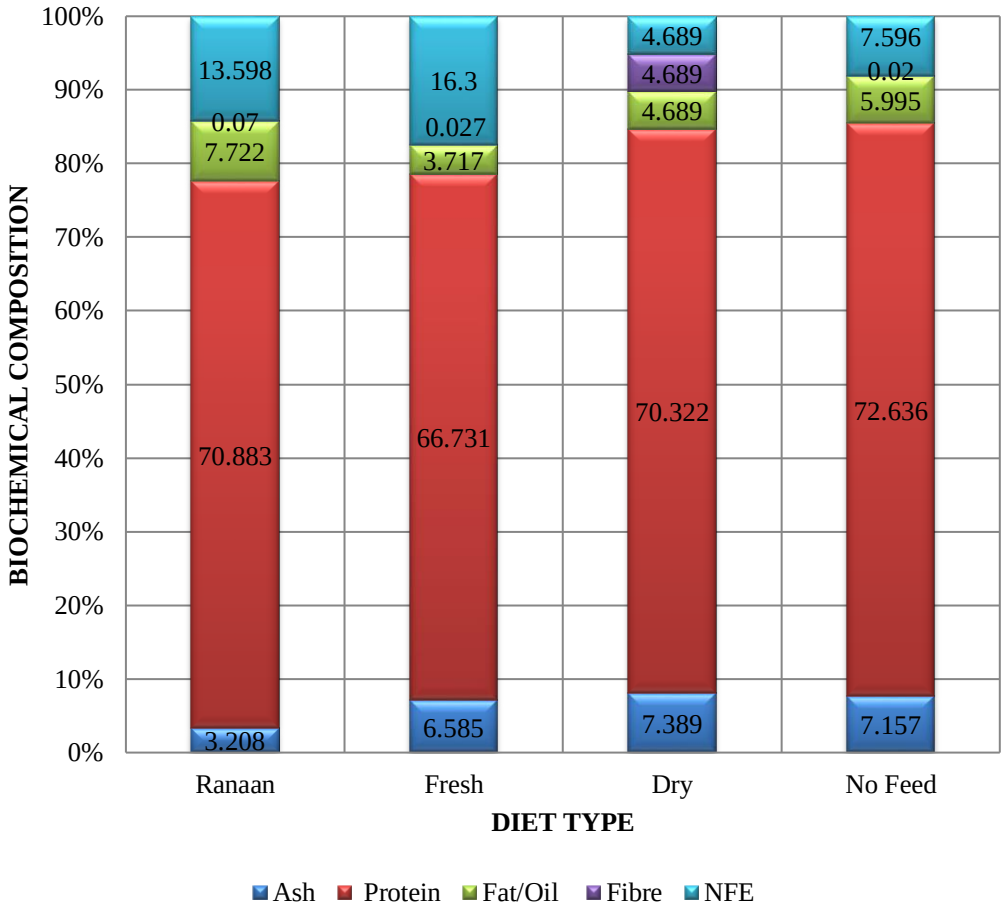


Figure 18: Carcass analysis of fish fed on the various diet types, after experiment

Conclusion

Thus, based on the findings of the study I fail to reject the null hypothesis.

CHAPTER FIVE

DISCUSSION

Introduction

This chapter deals with the interpretation of the findings in this study with reference to relevant literature and previous findings from similar work on related species.

Proximate Analysis

The results from the proximate analysis (Figure 4) showed the nutritional differences of the Raanan, Dry and Fresh diet types used for the experiment. Fresh had the highest moisture content (87.76%) which was to be expected considering the fact that it is an aquatic or semi-aquatic plant found either floating on water or growing on moist soils (Anonymous, 1959 cited by Prasad *et al.*,2008; Hasan & Chakrabati, 2009; Etse, 2015). The high protein content of Fresh Leaf *Ipomoea* (FLI) (44%) which was approximately double of what has been found in other works (Banerjee & Matai, 1990; Prasad *et al.*, 2008; Hasan & Chakrabati, 2009; Abarike *et al*., 2013; Etse, 2015; Ganzon-Naret, 2015) could be interpreted with caution as it is known that protein content of fresh leaf which was used in this case, is usually higher than that of the whole plant (Banerjee & Matai, 1990; Ganzon-Naret, 2015). The high lipid content of Raanan could be due to the fact that feed formulators make sure the lipid content of tilapia feeds is high (Anani, 2015) so as to ensure faster growth. The higher carbohydrate content of the Dry (34%) does not seem to have had the necessary protein sparing effect that is said to improve growth (Stone, 2003). Fibre in a diet contains indigestible plant

matter and other complex carbohydrates and should not exceed 8 – 12% of the diet as that would lead to a decrease in the available nutrients in the diet (Agbo, 2008 cited in Abarike, 2011). The Fresh diet type had a lower fibre content than the Dry diet and thus experienced slightly better growth even though this was not statistically significant. The higher performance of the fish fed with the Raanan which has a higher crude fibre content (26.66%) contradicts the results of Falaye and Jauncey (1999) - cited in Abarike (2011) - who attributed the lower growths of *Oreochromis niloticus* to the high crude fibre content of the feed given them.

Growth Performance

Growth performance was assessed by the following indicators; Absolute growth rate (AGR), Specific growth rate (SGR), Percentage weight gain (PWG), Condition factor (CF) and Length Weight Relationship (LWR). Anani (2015) cited the works of Gjedrem (1997) and Noor *et al*. (2010) as being sources of information to the effect that the growth performance and feed utilization efficiency of juvenile *O. niloticus* are affected by food quantity and quality, genetic make-up, sex of the fish and their interaction. Anani then went on to state that in his research, the body weights and body lengths of the experimental fish recorded at the commencement of the experiment were similar and were not significantly different ($p > 0.05$) and thus the performance differences observed among treatments at the end of the growth trial was due mainly to dietary effect. This was confirmed from this study.

The Percentage Weight Gain values obtained during this study (Figure 7) were generally lower than those recorded by Abarike (2011) when he fed

fingerlings of *O. niloticus* with diets formulated with the agro-industrial by-products Wheat Bran, Pito Mash, Rice Bran and Groundnut Bran, with the Wheat Bran diet having the most significant PWG of 593.07%. The notable exception to the trend of low Percentage Weight Gains (77.8% to 150.6%) observed in this study was the Raanan- fed *O. niloticus* which had a significantly higher PWG of 2252%.

The significant differences among the SGRs of all the treatments were a reflection of the effects of the treatments on the *O. niloticus* fingerlings with the values decreasing from Raanan (1.62) to No Feed (0.47) to Fresh Ipomoea (0.29) with the lowest being Dry *Ipomoea* (0.16). Anani (2015) reported an SGR value of 1.63 for his fingerlings fed on Raanan which was very close to the 1.62 obtained for the Raanan diet type in this study. The fishmeal based Diet 1 of Abarike *et al.* (2013) recorded an SGR of 1.49.

Tanduyan and Bontia (2001) tested *Ipomoea aquatica* as feed for *O. niloticus* in Lake Danao, Cebu in the Philippines. Though they did not calculate parameters such as AGR and SGR, their results portray the same picture that emerges from the current study, which is that unprocessed *Ipomoea* does not promote much growth in *Oreochromis niloticus*. Over their 120-day experimental period, the chicken commercial feed treatment gained 98.7 g, the *Ipomoea* feed treatment 65.2 g and the No Feed 41.3 g. Thus, as was seen in the current study, the *O. niloticus* most likely obtained some nourishment from the phytoplankton in the natural environment. The result of the current study followed a similar pattern, in which the Raanan had the highest followed by the *Ipomoea* treatments and then

the control fish in that order. Thus, it can be concluded that the Raanan feed shows better growth than the *Ipomoea* which also had better growth than the fish which were not fed. Hence, it would be advisable to do supplementary feeding using Raanan in a commercial venture involving *O. niloticus.*

Length Weight Relationship (LWR)

In the present study, the coefficient of determination (R^2) values of between 0.876 and 0.975 for all the treatments showed a very strong positive relationship between length and body weight. The b values recorded were indicative of the *O. niloticus* growing isometrically and this means that the experimental fish grew proportionally in all directions. The b values (3.04 - 3.12) in this study, were within the range (2 - 4) recommended by (Hile, 1936; Martin, 1949; Bagenal and Tesch, 1978) and cited by both Anani (2015) and Migiro *et al.* (2015) as ideal for fresh water fishes. Adam and Khalid (2016) also observed an isometric growth pattern (b = 3.03357) in the samples of *O. niloticus* they worked from the Jebel Aulia Dam on the White Nile in Sudan.

Condition Factor or Index (K)

The Condition Factor (CF) or Fulton's Condition Index of the fingerlings varied from the significantly highest value of 1.6010 for the fish fed on the Raanan commercial feed to the lowest of 1.4645 for the treatment which received No Feed (see Figure 12). A condition factor of less than one (1) means the fish is elongated, starving and generally not in good condition (Alhassan, Abobi, Mensah & Boti, 2014) while an index of 1-1.2 means the fish is doing well (Alhassan *et al.*, 2014 cited in Tseku, 2016). On that basis, it can be said that the

fish under all treatments in this experiment were doing well as they all had condition indices greater than one. Shahabuddin *et al*. (2015) reported condition factor values in the range of 1.2 to 1.7 for *O. niloticus* fed on *Piropia* spheroplasts in a Recirculating Aquaculture System (RAS). Additionally, Anani (2015) also reported a condition index of 2 for *O. niloticus* fed on Raanan while Coppens (another commercial feed which had the next best growth) recorded a condition factor of 3.3. In a work carried out in Lake Geriyo, Adamawa State, male *O. niloticus* had a condition factor of 1.93 while the females had a condition factor of 1.95 (Adedeji *et al*., 2016).

Survival

The survival rates were 88.89% for Dry *Ipomoea*, then 83.3% for No Feed and Raanan respectively with the lowest survival rate being 69.4% for Fresh *Ipomoea*. The survival rates in this study were on the high side when compared to values recorded in previous studies by Ahiah (2008) of 43.3% to 93.3%, Abarike (2011) who obtained 62.17% to 81.00% and Duodu (2014) observed 62.6% and 63.9%. However, Velasquez (2014) who worked in glass aquaria had much higher survival rates of 95.3% to 100% which could be attributed to the lack of predators in the culture medium, as opposed to Abarike (2011), Duodu (2014) and Ahiah's (2008) experiments which were done in the field and therefore subjected to predation. Trushenski *et al*. (2013) state that fish are particularly vulnerable to external and internal injury during physical restraint. With this in mind, Tricaine methane-sulphonate (MS 222) which is one of the most widely used anaesthetics for poikilotherms worldwide (Popovic *et al.*, 2012) was utilized to sedate the fish

prior to the taking of biometric data on a bi-weekly basis and this might also have resulted in less stress and injury and thus contributed to the higher survival rates observed.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

Conclusion

The general outcome of this study was that the treatments of *Ipomoea* were not nutritionally complete enough to cause any substantial and statistically significant growth as compared to the Raanan commercial feed which resulted in superior performance in the following growth parameters: Percentage Weight Gain (PWG) Absolute Growth Rate (AGR), Specific Growth Rate (SGR), Condition Factor (CF) and also in terms of Survival Rate.

Recommendations

Some recommendations are made for those in Research and the Private Sector/Industry.

Research

1. Tests should be done to establish a protocol for obtaining Leaf Protein Concentrates (LPC) from *Ipomoea.* Trials can then be carried out with the LPC as a fishmeal replacer to formulate a feed.

2. Studies should be carried out on other aquatic plants such as duckweed (*Lemna spp.*) and water hyacinth (*Eichhornia crassipes*) to evaluate their potential as feed supplements.

3. Screening of botanicals capable of combating the observed pest infestation (please see Plate 7) of *Ipomoea aquatica* should be carried out geared towards the development of a commercial biopesticide safe enough for use.

4. Technologies such as aquaponics, Biofloc Technology (BFT), Integrated Irrigated Aquaculture (IIA) and Organic aquaculture (with their reliance on less commercial feed or feed which have lower environmental impacts) are the key to a sustainable future for aquaculture and need to be researched into and implemented urgently. As trumpeted by SOFIA (2016) about aquaponics, "In the future, the agriculture sector will need to produce more with less. Thus, aquaponics has the potential to support economic development and enhance food security and nutrition through efficient resource use, and become an additional means of addressing the global challenge of food supply".

6. A thorough search (of literature, through personal communications or any other media) of all fishmeal replacement research carried out in research institutions needs to be carried out and a database created. The standard processes carried out by feed mills in determining nutritional profiles and ensuring quality of feed ingredients to be used as feed would then be put in place as part of efforts to develop a feed industry in Ghana.

7. There should be a concerted effort to synchronize research efforts countrywide. For instance, the International Conference on Animal Nutrition held from 8th to 9th August, 2016 Technology (Kwame Nkrumah University of Science and Technology - KNUST, 2016) was a positive step in that regard but further collaborations with other Ghanaian and West African Universities is needed for maximum impact.

Private Sector/Industry

The private sector should collaborate with researchers nationwide to conduct feed manufacturing driven research in Ghana.

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APPENDICES

APPENDIX A: Proximate Analysis (PA) (Diets and Carcasses)

PA I: GNAT Hostel *Ipomoea* used for Experiment (Descriptive Statistics with Minitab 17.3.1)

Variable	Mean	SE Mean	StDev	Minimum	Maximum
% DM	86.103	0.0495	0.0857	86.026	86.195
% Moisture	13.897	0.0495	0.0857	13.805	13.974
% Ash	13.569	0.0964	0.167	13.377	13.668
% Protein	20.095	0.0691	0.120	19.975	20.214
% Fibre	17.983	0.460	0.797	17.257	18.837
% Oil/EE	0.8316	0.0332	0.0575	0.7865	0.8964
% NFE	33.624	0.444	0.769	32.814	34.344

PA II: Leaves from Kwaprow

Variable	Mean	SE Mean	StDev	Minimum	Maximum
% DM	**11.965**	**0.237**	**0.410**	**11.629**	**12.422**
% Moisture	**88.035**	**0.237**	**0.410**	**87.579**	**88.371**
% Ash	**1.3834**	**0.0133**	**0.0231**	**1.3611**	**1.4072**
% Oil	**0.26687**	**0.00164**	**0.00284**	**0.2648**	**0.2701**
% Protein	**21.814**	**0.231**	**0.400**	**21.410**	**22.210**
% CHO	**11.300**	**0.179**	**0.310**	**11.025**	**11.636**
% Fiber	**5.8892**	**0.0670**	**0.1160**	**5.7698**	**6.0014**

PA III – Ranaan Commercial Feed

Variable	Mean	SE Mean	StDev	Minimum	Maximum
% DM	90.792	0.0224	0.0388	90.767	90.837
% Moisture	9.2078	0.0224	0.0388	9.1632	9.2333
% Ash	8.0036	0.0651	0.1127	7.9262	8.1329
% Protein	28.801	0.292	0.506	28.258	29.261
% Fibre	26.657	0.185	0.321	26.366	27.001
% Oil/EE	3.437	0.183	0.318	3.109	3.744
% NFE	23.894	0.481	0.833	23.334	24.852

PA IV – Before Experiment - Fingerlings

Variable	Mean	SE Mean	StDev	Minimum	Maximum
% DM	22.804	0.107	0.185	22.660	23.012
% Moisture	77.196	0.107	0.185	76.987	77.340
% Ash	5.2327	0.0729	0.1263	5.1170	5.3674
% Protein	61.997	0.400	0.693	61.360	62.735
% Fibre	0.03920	0.00362	0.00626	0.03270	0.04520
% Oil/EE	3.9568	0.0380	0.0658	3.9155	4.0327
% NFE	15.971	0.155	0.268	15.695	16.232

PA V – After Experiment – Adults

Fresh

Variable	Mean	SE Mean	StDev	Minimum	Maximum
% DM_1	20.276	0.382	0.661	19.518	20.734
%Moisture_1	79.724	0.382	0.661	79.266	80.482
% Ash_1	6.585	0.155	0.269	6.354	6.880
% Protein_1	66.731	0.171	0.296	66.476	67.056
% Fat/Oil_1	3.7168	0.0791	0.1370	3.5916	3.8631
% Fibre_1	0.02713	0.00125	0.00217	0.02550	0.02960
%NFE_1	16.300	0.180	0.313	15.954	16.561

Raanan

Variable	Mean	SE Mean	StDev	Minimum	Maximum
% DM	22.946	0.206	0.357	22.533	23.157
%Moisture	77.054	0.206	0.357	76.843	77.467
% Ash	3.208	0.101	0.176	3.012	3.350
% Protein	70.883	0.401	0.694	70.109	71.450
% Fat/Oil	7.722	0.124	0.214	7.563	7.965
% Fibre	0.069600	0.000493	0.000854	0.068800	0.070500
%NFE	13.598	0.241	0.418	13.184	14.020

Dry

Variable	Mean	SE Mean	StDev	Minimum	Maximum
% DM_2	20.748	0.321	0.556	20.139	21.230
%Moisture_2	79.252	0.321	0.556	78.770	79.861
% Ash_2	7.3885	0.0271	0.0469	7.3381	7.4308
% Protein_2	70.322	0.392	0.680	69.537	70.722
% Fat/Oil_2	4.6892	0.0666	0.1154	4.5966	4.8184
% Fibre_2	0.028733	0.000549	0.000950	0.027800	0.029700
%NFE_2	10.776	0.437	0.757	10.258	11.646

No Feed

Variable	Mean	SE Mean	StDev	Minimum	Maximum
% DM_3	22.285	0.198	0.342	21.890	22.506
%Moisture_3	77.715	0.198	0.342	77.494	78.110
% Ash_3	7.1572	0.0484	0.0839	7.1035	7.2539
% Protein_3	72.636	0.133	0.230	72.373	72.794
% Fat/Oil_3	5.9954	0.0136	0.0236	5.9685	6.0125
% Fibre_3	0.020200	0.000577	0.001000	0.019200	0.021200
%NFE_3	7.596	0.217	0.376	7.189	7.930

1.-Protein t-test results - Carcass analysis of *O. niloticus* after experiment (Analysis Toolpak – Microsoft Excel 2007)

S-P/R-P						S-P/N-P					
t-Test: Two-Sample Assuming Unequal Variances						t-Test: Two-Sample Assuming Unequal Variances					
	Variable 1	*Variable 2*					*Variable 1*	*Variable 2*			
Mean	61.99707	70.8829				Mean	61.99707	72.63637			
Variance	0.480448	0.481681				Variance	0.480448	0.05279			
Observati	3	3				Observati	3	3			
Hypothesi	0					Hypothesi	0				
df	4					df	2				
t Stat	-15.6907					t Stat	-25.2356				
P(T<=t) on	4.82E-05					P(T<=t) on	0.000783				
t Critical o	2.131847					t Critical o	2.919986				
P(T<=t) tw	9.64E-05					P(T<=t) tw	0.001567				
t Critical t	2.776445					t Critical t	4.302653				

S-P/D-P

t-Test: Two-Sample Assuming Unequal Variances

	Variable 1	*Variable 2*
Mean	61.99707	70.3222
Variance	0.480448	0.461993
Observati	3	3
Hypothesi	0	
df	4	
t Stat	-14.8534	
P(T<=t) on	5.98E-05	
t Critical o	2.131847	
P(T<=t) tw	0.00012	
t Critical t	2.776445	

S-P/F-P

t-Test: Two-Sample Assuming Unequal Variances

	Variable 1	*Variable 2*
Mean	61.99707	66.7314
Variance	0.480448	0.087849
Observati	3	3
Hypothesi	0	
df	3	
t Stat	-10.8776	
P(T<=t) on	0.000831	
t Critical o	2.353363	
P(T<=t) tw	0.001663	
t Critical t	3.182446	

2. Fat and Oil (Ether Extract) t-test results (Analysis Toolpak – Microsoft Excel 2007)

S - F&O/R - F&O		
t-Test: Two-Sample Assuming Unequal Variances		
	Variable 1	*Variable 2*
Mean	3.9568	7.7218
Variance	0.004332	0.045846
Observati	3	3
Hypothesi	0	
df	2	
t Stat	-29.1117	
P(T<=t) on	0.000589	
t Critical o	2.919986	
P(T<=t) tw	0.001178	
t Critical t	4.302653	

S - F&O/N - F&O		
t-Test: Two-Sample Assuming Unequal Variances		
	Variable 1	*Variable 2*
Mean	3.9568	7.7218
Variance	0.004332	0.045846
Observati	3	3
Hypothesi	0	
df	2	
t Stat	-29.1117	
P(T<=t) on	0.000589	
t Critical o	2.919986	
P(T<=t) tw	0.001178	
t Critical t	4.302653	

S - F&O/D - F&O							S - F&O/F - F&O						
t-Test: Two-Sample Assuming Unequal Variances							t-Test: Two-Sample Assuming Unequal Variances						
	Variable 1	*Variable 2*						*Variable 1*	*Variable 2*				
Mean	3.9568	4.689167					Mean	3.9568	3.716833				
Variance	0.004332	0.013307					Variance	0.004332	0.01876				
Observati	3	3					Observati	3	3				
Hypothesi	0						Hypothesi	0					
df	3						df	3					
t Stat	-9.55108						t Stat	2.735166					
P(T<=t) on	0.001217						P(T<=t) on	0.035814					
t Critical o	2.353363						t Critical o	2.353363					
P(T<=t) tw	0.002435						P(T<=t) tw	0.071629					
t Critical t	3.182446						t Critical t	3.182446					

3. Ash - t-test results (Analysis Toolpak – Microsoft Excel 2007)

S - A/R - A						S - A/N - A					
t-Test: Two-Sample Assuming Unequal Variances						t-Test: Two-Sample Assuming Unequal Variances					
	Variable 1	*Variable 2*					*Variable 1*	*Variable 2*			
Mean	5.232667	3.208233				Mean	5.232667	7.157233			
Variance	0.015948	0.030852				Variance	0.015948	0.007037			
Observati	3	3				Observati	3	3			
Hypothesi	0					Hypothesi	0				
df	4					df	3				
t Stat	16.20853					t Stat	-21.9872				
P(T<=t) on	4.24E-05					P(T<=t) on	0.000103				
t Critical o	2.131847					t Critical o	2.353363				
P(T<=t) tw	8.48E-05					P(T<=t) tw	0.000206				
t Critical t	2.776445					t Critical t	3.182446				

S - A/D - A							S - A/F - A					
t-Test: Two-Sample Assuming Unequal Variances							t-Test: Two-Sample Assuming Unequal Variances					
	Variable 1	*Variable 2*						*Variable 1*	*Variable 2*			
Mean	5.232667	7.3885					Mean	5.232667	6.584933			
Variance	0.015948	0.002198					Variance	0.015948	0.072146			
Observati	3	3					Observati	3	3			
Hypothesi	0						Hypothesi	0				
df	3						df	3				
t Stat	-27.7201						t Stat	-7.89133				
P(T<=t) on	5.15E-05						P(T<=t) on	0.00212				
t Critical o	2.353363						t Critical o	2.353363				
P(T<=t) tw	0.000103						P(T<=t) tw	0.004241				
t Critical t	3.182446						t Critical t	3.182446				

4. Crude Fibre - t-test results (Analysis Toolpak – Microsoft Excel 2007)

S - F/R-F						S - F/N-F					
t-Test: Two-Sample Assuming Unequal Variances						t-Test: Two-Sample Assuming Unequal Variances					
	Variable 1	*Variable 2*					*Variable 1*	*Variable 2*			
Mean	0.0392	0.0696				Mean	0.0392	0.0202			
Variance	3.93E-05	7.3E-07				Variance	3.93E-05	0.000001			
Observati	3	3				Observati	3	3			
Hypothesi	0					Hypothesi	0				
df	2					df	2				
t Stat	-8.32747					t Stat	5.18718				
P(T<=t) on	0.007058					P(T<=t) on	0.017607				
t Critical o	2.919986					t Critical o	2.919986				
P(T<=t) tw	0.014116					P(T<=t) tw	0.035214				
t Critical t	4.302653					t Critical t	4.302653				

S - F/D-F

t-Test: Two-Sample Assuming Unequal Variances

	Variable 1	*Variable 2*
Mean	0.0392	0.028733
Variance	3.93E-05	9.03E-07
Observati	3	3
Hypothesi	0	
df	2	
t Stat	2.860937	
P(T<=t) on	0.051772	
t Critical o	2.919986	
P(T<=t) tw	0.103545	
t Critical t	4.302653	

S - F/F-F

t-Test: Two-Sample Assuming Unequal Variances

	Variable 1	*Variable 2*
Mean	0.0392	0.027133
Variance	3.93E-05	4.72E-06
Observati	3	3
Hypothesi	0	
df	2	
t Stat	3.151761	
P(T<=t) on	0.043819	
t Critical o	2.919986	
P(T<=t) tw	0.087637	
t Critical t	4.302653	

5. **Nitrogen Free Extract (NFE) - t-test results (Analysis Toolpak – Microsoft Excel 2007)**

S - NFE/R- NFE

t-Test: Two-Sample Assuming Unequal Variances

	Variable 1	*Variable 2*
Mean	15.97087	13.59813
Variance	0.071987	0.174435
Observati	3	3
Hypothesi	0	
df	3	
t Stat	8.278856	
P(T<=t) on	0.001846	
t Critical o	2.353363	
P(T<=t) tw	0.003692	
t Critical t	3.182446	

S - NFE/N- NFE

t-Test: Two-Sample Assuming Unequal Variances

	Variable 1	*Variable 2*
Mean	15.97087	7.596133
Variance	0.071987	0.141392
Observations	3	3
Hypothesized M	0	
df	4	
t Stat	31.40188	
P(T<=t) one-tail	3.06E-06	
t Critical one-ta	2.131847	
P(T<=t) two-tail	6.13E-06	
t Critical two-ta	2.776445	

S - NFE/D- NFE						S - NFE/F- NFE					
t-Test: Two-Sample Assuming Unequal Variances						t-Test: Two-Sample Assuming Unequal Variances					
	Variable 1	*Variable 2*					*Variable 1*	*Variable 2*			
Mean	15.97087	10.77637				Mean	15.97087	16.29967			
Variance	0.071987	0.573617				Variance	0.071987	0.097715			
Observations	3	3				Observati	3	3			
Hypothesized M	0					Hypothesi	0				
df	2					df	4				
t Stat	11.1975					t Stat	-1.38245				
P(T<=t) one-tail	0.003941					P(T<=t) on	0.119504				
t Critical one-ta	2.919986					t Critical o	2.131847				
P(T<=t) two-tail	0.007881					P(T<=t) tw	0.239008				
t Critical two-ta	4.302653					t Critical t	2.776445				

ANOVA of Carcass analysis of *O. niloticus* after experiment (Means ± SE)

Analysis	Feed Treatments			
	Ranaan	**Fresh**	**Dry**	**No Feed**
% DM	22.946^{f} ±0.206	20.276^{g}±0.382	20.740^{g}±0.321	22.285^{f}±0.198
% Moisture	77.054^{b}±0.206	79.724^{a}±0.382	79.252^{a}±0.321	77.715^{b}±0.198
% Ash	3.208^{n}±0.101	6.585^{kl}±0.155	7.389^{k}±0.0271	7.157^{kl}±0.0484
% Protein	70.883^{d}±0.401	66.731^{e}±0.171	70.322^{d}±0.392	72.636^{c}±0.133
% Fat/Oil	7.722^{k}±0.124	3.717^{mn}±0.0791	4.689^{m}±0.0667	5.995^{l}±0.0136
% Fibre	0.070^{o}±0.001	0.027^{o}±0.0013	0.029^{o}±0.001	0.020^{o}±0.001
% NFE	13.598^{i}±0.241	16.300^{h}±0.180	10.776^{j}±0.437	7.596^{k}±0.217

Means with the same alphabet superscript are not significantly different

APPENDIX B: Sample of Entered Data Collection Sheet – At Stocking

AT STOCKING (20/03/2016)														
	D2				R3				N3				F3	
	SL	TL	W		SL	TL	W		SL	TL	W		SL	TL	W
	6.1	7.7	8.41		5.2	6.6	4.8		4.9	6.2	3.57		5	6.3	3.72
	5.5	7	5.23		5.6	7.3	5.2		5.3	6.6	3.98		5	6.5	4.09
	5.1	6.5	4.44		5	6.3	3.78		4.5	5.6	2.81		5	6.3	3.98
	5.2	6.6	4.23		5	6.3	3.84		5.9	7.5	6.55		5.3	6.5	4.52
	6	7.5	6.81		5.2	6.7	5.73		5.8	7.4	5.76		4.9	6	3.44
	4.9	6.2	3.53		5.2	6.7	4.54		5.1	6.5	4.53		4.6	5.4	3.48
	5.5	7.1	4.78		5.2	6.4	4.31		4.5	5.8	3.14		5	6.3	3.77
	4.7	6	3.48		4.9	6.2	3.52		4.7	6	3.53		4.9	6.2	3.63
	4.8	6.2	3.83		5.3	6.7	4.82		5	6.3	3.95		5.5	7	5.15
	5.5	7	5.32		6	7.6	6.72		4.9	6.2	3.13		6.2	7.3	7.73
	4.6	5.5	2.58		5.2	6.6	4.48		4.6	5.3	2.76		6	7.6	6.73
	5	6.4	3.83		4.7	5.8	2.9		5.2	6.5	3.69		6	7.7	6.95
Mean	**5.24**	**6.64**	**4.71**		**5.21**	**6.60**	**4.55**		**5.03**	**6.33**	**3.95**		**5.28**	**6.59**	**4.77**
N	12	12	12		12	12	12		12	12	12		12	12	12
SD	0.487029	0.640253	1.59663		0.334279	0.48053	1.027002		0.46188	0.651048	1.160172		0.521943	0.68152	1.522077
SE	0.140593	0.184825	0.460907		0.096498	0.138717	0.29647		0.133333	0.187941	0.334913		0.150672	0.196738	0.439386
MIN	4.6	5.5	2.58		4.7	5.8	2.9		4.5	5.3	2.76		4.6	5.4	3.44
MAX	6.1	7.7	8.41		6	7.6	6.72		5.9	7.5	6.55		6.2	7.7	7.73

N2				R2				D3				D1		
SL	TL	W		SL	TL	W		SL	TL	W		SL	TL	W
6	7.6	6.45		5.6	7	5.23		5.5	7	5.64		5.2	6.6	4.82
5.2	6.7	4.65		5.4	6.8	4.1		5.4	6.7	4.46		5.4	6.9	4.53
5.5	6.9	5.04		5.6	7.3	5.16		6	7.6	6.39		5.3	6.6	5.25
5.5	7	5.75		5.4	6.9	5.12		6	7.5	5.97		5.5	7	6.34
5.7	7.2	6.4		5.4	6.8	4.48		6.1	7.8	6.83		6.1	7.6	7.65
5.4	6.7	5.91		5.5	7	4.93		6.2	7.7	7.03		5.7	7.3	5.79
5	6.2	3.81		5.3	6.7	4.91		6	7.4	6.31		5.5	7	5.44
5.6	7.2	6.13		5.4	6.9	4.98		5.5	7	5.42		5.2	6.6	3.59
5.2	6.6	4.12		6	7.5	6.84		5.5	6.9	5.33		6.3	7.9	7.37
5.5	6.8	4.61		5.1	6.5	4.27		5.3	6.7	4.41		5.7	7.2	5.34
5.8	7.3	6.04		5.6	7.2	6.14		5.5	6.1	5.23		5.1	6.5	4.16
5.4	6.9	5.04		5.8	7.4	6.78		5.2	6.6	4.63		5	6.2	3.16
5.48	**6.93**	**5.33**		**5.51**	**7.00**	**5.25**		**5.68**	**7.08**	**5.64**		**5.50**	**6.95**	**5.29**
12	12	12		12	12	12		12	12	12		12	12	12
0.275791	0.369582	0.903513		0.235327	0.298481	0.897112		0.34859	0.520198	0.889659		0.395428	0.490825	1.374352
0.079614	0.106689	0.260822		0.067933	0.086164	0.258974		0.100629	0.150168	0.256822		0.11415	0.141689	0.396741
5	6.2	3.81		5.1	6.5	4.1		5.2	6.1	4.41		5	6.2	3.16
6	7.6	6.45		6	7.5	6.84		6.2	7.8	7.03		6.3	7.9	7.65

R1				F1				N1				F2		
SL	TL	W		SL	TL	W		SL	TL	W		SL	TL	W
5.7	7.5	6.54		6.2	7.8	6.45		5.7	7.3	5.65		5.2	6.4	4.47
4.8	6.1	3.86		6	7.2	6.72		6.1	7.9	7.5		5.5	7	4.61
5.5	7.2	5.52		5.2	6.8	4.63		5.3	6.6	4.57		6	7.5	6.98
5.2	6.7	4.29		5.7	7.4	6.38		5.3	6.8	5.31		4.8	6.2	2.59
6.3	8	7.14		6.4	8.1	8.52		5.7	7.2	5.93		5.5	6.9	4.68
5.7	7.2	5.69		5.8	7.3	5.29		5.2	6.6	4.82		5.8	7.4	6.3
6.1	7.5	6.94		5.5	7	5.23		5.7	7.3	6.12		5.5	7.3	5.27
5.2	7.2	5.36		6	7.5	7.43		5	6.5	4.05		5.5	7.2	5.98
5.7	7.4	5.78		6.9	8.8	10.38		5	6.2	4.16		5.5	7.1	5.65
5.5	7	4.75		5.5	7.3	5.51		6	7.6	7.04		5.6	7.1	5.92
5	6.3	3.87		6.4	8.3	7.81		5.6	7	5.25		5	6.4	4.09
5.5	7	5.3		5.6	7.2	6.28		5.8	7.1	5.6		5.9	7.5	6.9
5.52	**7.09**	**5.42**		**5.93**	**7.56**	**6.72**		**5.53**	**7.01**	**5.50**		**5.48**	**7.00**	**5.29**
12	12	12		12	12	12		12	12	12		12	12	12
0.43029236	0.5282188	1.100231		0.48116	0.583809	1.618279		0.36763	0.490748	1.057329		0.34859	0.445176	1.268788
0.1242147	0.1524836	0.317609		0.138899	0.168531	0.467157		0.106126	0.141667	0.305225		0.100629	0.128511	0.366268
4.8	6.1	3.86		5.2	6.8	4.63		5	6.2	4.05		4.8	6.2	2.59
6.3	8	7.14		6.9	8.8	10.38		6.1	7.9	7.5		6	7.5	6.98

APPENDIX C: Sample of Entered Data Collection Sheet – End of Study

SAMPLING 13 (17/09/2016)															
	R1/D2				R2/R3				IF1/N3				ID3/F3		
	SL	TL	W		SL	TL	W		SL	TL	W		SL	TL	W
					18.4	23.2	198.57		7.5	9.5	12.73		8.2	10.5	16.43
					17	21.2	182		6.8	8.8	10.02		8	10.2	17.08
					16.5	21	170		7.5	9.8	14.61		8.5	11	18.96
					16.5	19.3	138.8		7	9.1	12.18		8.5	10.9	20.12
					14	17.4	90.54		7.5	9.6	14.53		8.5	10.7	18.4
					14	17.8	96.73		7	9	10.66		8.5	10.6	17.39
					12.5	13.6	63.23		7	8.8	10.55		7.8	10.2	14.84
					13.5	17	80.93		7	9	8.69		7.7	9.7	13.97
					12	15	52.6		6.2	8	7.15		7.7	9.7	13.27
									6.8	8.6	8.77				
mean	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**		**14.9333**	**18.3889**	**119**		**7.03**	**9.02**	**11**		**8.15556**	**10.3889**	**17**
N	0	0	0		9	9	9		10	10	10		9	9	9
SD	#DIV/0!	#DIV/0!	#DIV/0!		2.222611	3.089678	54.27625		0.402906	0.526624	2.500824		0.36094	0.475511	2.320074
SE	#DIV/0!	#DIV/0!	#DIV/0!		0.74087	1.029893	18.09208		0.12741	0.166533	0.79083		0.120313	0.158504	0.773358
MIN	0	0	0		12	13.6	52.6		6.2	8	7.15		7.7	9.7	13.27
MAX	0	0	0		18.4	23.2	198.57		7.5	9.8	14.61		8.5	11	20.12

IF3/N2				IF2/R2				R3/D3				M1/D1		
SL	TL	W		SL	TL	W		SL	TL	W		SL	TL	W
7.7	10	14.73		17	21.2	159.16		8	10.4	17.26		5.5	7.2	5.53
7.5	9.4	12.43		17.5	22	181.37		8.3	10.5	18.91		5.7	7.5	5.84
7	9.2	11.78		18	22.5	185.07		8.9	11.2	21.13		6.5	8.5	8.86
7.5	9.5	12.37		17	21.5	163.48		7.5	9.6	14.06		6	7.8	7.36
7.5	10.6	13.2		14.5	17.9	97.75		8.3	10.5	16.5		6.3	8.1	7.48
7.5	9	11.3		14.5	18.2	103.34		8	10.2	16.4		5.7	7.3	5.89
7.5	9.4	12.62		15.5	19.4	126.83		7.7	9.6	14.03		6.8	8.8	10.02
6	7.8	6.35		12	15.2	54.95		8.5	10.6	17.66		6.5	8.4	7.64
7	9	10.7		13.5	17.3	76.65		7.5	9.7	12.44		5.5	7.2	5.3
6.5	8.4	8.54		13.5	16.7	72.08		7	9.1	13.54				
5.5	7.1	4.57		11	14	38.28		7.3	9.3	10.99				
								7.5	9.7	11.26				
7.01818	**9.03636**	**11**		**14.9091**	**18.7182**	**114**		**7.875**	**10.0333**	**15**		**6.05556**	**7.86667**	**7**
11	11	11		11	11	11		12	12	12		9	9	9
0.723627	0.978031	3.075362		2.311041	2.847742	51.95205		0.554527	0.624257	3.138899		0.485054	0.608276	1.61571
0.218182	0.294888	0.927256		0.696805	0.858627	15.66413		0.160078	0.180208	0.906122		0.161685	0.202759	0.53857
5.5	7.1	4.57		11	14	38.28		7	9.1	10.99		5.5	7.2	5.3
7.7	10.6	14.73		18	22.5	185.07		8.9	11.2	21.13		6.8	8.8	10.02

K2/R1				K1/F1				ID2/N1				ID1/F2		
SL	TL	W		SL	TL	W		SL	TL	W		SL	TL	W
16	20.3	140.26		7	8.8	9.61						8.5	10.6	20.13
16.5	20.2	153.23		7.7	10	14.95						8.3	10.6	16.9
16	20.2	134.03		8.2	10.5	17.8						7.4	9.2	11.85
16.5	21.2	149.75		8	10.2	14.76						6.6	8.4	9.25
15.5	20	137.38		7.5	9.6	12.05						6.5	8.3	9.04
15.3	19.3	124.58		6.8	8.7	10.62						6.2	7.6	6.89
14	17.1	82.09		6	7.7	6.69						5.6	6.8	3.98
13.1	16.7	78.97		5.6	7.4	6.58								
14.5	17.8	94.15		5.6	7.5	6.07								
12.5	15.4	56.48		5.6	7.2	5.41								
14.99	**18.82**	**115**		**6.8**	**8.76**	**10**		**#DIV/0!**	**#DIV/0!**	**#DIV/0!**		**7.01429**	**8.78571**	**11**
10	10	10		10	10	10		0	0	0		7	7	7
1.41220867	1.9286149	34.16041		1.038161	1.262449	4.344133		#DIV/0!	#DIV/0!	#DIV/0!		1.088468	1.442716	5.654076
0.44657959	0.6098816	10.80247		0.328295	0.399221	1.373736		#DIV/0!	#DIV/0!	#DIV/0!		0.411402	0.545295	2.13704
12.5	15.4	56.48		5.6	7.2	5.41		0	0	0		5.6	6.8	3.98
16.5	21.2	153.23		8.2	10.5	17.8		0	0	0		8.5	10.6	20.13

APPENDIX D: Full Study – Data Means

		DAY	N1	N2	N3	D1	D2	D3	F1	F2	F3	R1	R2	R3
	At Stocking	0	5.50	5.33	3.95	5.29	4.71	5.64	6.72	5.29	4.77	5.42	5.25	4.55
	Week 2	13	5.69	4.69	3.57	6.05	5.37	5.62	6.62	5.56	4.23	11.42	12.34	10.58
Month 1	Week 4	27	5.62	4.37	3.23	5.97	5.45	5.73	7.10	6.31	5.66	16.23	18.01	16.27
	Week 6	41	6.27	5.27	4.19	6.57	6.57	7.73	9.17	7.61	7.41	29.88	29.45	28.61
Month 2	Week 8	55	5.78	5.38	5.07	6.28	6.28	8.94	8.22	6.90	7.75	43.56	38.72	39.13
	Week 10	69	4.81	5.28	4.81	6.60	5.56	10.28	8.57	7.16	8.58	54.49	47.46	48.59
Month 3	Week 12	83	5.41	7.82	8.08	6.09	6.31	13.17	8.19	6.89	10.54	69.76	54.83	53.10
	Week 14	97	5.75	8.80	8.35	6.61	6.32	14.01	8.35	7.24	13.32	66.91	66.36	65.87
Month 4	Week 16	111	5.72	8.44	8.78	6.62	6.43	13.58	10.56	7.36	12.58	76.35	70.56	64.92
	Week 18	125	6.00	8.05	8.51	6.37	6.22	12.84	8.29	7.16	13.72	75.69	68.23	72.10
Month 5	Week 20	139		9.22	9.66	7.32		13.41	9.99		15.01	85.15	95.74	84.86
	Week 22	153		9.73	10.13	7.05		15.19	10.03	9.82	16.19	82.39	81.40	97.85
Month 6	Week 24	167		10.34	11.18	7.32		14.63	10.30	10.17	17.11	106.95	108.43	105.50
	Week 26	181		10.78	10.99	7.10		15.35	10.45	11.15	16.72	115.09	114.45	119.27
Month 7	Week 28	195		11.40	11.35	7.37		15.80	10.67	7.98	10.67	116.16	117.37	121.78

APPENDIX E: Weight Gain of Fingerlings of *O. niloticus* Fed on Different Dietary Treatments for 28 Weeks (Means ± SE).

Weeks	Ranaan (R)	Fresh (F)	Dry (D)	No Feed (N)
Week 0	5.073±0.265	5.591±0.584	5.210±0.272	4.926±0.491
Week 2	11.448± 0.510	5.468±0.692	5.679±0.198	4.650±0.612
Week 4	16.835±0.587	6.356±0.417	5.717±0.152	4.410±0.690
Week 6	29.313±0.374	8.064±0.557	6.956±0.388	5.242±0.603
Week 8	40.47±1.55	7.624±0.388	7.166±0.886	5.413±0.206
Week 10	50.18± 2.18	8.103±0.471	7.48±1.43	4.964±0.156
Week 12	59.23±5.29	8.54±1.07	8.52±2.32	7.103±0.848
Week 14	66.378±0.300	9.64±1.87	8.98±2.52	7.633±0.952
Week 16	70.61±3.30	10.17±1.52	8.88±2.35	7.647±0.971
Week 18	72.01±2.15	9.72±2.02	8.48±2.18	7.520±0.769
Week 20	88.58±3.58	12.50±2.51	10.37±3.05	9.439±0.220
Week 22	87.21±5.32	12.01±2.09	11.12±4.07	9.928±0.198
Week 24	106.96±0.845	12.53±2.29	10.98±3.66	10.759±0.423
Week 26	116.27±1.51	12.77±1.98	11.23±4.12	10.885±0.104
Week 28	118.44±1.71	9.771±0.897	11.59±4.21	11.376±0.0278

APPENDIX F: Summary Table (Means ± SE) of Experimental Parameters

Parameters	Ranaan (R)	Fresh *Ipomoea* (F)	Dry *Ipomoea* (D)	No Feed (N)
AIW (g/fish)	5.073a±0.265	5.591a±0.584	5.210a±0.272	4.926a±0.491
AFW (g/fish)	118.44±1.71	9.771 ±0.897	11.59±4.21	11.376±0.0278
MWG (g/fish)	113.36±1.97	4.180±0.934	4.180±0.934	4.66±2.11
PWG (g/fish)	2252a±164	77.8b±23.1	109.8b±70.4	150.6b±36.7
SGR (%/day)	1.6170a±0.0348	0.2871b±0.0635	0.1567bc±0.0139	0.4657bc±0.0755
SR (%)	83.33a±4.81	69.4a±10.0	88.89a±7.35	83.33a±4.81
K	1.6010a±0.0200	1.4977b±0.0197	1.4853b±0.0244	1.4645b±0.0292

APPENDIX G: Length Weight Relationship (LWR) – Regression Analysis with Excel 2007

Ranaan					
TL	BW	L^3	W/L^3*100	logTL	logBW
21.5	152.84	9938.375	1.537877	1.332438	2.184237
20.6	150.11	8741.816	1.717149	1.313867	2.17641
20.6	143.68	8741.816	1.643594	1.313867	2.157396
20.3	136.48	8365.427	1.631477	1.307496	2.135069
20.5	140.83	8615.125	1.634683	1.311754	2.148695
19.4	123.44	7301.384	1.690638	1.287802	2.091456
18	97.48	5832	1.671468	1.255273	1.988916
15.3	57.66	3581.577	1.609905	1.184691	1.760875
16.7	77.97	4657.463	1.674087	1.222716	1.891928
17	81.08	4913	1.650315	1.230449	1.908914
22.8	161.85	11852.35	1.365552	1.357935	2.209113
22.6	189.66	11543.18	1.643049	1.354108	2.277976
21.7	169.76	10218.31	1.661331	1.33646	2.229835
23	189.4	12167	1.55667	1.361728	2.27738
20	130.65	8000	1.633125	1.30103	2.116109
18.5	105.22	6331.625	1.661817	1.267172	2.022098
17.5	77.63	5359.375	1.44849	1.243038	1.89003
18	99.2	5832	1.70096	1.255273	1.996512
17.7	73.65	5545.233	1.328168	1.247973	1.867173
15.4	56.1	3652.264	1.536034	1.187521	1.748963
14	37.91	2744	1.38156	1.146128	1.578754
21.5	170.2	9938.375	1.712554	1.332438	2.23096
23.5	200.15	12977.88	1.54224	1.371068	2.301356
22	180.5	10648	1.695154	1.342423	2.256477
20.2	147.1	8242.408	1.784673	1.305351	2.167613
18.1	99.98	5929.741	1.686077	1.257679	1.999913
17.5	82.31	5359.375	1.535813	1.243038	1.915453
18.1	94	5929.741	1.585229	1.257679	1.973128
16	65.38	4096	1.596191	1.20412	1.815445
15.5	56.43	3723.875	1.515357	1.190332	1.75151

Fresh					
TL	BW	L^3	W/L^3*100	logTL	logBW
10.4	18.38	1124.864	1.633975	1.017033	1.264346
9.5	12.6	857.375	1.469602	0.977724	1.100371
10	14.5	1000	1.45	1	1.161368
9	10.2	729	1.399177	0.954243	1.0086
7.6	6.7	438.976	1.526279	0.880814	0.826075
9	11.08	729	1.51989	0.954243	1.04454
10.1	14.94	1030.301	1.450062	1.004321	1.174351
7.4	5.92	405.224	1.46092	0.869232	0.772322
7.6	7.53	438.976	1.715356	0.880814	0.876795
7.3	4.83	389.017	1.241591	0.863323	0.683947
11	18.87	1331	1.417731	1.041393	1.275772
11	20.28	1331	1.523666	1.041393	1.307068
10.7	20.03	1225.043	1.635045	1.029384	1.301681
10.2	15.65	1061.208	1.474734	1.0086	1.194514
11.1	19.82	1367.631	1.449221	1.045323	1.297104
10.4	17.8	1124.864	1.582414	1.017033	1.25042
9.8	13.85	941.192	1.471538	0.991226	1.14145
10.4	14.9	1124.864	1.324605	1.017033	1.173186
9.9	15.05	970.299	1.551068	0.995635	1.177536
11	20.6	1331	1.547708	1.041393	1.313867
10.2	15.41	1061.208	1.452119	1.0086	1.187803
9.2	12.21	778.688	1.568022	0.963788	1.086716
8.8	10.45	681.472	1.533445	0.944483	1.019116
7.9	7.34	493.039	1.488726	0.897627	0.865696
8.5	9.55	614.125	1.555058	0.929419	0.980003

No Food					
TL	BW	L^3	W/L^3*100	logTL	logBW
9.5	13.07	857.375	1.52442	0.977724	1.116276
10	14.55	1000	1.455	1	1.162863
9.5	13.85	857.375	1.615396	0.977724	1.14145
9.6	13.85	884.736	1.565439	0.982271	1.14145
9.5	13.24	857.375	1.544248	0.977724	1.121888
9.5	13.58	857.375	1.583904	0.977724	1.1329
9	10.92	729	1.497942	0.954243	1.038223
9.2	11.69	778.688	1.501243	0.963788	1.067815
9.7	9.21	912.673	1.009124	0.986772	0.96426
7.7	6.87	456.533	1.50482	0.886491	0.836957
7	4.61	343	1.344023	0.845098	0.663701
9	10.17	729	1.395062	0.954243	1.007321
9.6	13.13	884.736	1.484059	0.982271	1.118265
10	14.26	1000	1.426	1	1.15412
9.9	14.44	970.299	1.488201	0.995635	1.159567
8.9	10.94	704.969	1.551841	0.94939	1.039017
9	11.16	729	1.530864	0.954243	1.047664
9.4	12.87	830.584	1.549512	0.973128	1.109579
9	9.48	729	1.300412	0.954243	0.976808
8	7.89	512	1.541016	0.90309	0.897077
8.8	9.14	681.472	1.341214	0.944483	0.960946

Dry					
TL	BW	L^3	W/L^3*100	logTL	logBW
8.8	9.84	681.472	1.443933	0.944483	0.992995
7.1	4.97	357.911	1.388613	0.851258	0.696356
8.5	9.25	614.125	1.506208	0.929419	0.966142
8	7.37	512	1.439453	0.90309	0.867467
7.4	5.95	405.224	1.468324	0.869232	0.774517
8	7.8	512	1.523438	0.90309	0.892095
8.6	8.91	636.056	1.40082	0.934498	0.949878
7.5	5.77	421.875	1.367704	0.875061	0.761176
7.3	6.5	389.017	1.670878	0.863323	0.812913
10.3	16.85	1092.727	1.542014	1.012837	1.2266
11.4	21.39	1481.544	1.443764	1.056905	1.330211
9.3	10.95	804.357	1.361336	0.968483	1.039414
10.6	19.54	1191.016	1.640616	1.025306	1.290925
10.8	19.42	1259.712	1.541622	1.033424	1.288249
10.5	18.02	1157.625	1.556635	1.021189	1.255755
10.5	16.84	1157.625	1.454703	1.021189	1.226342
9.8	14.58	941.192	1.549099	0.991226	1.163758
9.8	12.45	941.192	1.322791	0.991226	1.095169
9.6	14.15	884.736	1.599347	0.982271	1.150756
9.6	11.35	884.736	1.282869	0.982271	1.054996
9.4	14.02	830.584	1.687969	0.973128	1.146748

Appendix H1 – LWR Summary t-test outputs.

– LWR- Summary t-test output (Raanan) with Excel 2007

SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.987627028							
R Square	0.975407146							
Adjusted R Square	0.97452883							
Standard Error	0.030431166							
Observations	30							
ANOVA								
	df	*SS*	*MS*	*F*	*gnificance F*			
Regression	1	1.028424047	1.028424	1110.542	4.48E-24			
Residual	28	0.025929564	0.000926					
Total	29	1.054353612						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0%*	*Upper 95.0%*
Intercept	-1.955313305	0.119888565	-16.3094	7.91E-16	-2.20089	-1.70973	-2.20089	-1.709732715
X Variable 1	3.124222261	0.093750676	33.3248	4.48E-24	2.932183	3.316262	2.932183	3.316261812

Appendix H2– LWR - Summary t-test output with Excel 2007

(Fresh)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.987019071
R Square	0.974206647
Adjusted R Square	0.973085197
Standard Error	0.029584583
Observations	25

ANOVA

	df	*SS*	*MS*	*F*	*ignificance F*
Regression	1	0.76033	0.76033	868.7026	8.99E-20
Residual	23	0.020131	0.000875		
Total	24	0.78046			

	Coefficients	*andard Erro*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0%*	*Jpper 95.0%*
Intercept	-1.86490224	0.100748	-18.5106	2.59E-15	-2.07331	-1.65649	-2.07331	-1.65649
X Variable 1	3.040410872	0.103157	29.47376	8.99E-20	2.827015	3.253806	2.827015	3.253806

Appendix H3 – LWR - Summary t-test output with Excel 2007

Summary t-test output (Dry)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.985933
R Square	0.972064
Adjusted R	0.970594
Standard E	0.033241
Observatio	21

ANOVA

	df	*SS*	*MS*	*F*	*ignificance F*
Regression	1	0.730506065	0.730506	661.1228	3.17E-16
Residual	19	0.020994006	0.001105		
Total	20	0.751500071			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0%*	*Jpper 95.0%*
Intercept	-1.89839	0.114772675	-16.5404	9.74E-13	-2.13861	-1.65816	-2.13861	-1.65816
X Variable :	3.072014	0.119476406	25.71231	3.17E-16	2.821947	3.322081	2.821947	3.322081

Appendix H4- Summary t-test output with Excel 2007

(No Feed)

SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.935814							
R Square	0.875748							
Adjusted R Square	0.869209							
Standard Error	0.045476							
Observations	21							
ANOVA								
	df	*SS*	*MS*	*F*	*gnificance F*			
Regression	1	0.276948509	0.276949	133.9155	4.77E-10			
Residual	19	0.039293607	0.002068					
Total	20	0.316242116						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0%*	*Upper 95.0%*
Intercept	-1.87631	0.252280568	-7.43741	4.86E-07	-2.40434	-1.34828	-2.40434	-1.348284574
X Variable 1	3.041702	0.262845964	11.57219	4.77E-10	2.491559	3.591845	2.491559	3.591845058