KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI
COLLEGE OF AGRICULTURE AND NATURAL RESOURCES
FACULTY OF RENEWABLE NATURAL RESOURCES
DEPARTMENT OF FISHERIES AND WATERSHED MANAGEMENT

EFFECT OF POND FERTILIZATION AND FEEDING LEVEL ON PRODUCTIVITY OF NILE TILAPIA (*Oreochromis niloticus*) IN GHANA

BY

COLLINS PRAH DUODU

September, 2014.

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A thesis submitted to the Department of Fisheries and Watershed Management of the College of Agriculture and Natural Resources. in partial fulfilment of the requirements for the degree of Master of Philosophy in Aquaculture.

DECLARATION

"I hereby declare that this submission is my own work and that, to the best of my knowledge, it contains no material previously published or written by another person nor material which to a substantial extent has been accepted for the qualification of any other degree or diploma of a university or other institution of higher learning, except where due acknowledgement is made".

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ABSTRACT

Fish farmers have the desire to increase productivity but are constrained by the high cost of formulated feeds. This study quantified the performance of fish cultured in fertilized ponds and fed half the recommended ration of formulated feed and the cost-effectiveness of using inorganic fertilizers to improve productivity of tilapia raised in ponds. The study was conducted at the Renewable Natural Resources Management fish farm, Kwame Nkrumah University of Science and Technology (KNUST), located in Kumasi. In all, four $200m^2$ and two $300m^2$ ponds were used. Three of the ponds were unfertilized while the other three were fertilized. Ponds were dried, mud scooped out and limed before filling with water. Ponds were stocked with all-male tilapia (*Oreochromis niloticus*) fingerlings of average size 2g at $2fish/m^2$. Ponds were fertilized with Mono Ammonium Phosphate (MAP) at $2g/m^2$ and Urea at $3g/m^2$ strictly according to the phytoplankton abundance and Secchi-disk readings. Fish in the unfertilized ponds were fed 3-6% of their body weight twice daily with a 30-33% protein extruded feed. Fertilized ponds were fed half (1.5 – 3%) of the recommended ration whilst unfertilized ponds were fed strictly according to response. The results of the study showed a comparable growth of 202.9±23.8g and 204.2±36.3g between half ration and full ration ponds respectively. A similar observation was recorded for the Total Weight Gain (kg), Specific Growth Rate (%/day), Feed Conversion Ratio and Feed Intake with corresponding values of 101.7±35.6kg; 101.9±34.0kg, 1.2±0.2; 1.2±0.2, 1.2±0.3; 1.1±0.2, and 0.6±0.3; 0.7± 0.5 for half and full ration ponds, respectively. Total cost of production showed no significant difference ($p=0.9888$) between the half ration (GH₵ 1,621.1) and full ration (GH₵ 1,615.8) treatments. A total of profit estimated at GH₵ 596.7 and GH₵ 631.9 was realized for the full ration and half ration treatments, respectively. The results of this study indicate that farmers could increase their pond productivity, reduce production cost, and increase profit through fertilization and feeding at half ration with formulated feed. It is however, worth noting that to achieve best results, feeding strictly according to response is recommended.

TABLE OF CONTENT

LIST OF TABLES

LIST OF PLATES

LIST OF FIGURES

CHAPTER ONE

INTRODUCTION

1.1 Background study

Fish feed represents 50-70% of the production costs of commercial fish farming (El-Sayed, 2004). In the past decade, fish nutrition has advanced dramatically with the development of commercial diets that promote optimal fish growth and health. Commercial feed formulations have enabled the aquaculture industry to expand thus, satisfying the increasing demand for high-quality fish products.

In Ghana, the use of complete commercial feed especially by pond farmers is limited due to the relatively higher cost of the feed in comparison to supplementary feeds. Pond farmers, therefore rely on low quality agro by-products like rice bran, wheat bran, groundnut peels among others. However, many research works have examined the as a replacement of fish meal in experimental fish diets. Among these are defatted soybean meal (Fontainhas-Fernandes *et al*., 1999), sunflower cakes (Maina *et al*., 2002), cottonseed meal (El-Saidy and Gaber, 2003) and several others. Even though the results of some of these studies looked promising, agro-by-products are however, nutritionally incomplete because they lack essential amino acids such as methionine and lysine, thus, prolonging the grow-out period and increasing production cost. Although the protein content of soybean meal (42.97%), cottonseed meal (41.79%), groundnut meal/cake (43.75%) are comparable to fishmeal (47.88%) their high inclusions in fish diets often results in reduced growth and/or high mortalities attributed to poor palatability, high crude fibre, reduced digestibility of lipid and energy, imbalance of essential amino acids and presence of anti-nutritional factors such as tannins/saponins (Tacon, 1993; Annongu *et al*., 1996; Francis *et al*., 2001; and Ogunji, 2004). These anti-nutritional factors are found in most potential plant-derived nutrient sources (Agbo, 2008) and they interfere with food utilisation and affect health and production of animals (Makkar, 1993). In addition, the ability of a fish to detect and ingest feed can be dependent on physical properties like pellet density (sinking rate), size (shape, diameter and length), colour (contrast) and texture (hardness) (Jobling *et al.*, 2001). Since most of these feedstuffs are used by local farmers without any form of processing into suitable forms, a lot of the feed when fed to fish remain uneaten leading to poor performance. In spite of all these problems, local farmers continuously rely on agro-by-products because they are readily available and cheaper. Pond culture presently contributes less than 10% of aquaculture production (30,000mt) in Ghana (FAOSTAT, 2013). There is about 3000 ponds providing a total water area of over 10,000 ha (FAOSTAT, 2013). Farmers have the desire to increase productivity but are constrained by the high cost of formulated feeds. In pond culture, formulated feed utilization by the culture fish is optimized while maximizing the gains from natural food sources in the ponds.

Almazan and Boyd (1978) further emphasized that a strong relationship exist between increased primary production and tilapia production. Traditionally, fertilizers were mainly locally available waste products for example, agricultural waste, animal manures derived from cattle, buffalo, goat and sheep, pig, duck, and poultry (Lin *et al*. 1997), and even human excreta, and that early fertilization systems used animal manures and human excrement as a nutrient and energy source for carp polyculture in ponds but recent practices as a result of the Green Revolution introduced the use of inorganic fertilizers (Diana, 2012). But according to Edwards (1993) nutrients released from these waste products may be inadequate or unbalanced even though they are generally cheaper. However, inorganic fertilizers are believed to be hygienic and to produce better water and fish quality (Diana, 2012). These fertilizers contain a combination of nitrogen, phosphorus and potassium in different proportions but are often applied separately. According to Lin *et al*. (1997), nitrogen is applied as either urea, or sodium nitrate or calcium nitrate whereas phosphorus is added as super phosphate, triple super phosphate (TSP) or monoammonium phosphate (MAP). Fertilization of ponds is often done with a number of goals which includes (1) increasing fertility for phytoplankton by applying limiting nutrients (nitrogen, phosphorus and carbon dioxide) to allow increases in overall production, (2) enhancing secondary production and overall productivity of potential food organism (best done with organic manure) (3) growing larger fish and finally (4) to increase fish density (Diana, 2012).

Research by Green (1992) and Diana *et al.* (1994) have shown that the growth performance of tilapia in ponds could be significantly improved by use of organic and inorganic fertilizers with formulated feeds at reduced ration. Fertilization in fish ponds is known worldwide to improve pond productivity by promoting the growth of phytoplankton thereby increasing natural food available to fish (Boyd and Tucker 1998). Other works by Hepher (1962), Knud-Hansen *et al*. (1993), and Teichert-Coddington *et al*. (1992) that tried different fertilization rates reported greater production levels. Shroeder (1980) reported that natural food could account for as much as 50-70% of total available food for tilapia in pond culture even when a complete diet is provided. Diana (2012) suggested that the main goal for fertilization should be to apply fertilizer at the rate needed by algae and not on a set schedule.

Shang (1990) indicated that even though economic research is primarily important, it is often neglected by aquaculturist. Furthermore, Yi and Diana (2008) suggested that economic analysis to determine efficiency of resource allocation and management practices is essential in aquaculture. Moreover in Ghana, many tilapia pond fish farmers complain of poor returns and so do not see aquaculture as a lucrative business (Fish farmer, personal communication). In spite of all these, little or no attempt has been made to ascertain the cost-effectiveness of using inorganic or organic fertilizers to improve fish pond productivity in Ghana.

1.2 Objectives

The objectives of this study are therefore to

1) Compare growth performance of Nile tilapia fed full ration of commercial type feed against those fed half ration but with pond fertilization to boost natural food production.
2) Develop a simple enterprise budget to compare income generation potential of tilapia maintained under the two different pond management regimes.

CHAPTER TWO

LITERATURE REVIEW

2.1 World Aquaculture

The demands on capture fisheries by growing populations especially in poorer countries have almost erased the historic perception that the oceans were limitless and thought to harbor enough fish to feed an ever-increasing human population (Tidwell and Allan, 2001). Globally, fish is a first class high-quality animal protein (Tidwell and Allan, 2001) and its consumption cuts across ecological, socio-economic, and cultural as well as religious boundaries (Agbo, 2008). According to FAO (2007), about 15.5 % of fish consumption was reported in 2003. The increasing demand in fish and fish products across the world has put great pressure on the capture fisheries which is done mostly in the sea. Over the past decades, marine resources have been exploited and are presently beyond the stage of sustainability. The FAO in 2012 reported that global capture fisheries production has stagnated and is now approximately 90 million tons.

The sure means of bridging the gap between the increasing demand and supply of fish and fish products is through aquaculture as suggested by Agbo, (2008). Swann (1992) states that world fish farming was first practiced as long ago as 2000 B.C., in China and White *et al.,* (2004) mentioned that the advent of aquaculture dates back several millennia, though its exact origins are unknown. Aquaculture is defined by FAO (1990) as the farming of aquatic organisms including fish, molluscs, crustaceans and aquatic plants with some sort of intervention in the rearing process to enhance production, such as regular stocking, feeding and protection from predators. Reports from FAO (2012) showed impressive statistics of aquaculture benefits; in that more than one out of every ten livelihood worldwide is supported by aquaculture, even providing opportunities to increase food security, alleviate poverty, promote economic growth and ensure improved use of resources, which are linked to people's livelihoods. In this regard, aquaculture is now considered as the fastest growing animal producing sector worldwide generating average annual growth rate of 8.8% per year since 1970, compared with only 1.2% for capture fisheries and 2.8% for terrestrial farmed meat production systems (FAO, 2007). Although, aquaculture seems to be increasing at a high rate, it is still unable to supply the needed quantity. The question therefore is "how do we increase aquaculture production capacity?". Sadiku and Jauncey (1995) suggested that increasing primary, intermediate and terminal productivity capacities of our natural aquatic ecosystem and creation of productive artificial aquatic ecosystems through proper planning, development and management could be the solution.

2.2 Aquaculture in Africa

Fish has been the primary dietary protein source for many of Africans with a consumption rate of 9.1 million tonnes and 9.1kg per capita (The Fish Site, 2012). Cocker (2014) mentioned that there is significant pressure for aquaculture to continue to develop as indigenous capture fisheries are believed to be either over-exploited or stagnating and therefore incapable in supplying growing populations and an increasingly urbanized market. Aquaculture production actually began to show noteworthy increases in 1995 and has subsequently grown with an accumulative volume of over 942,000 metric tonnes produced in 2008 (Hall *et al*, 2011). Currently Africa ranks low in the domain of aquaculture production as compared to Asia and Europe; producing less than 1% of the world's total output (FAO, 2010). Nonetheless a report by Cocker (2014) suggests that there is a rise in the aquaculture sector on the African continent and this has come about as nations begin to realize the importance and potential of aquaculture in terms of poverty alleviation, food security and also as a means of reducing the current volumes of imported fish needed to supply domestic appetite. Though Africa is putting in efforts to intensify aquaculture, an estimate of 300% of food production is to be generated by 2050 in order to meet the challenge of providing to tremendously increased populations on the continent (Cocker, 2014).

2.3 Aquaculture in Ghana

Ghana is a tropical country and has an estimated land area to be approximately 238,500 square km (Dankwa *et al*. 1999), located on the west coast of Africa between latitude 4^{o} 30'N and longitudes 1^{o} 10'E to 3^{o} 15'W and 1^{o}E bounded to the north, west, east and south by Burkina Faso, Ivory Coast, Togo, and Gulf of Guinea of the Atlantic Ocean, respectively (BODFAM, 2003) (**Figure 2.1**). Ghana has a coastline of nearly 540 km and a continental shelf of about 24,000 km^2. The entire country is traversed by many water bodies (rivers and lakes) with over 50 lagoons of different sizes perceived as huge natural potentials for aquaculture development in Ghana (Prein *et al*., 1996).

According to Aggrey-Fynn (2001), fish is recognized as the most important source of protein supplying 60-70% of natural animal protein to the people of Ghana. As a result, Ghana depends heavily on the marine and other numerous rivers and lagoons for its fish and fish products.

Figure 2. 1: Map of Ghana (Source: Cobbina, 2010).

Generally, the fisheries sector is estimated to have contributed 3% of the total national GDP and 5% of the agriculture GDP of Ghana (FAO, 2011) and supports the livelihood of about 10% of the population (Seini *et al.*, 2004). According to Asmah (2008), the Directorate of Fisheries estimated the annual fish requirement for Ghana to be around 880,000 tonnes but unfortunately only about half of this amount is provided by the capture fisheries leaving a deficit of almost 460,000 tonnes. The deficit is, however, made up for through fish imports which were estimated at 213,000 tonnes in the year 2007 and valued at US $262 million (DoF, 2007) which is still less than half the deficit. To bridge this gap of huge deficit, aquaculture is a proposed means to meet the fish needs of the nation and add-on to the capture fisheries. The aquaculture sector in Ghana is still in the developing stage even though it started about 50 years ago (Cobbina, 2010). In general, aquaculture development in Ghana over the years has been based on two different approaches: (a) targeting communities for adoption of communally owned and managed ponds. This was a means of bringing benefits in the form of fish for nutrition and cash to communities so as to reduce poverty whereas (b) the second targeted individuals or households who were landowners or entitled to making management decisions and were the only beneficiaries (Cobbina, 2010). Basically, aquaculture is not a marine activity in Ghana and so the abundance of rivers and lagoons of different sizes were seen as huge natural potentials for aquaculture development in Ghana (Prein *et al*., 1996). According to Balarin (1988) aquaculture had long begun and was traditionally practiced in diverse ways such as the 'atidjas' (brush parks in lagoons and reservoirs), and 'hatsis' (fish holes) and 'whedos' (mini-dams in coastal lagoons). The culture of freshwater clams (*Egeria radiata*) in the lower Volta has also been practiced where young clams are collected and "planted" in "owned" areas of the river (Prein *et al*., 1996). However, FAO (2000) reported that modern forms of aquaculture became popular in Ghana in the 1950s when the Department of Fisheries began to construct ponds for experimental purposes as well as reservoirs for irrigation and as sources of water for animals in Lawra in the Upper West Region. Besides, in a report by FAO (2009), some of these reservoirs were also to serve as hatcheries to support the culture-based reservoir fishery development programme instituted by the colonial administration as a way of increasing livelihood opportunities. Thereafter, Asamoah *et al*. (2012) mentioned that the first scientifically managed aquaculture facility was put up by the University of Ghana at its Agricultural Research Station situated near Nungua in 1959. Within this period Asmah (2008) reported that the number of fish farmers rose to about 1000 with over 2000 earthen ponds with a total surface area of about 350 hectares. Furthermore, in the early 1980s, aquaculture became more popular especially in the Ashanti, Central, Eastern, Western and Greater Accra regions as a result of a massive campaign launched by the government to encourage pond fish culture (Mensah *et al*., 2006). This saw a lot of private entrepreneurs showing real interest in aquaculture (Manu, 2004). But, these interests according to Prein *et al*. (1996) were not sustainable due to several reasons including inadequate technical support for new adopters. These technical support included pond siting, pond size, necessity of drainability, design of appropriate technology inflows and outflows, pond management, fish species, fertilization, feeding, harvesting strategies, marketing and processing. In a report by FAO (1990), by the end of the 1980s, about 23% of ponds constructed had been abandoned and those remaining in operation were not very productive.

The major types of fish species cultured in Ghana include Tilapia, the Catfishes (*Clarias sp*, *Heterobranchus sp*), and *Heterotis niloticus*. Despite all the effort by past governments to give a face-lift and promote aquaculture in the country, not much impact has been seen in terms of fish production (MoF, 2008). This according to the Directorate of Fisheries could be attributed to several constraints which include the lack of good quality seed (fingerlings) and suitable feed (Moehl *et al.*, 2006), inadequate supply of seed (Cobbina, 2010), weak extension support (Ridler and Hishamunda, 2001) and overzealous and unplanned promotion of the technology coupled with lack of technical know-how (Asmah, 2008). In addition to this, Anane-Taabeah *et al.* (2012) reported that, the difficulty in accessing credit facilities from financial institutions and the lack of organized markets (Moehl *et al.*, 2006) are also some of the major challenges. Above all, most people in Ghana see aquaculture as a part-time, limited investment hobby due to the poor regard they have for aquaculture as an economic activity (Gitonga *et al.*, 2004; and Hiheglo, 2008). However, in the last five years, fish farming or aquaculture has become an enterprise acknowledged by both urban and rural communities, and is currently gaining ground especially in urban centers. Over the last decade, aquaculture production in Ghana has seen an annual average growth rate of 12.4% (Asamoah *et al.*, 2012) which according to FAO (2011), production peaked to 6000 tons, valued at US$ 11.4 million between 2001 to 2002 (**Figure 2.2**) and with US$ 1.5 million estimated to be the worth of production from ponds and culture-based fisheries a year. According to Agbo (2008), over-estimation of aquaculture production before 2003 might have led to the high production levels until a proper survey was carried out by the Directorate of Fisheries afterwards accounting for the decline in 2003. However, there has been a gradual increase ever since.

Cobbina (2010) mentioned that the aquaculture sub sector in Ghana is comprised largely of small scale subsistence farmers who consider fish farming as a source of livelihood. They often practice extensive farming with very few commercial operators.

Figure 2.2: Ghana's annual Aquaculture production from 1996 to 2006 (Source: FAO, 2007).

In the FAO's (2010) report, fish production rate from aquaculture from small-scale operators was estimated to be 1.5tons/ha/yr in 2007. According to records from the Directorate of Fisheries (2009), aquaculture in Ghana has seen an exponential growth rate with production values ranging from about 500 metric tons in 2003 to a little over 7000 metric tons in 2009. In Ghana, aquaculture with its principal form as fish farming is practiced at different levels: extensive, semi-intensive, intensive, and integrated (Swift, 1993).

2.4 Levels of Aquaculture

In Ghana, there are three main levels of aquaculture namely; extensive, semi-intensive and intensive (commercial). Though the last two are the most common, lately most stakeholders are shifting to intensive as there is continuous rise in the demand for fish protein (Kassam, 201).

2.4.1 Extensive fish farming

Extensive fish farming is the most natural method of farming fish where fish are not given additional feed (Tetreault, 2009). Food sources in this system of farming are almost totally dependent on the natural sources; which include zooplankton or benthic animals, and on phytoplankton (basically pelagic algae). In this system, stocking density is low and the farmer has little or no influence on the culture environment and the cost of production is far less expensive. The farmer only returns after a while to harvest whatever yield that is available. Swift (1993) revealed that a similar system known as ranching is practiced in Asia, USA and Scandinavia. In this system, fish are reared on the farm to a certain age and then released without control or additional food (supplement) into large bodies of natural waters where they complete their life cycle and grow to maturity. Increased intensification uses up more natural resources and causes greater environmental degradation. This system is practiced on a subsistence level.

2.4.2 Semi-intensive fish farming

Tetreault (2009) explained that semi-intensive farming requires some supplementary feeds and fertilizer inputs. Additionally, the system sometimes relies on formulated pelleted feeds known as complete feeds, where a large amount of this feed remains uneaten as waste. However, the natural food forms the main food source in semi-intensive fish farming. The fertilizer input enhances the production and abundance of the natural food. Furthermore, the stocking density is higher compared to the extensive system and the culture environment is monitored and somehow controlled so as to ensure good water quality and better yields. Feeding in this system may be done two or three times or even once a week while fertilizer is applied at least once per week (Nilson and Wetengere, 1994) or month. The cost of production is moderately high due to the fertilizer input and the addition of supplementary feed. Fish output is increased compared to the extensive system of farming.

2.4.3 Intensive farming

Intensive fish farming is practiced on commercial basis. It requires high input, high fish density, and results in high output. In this system, freshwater, sufficient oxygen and food are provided through integration of massive water purification system in the fish farm. The knowledge level of the farmer about aquaculture or fish farming is high and there is often close monitoring of water quality and all other production parameters (Rao, 2012). Feeds at this level of farming are mostly complete diets (FAO, 2009) that are fed everyday throughout the production period. The complete diets may either be locally prepared or imported often in the form of pellets. The cost of production is very high and as a result very few farmers are able to venture into this level of farming. However, the output is enormous compared to the other levels discussed above. This commercialized form of fish farming is believed to have contributed to the increase production in Ghana accounting for about 75% of the production and also providing employment (DoF, 2007).

2.5 Types of Aquaculture/Culture systems

Most farmers in Ghana use earthen ponds in the culture of fish. However, there are different types of culture systems available but their use is dependent on the size of the farm and the level of farming. According to Swann (1992), culturing systems could be grouped into (a) Cage culture system, (b) concrete tank culture system, (c) earthen pond culture system and (d) recirculation systems. These production systems are being used at varying intensities (Machena and Moehl, 2001). Other systems of culture include the pen, and raceway systems, which are not commonly practiced (Awity, 2005) especially in Ghana.

2.5.1 Cage culture

Cage culture like most other types of aquaculture according to Ling (1977) began in the Southeast Asia even though it is thought to be of comparatively recent origin. This traditional type of culture has been practiced since the last century (Ling, 1977) throughout the world. This technology of raising fish according to Beveridge (1984) involves confining fish in enclosures often nets usually floated in rafts, and held to the water bottom by an anchor or connected to the shore by wooden walkways and rope. The system allows easy flow of water between the fish in the cage and the lake, pond, reservoir or irrigation dam to ensure good water quality in and around the cage and the removal of waste into the surrounding water. Swann (1992) further explained that cage culture of fish uses existing water resources like lakes or ponds but encloses the fish in a cage or basket (**Plate 1 AB**), which allows water to pass freely between the fish and the pond or lake. The FAO (2007) reported that the cage aquaculture subsector has shown rapid growth during the past 20 years and is still undergoing rapid changes as a result of pressures from globalization and increasing demand for aquatic products. Cage aquaculture was suggested by Petr (1994) and Blow and Leonard (2007) as an astute way of exploiting inland water resources to achieve development.

Current interest in cage aquaculture has increased in the last two decades in Ghana, increasing from only two recognized cage farm companies in the late 1990s (Blow and Leonard, 2007) to over sixty cage farms by the end of 2012 at the Asuogyaman District alone (Department of Fisheries, Akosombo, unpublished data). Most of these cage farms are located on the Volta Lake with a few found in irrigation dams in Akuse (Asmah, 2008) and reservoirs. However, it is recognised in the commercial sector and accounts for less than 5% of existing farms (Cobbina, 2010). This form of farming technology is mostly explored at the intensive level of fish farming in lakes and reservoirs. Anane-Tabeah *et al.* (2012) revealed that apart from the many advantages cages share with pond aquaculture, cage aquaculture has an added advantage of exploiting existing water bodies, especially in areas where land and ground water are scarce, as well as enabling higher stocking densities. Moreover, there are several different materials that have been used in designing and building cages since its inception ranging from simple bamboo sticks and grass solely interwoven together, depending on type of species (fish) to be raised and cultural practice to be employed (Olivares, 2003) to a more complex high technology plastic materials (**Plate 1 CDE**).


A
B
C
D

Plate 1: The different materials and designs (A-E) in cage building.

2.5.2 Earthen pond culture

Swann (1992) posited that earthen ponds (**Plate 2**) are the most common among all the fish farming production systems that are in use and forms majority of aquaculture farms in Ghana, constituting about 98% of the existing farms Cobbina (2010). They may be constructed in several forms or shapes including rectangular, square, circular, or triangular according to the topography of the land and sometimes what the farmer desires. Nonetheless, rectangular ponds are the most common. These farms are dominant in the southern and middle belts of the country according to Cobbina (2010) and rely on natural productivity while others supplement with agricultural by-products (Awity, 2005). Asmah (2008) estimated that fish production in ponds could range from about 35kg to about 25,750kg/ha/year with maximum production from about 60% of fish farmers ranging from less than 1,000kg/ha/year to 5,000kg/ha/year. Furthermore, about 10% of commercial pond fish farmers exceed production levels of 20,000kg/ha/year (Asmah, 2008).

Plate 2: Earthen pond.

2.6 Culture species

In Ghana, the types of fishes cultured by fish farmers include *Sarotherodon galilaeus and Hemichromis fasciatus;* several species of tilapia such as *Oreochromis niloticus*, *Heterotis niloticus* and *Tilapia zillii* as well as catfish species mainly *Clarias gariepinus* and *Heterobranchus bidorsalis* (FAO, 2014). Tilapia which is the major species farmed, constitutes about 80 percent of aquaculture production in the West African sub-region. Catfishes (*Clarias* sp., *Heterobranchus* sp.) and *Heterotis niloticus* account for the remaining 20 percent (FAO, 2014).

2.6.1 *Clarias gariepinus* (African catfish)

The African catfish is an omnivorous, scale-less hardy freshwater fish which has an almost Pan-African distribution, ranging from the Nile to West Africa and from Algeria to Southern Africa (FAO, 2010). *Clarias gariepinus* is generally regarded as one of the most important tropical catfish species for aquaculture. The African Catfish (*Clarias gariepinus*) naturally tend to live in calm waters with vegetation though the living conditions in such an environment can be harsh (Isyagi *et al*., 2009). The African catfish is less prone to disease and does not have high water quality requirements. It tolerates high concentrations of ammonia (NH_3) and nitrite (NO_2) in the water and low oxygen concentrations are also tolerated because the fish utilizes atmospheric as well as dissolved oxygen. It grows fast and feeds on a large variety of agriculture by-products (De Graaf and Janssen, 1996). It can be raised in high densities resulting in high yields (6–16 tons ha^{-1}year^{-1}); and fetches a higher price than tilapia as it can be sold live at the market. The culture of this species is being practiced in the Ghana and it is considered as the second largest aquaculture species after tilapia. In Ghana, the most preferred method for processing catfish commonly known as "adwene" in the Akan language is by smoking.

2.6.2 *Oreochromis niloticus* (Nile tilapia)

Tilapia is one of the most important species for the 21st century aquaculture and is produced in more than 100 countries (Fitzsimmons, 2000). Nile tilapia *Oreochromis niloticus* (Linnaeus, 1758) is a laterally compressed deep-bodied fish with cycloid scales and long dorsal fins. It is a tropical freshwater species and is native to Africa and the Middle East (Trewavas, 1983). Most tilapia are planktonic filter feeders (Popma and Masser, 1999). Nile tilapia easily adapt and thrive in a variety of conditions making it favourable for aquaculture due to its ability to tolerate a wide range of environmental conditions, fast growth, successful reproductive strategies, and ability to feed at different trophic levels (Grammer *et al.*, 2012). *Oreochromis niloticus* is the most cultured species in West Africa accounting for about 80% of aquaculture production (FAO, 2014). The Nile tilapia is a delicacy for Ghanaians and it is consumed in many ways by households. Unlike catfish, Tilapia is processed diversely by smoking, salting, grilling/ roasting etc.

2.7 Feed and Feeding in Fish farming

Due to its biological nature and production environment, feeding aquatic organisms is to a large extent different from feeding terrestrial livestock such as cattle and poultry (Cocker, 2014). There are mainly two types of food cultured fishes rely on to grow. These are naturally produced fish food inside the pond, and supplemented fish food supplied from outside the pond to the fish. Natural fish food consists of algae (mainly phytoplankton) and tiny animals (zooplankton) and benthic organisms produced in the pond and are often enhanced by fertilizing the pond. Fertilization in fish ponds is known worldwide to improve pond productivity by promoting the growth of phytoplankton which forms the base of several food chains thereby increasing the natural food available to fish. Shroeder (1980) reported that natural food could account for as much as 50-70% of total available food for tilapia in pond culture even when a complete diet is provided. The farmer however, has no physical control over the quantity of the plankton as well as how much protein and vitamins the plankton can produce.

This natural food production can be supplemented, to a bigger or lesser extent, by the addition of artificial feeds (Assiah *et al*., 2004) like commercially pelleted feeds. Supplementary or commercial fish feed is provided by the farmer and supplied to the fish regularly to increase the amount of fish food in the pond. In semi-intensive systems supplementary feeding is often done in combination with fertilization. According to Isyagi *et al*., 2009 the strategy is to provide an alternative source of energy to the fish, while the plankton provides the fish with their protein and vitamin requirements. De Graaf and Janseen (1996) suggested that supplementary feed (e.g. sunflower cake, maize bran, etc.) for culturing catfish could contain 30–35% digestible protein (about 40–50% crude protein) and 2500–3500 kcal digestible energy kg^{-1} feed and about 3500–4500 crude energy kg^{-1} feed. Most commercial aquafeeds are in pellet form and extruder produced, and varies in formulation and physical size depending on the species and life stage in question.

2.8 Improving fish production in ponds

To guarantee success of fish production, good quality feeds at reasonable prices should be available to farmers, as they optimize their feed use by instituting appropriate on-farm feed management practices (FAOSTAT, 2013). The first step in the intensification of pond systems is the addition of basic nutrients in the form of fertilizers. Bardach *et al*. (1972) proposed that based on the quantity and quality of nutrients added to enhance, supplement, or replace natural pond productivity, pond culture of fish can be practiced at various levels of production intensity.

2.9 Fertilization in Fish ponds and Primary productivity

FAO (2012) reported that production of fish under small-scale production system is low due to small pond size coupled with poor management as a result of poor feeding and irregular pond fertilization. Typical extensive ponds produce around 500 kg/ha/yr (Machenal & Moehl, 2001), but the addition of fertilizer can significantly increase this to several metric tonnes/ha/year. In fertilized ponds, extra nitrogen, phosphorus, lime and possibly organic material like manure are added to the pond to enhance natural productivity (Isyagi *et al*., 2009). There are two basic types of fertilizer - organic and inorganic. In many African countries there are substantial volumes of organic fertilizers in the form of animal manure like cattle, goat, sheep, pig, duck, and poultry (Lin *et al.* 1997). Majority of farms in Sub-Saharan Africa is pond based and often utilise fertilizers to induce planktonic biomass in the production environment in order to feed their stock (El-Sayed, 2013). Organic manure is mostly used by small-scale farmers to fertilize their ponds with poultry droppings being the most typical organic manure used to stimulate tilapia growth because it is soluble in water, and high in nutrient content. Often, nutrients from these sources may be inadequate or unbalanced but are generally cheaper and ecologically efficient (Edwards, 1993). The use of inorganic fertilizers is quite minimal due to its high cost**.** Aquaculture ponds are fertilized to increase the available natural food for fry or larval fish (Brunson *et al*., 1999) since young tilapia are mainly particulate feeders, while fish >35 g transition to filter feeding - mainly on phytoplankton, rotifers, and small zooplankton (Bowen 1982; Diana *et al.*1990). Management strategies of fish ponds under small-scale systems involve the use of fertilizer to encourage growth of natural food and to improve the level of dissolved oxygen (Chenyambuga, 2012). In a report by Diana (2012) however, tilapia pond farmers have different goals when fertilizing their ponds, but their ultimate objective is to increase yield through increased primary production and cited the first goal as increasing fertility for phytoplankton by applying limiting nutrients, and enhancing secondary production and overall productivity of potential food organisms as the second fertilization goal, and the third goal as improving water quality. These nutrients were indicated by Boyd (1990) to be mainly nitrogen and phosphorus. Diana (2012) further reported that increased primary production usually results in increased tilapia production. Furthermore, due to the ontogenetic ability in foraging by fish, growing tilapia to larger size require different fertilization or feeding strategies. Apart from animal manures, waste plant material composed of agricultural by-products, other waste terrestrial vegetation, and even aquatic vegetation have at times been used in composting systems as fertilizers in aquaculture (Diana, 2012).

On the other hand, of late, inorganic fertilizers became more common in aquaculture after the World War II, since they are believed to be more hygienic and produce better water and fish quality (Diana, 2012). These materials are mainly supplied to provide nitrogen and phosphorus. Some typical fertilizer compounds for nitrogen include urea, sodium nitrate, ammonium nitrate, and calcium nitrate, while phosphorus is added as superphosphate, triple super phosphate (TSP), monoammonium phosphate (MAP), and diammonium phosphate (DAP) (Lin *et al*. 1997).

2.10 Economic analysis of farm-produced fish

In the study of aquaculture, economic research is often neglected by aquaculturists, although it is regarded as of primary importance (Shang, 1990). Economic analysis is essential to evaluate the viability of investment in aquaculture, to determine efficiency of resource allocation and management practices, and to evaluate usefulness of new culture technology. The implications of feed type, formulation and feed management practices on the economics of the farming operation are important issues that farmers need to take into consideration when planning their farming activities (Hasan and New, 2013). While these economic interrelationships are often difficult for farmers to assess, they can have a profound effect on the profitability of the farming operation (FAO, 2010; Shipton and Hecht, 2013).

In many countries, particularly in Africa, aquaculture is almost entirely for subsistence, with little surplus production being sold in the rural market (Rao, 2012). Because of this most pond fish farmers give little or no attention to develop a simple enterprise budget that gives them an idea of the profitability of their business activity. Engle and Neira (2005) describe an enterprise budget as one that provides a generalized snapshot of the cost and returns of an enterprise for a particular period of time, at least a year. Even though in aquaculture one production cycle is often six months. Furthermore, Engle and Neira (2005) identified important items that are needed to be included in an enterprise budget as variable cost such as fingerlings, feed, fertilizer, lime, labour among others, and fixed cost like equipment, ponds and so on and then gross revenue and net revenue. Economic analysis in aquaculture is a relatively recent practice and not much work has been reported on its social and economic impacts (Egna and Boyd 1997). In semi-intensive and intensive aquaculture systems, feed costs typically account for between 40 and 60 percent of production costs (De Silva and Hasan, 2007). As feed represents one of the highest operating costs in aquaculture systems (Hasan, 2007), feed choice and feed management practices have a significant impact on the economic performance of a production system.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study area

The study was conducted from January 2013 to September 2013 at the Renewable Natural Resources Management farm, Kwame Nkrumah University of Science and Technology (KNUST), located in Kumasi (longitude 6.35°-6.40° and 1.3°-1.35°) in the Ashanti Region. Kumasi falls within the wet sub-equatorial type with average temperature ranging from 21.5°C to 30.70°C giving it the moist semi-deciduous forest cover type (KMA, 2006). In all, six ponds ranging between 200 – 300m^2 were used.

3.2 Pond preparation

Four small ponds with surface area 200m^2 and two 300m^2 ponds were drained, dried (Plate 3A) and later de-silted by scooping out accumulated mud (Plate 3B) and then limed at a rate of 1kg agriculture lime per 10m^2 (Plate 4) to ensure that fish eggs and fingerlings left from previous production were eliminated. The pond dykes and surroundings were cleared to avoid predators from having easy access to the ponds. The ponds were then filled with water and treatments randomly assigned to the ponds.

Plate 3: (A) Drying of Experimental ponds and (B) Scooping of mud from pond after drying.

Plate 4: One of the limed ponds.

3.3 Fingerlings and stocking

Sex-reversed Nile tilapia (*Oreochromis niloticus*) fingerlings were initially obtained from Crystal Lake Limited, Dodi-Asantekrom, Eastern Region, Ghana. Fish were nursed to an approximate size of 25g per fish and stocked at approximately 2 fish per m^2 and at 10% compensation for mortality in all the experimental ponds. In all, 450 fishes were stocked in the $200m^2$ ponds and 650 fishes in the $300m^2$.

3.4 Fertilizer application

The fertilizers used in this study were purchased from the local market. Ponds were fertilized with mono ammonium phosphate (MAP) at 2g per m^2 and Urea at 3g per m^2; strictly according to the phytoplankton abundance, using secchi-disk depth as a proxy for abundance. The right proportions of MAP (Plate 5A) and Urea (Plate 5B) for each half feed pond were measured into a container, dissolved with approximately 15 litres of pond water and fertilizer solutions were broadcast over the surface of pond.

Plate 5: (A) Mono Ammonium Phosphate (MAP) and (B) Urea used in the study.

3.5 Experimental diet and Feeding

Commercial floating feed (Plate 6A) containing approximately 33% crude protein was used in this experiment. Fish were fed (Plate 6B) with the 33% protein diet (2.5mm) for the first two months of the trial followed by a 30% protein feed pellet size (4.5mm) for three months. Fish received a 6.0mm pellet from the sixth month until the end of the trial. Fish receiving the full feed ration were fed 3-6% of their body weight and those receiving the half feed ration and fertilizer application received 1.5–3% of their body weight. Feeding was done twice daily between 9:00am and 10:00am in the morning and 3:00pm to 4:00pm in the afternoon. Feeds were adjusted to determine new rations after every fish sampling.

Plate 6: Commercial floating feed used and (B) Student feeding fish during the study.

3.6 Data collection and sampling

Fish sampling and water quality data were collected monthly and fortnightly, respectively within the study period from February to July, 2013.

3.6.1 Fish sampling

About 50 fish in each pond were sampled (Plate 7) every month and their average body weight determined with a weighing balance (MITSUBA model: MB-320) to monitor growth and adjust feed levels.

Plate 7: Sampling of fish at the end of the month.

The growth performance and feed utilization of fish from each pond was determined using the following parameters:

3.6.2 Absolute Growth (AG)

Absolute growth of fish per day in each pond was measured as follows:

$$Absolute\ Growth = \frac{Wf - Wi}{T}$$

Where $Wi = Initial\ weight, Wf = Final\ weight\ and\ T = time\ (\ in\ days)$.

Source: Agbo *et al.*, 2011.

3.6.3 Specific Growth Rate (SGR)

SGR of fish in percentage per day was calculated using the formula below:

$$Specific\ Growth\ Rate\ = \frac{In\ (Final\ weight) -\ In\ (Initial\ weight)}{Time\ interval\ (in\ days)} \times 100$$

Source: Agbo *et al*., 2011.

3.6.4 Feed Conversion Ratio (FCR)

This was to determine how much of the feed consumed actually goes to build body tissues. It refers to the ratio of the feed fed to the weight gained. The formula for FCR is indicated below:

$$FCR\ = \frac{Amount\ of\ feed\ fed\ (kg)}{Weight\ gain\ (kg)\ by\ the\ fish}$$

Source: Agbo *et al*., 2011.

3.6.5 Survival Rate

The survival rate shows the percentage of fish left at the end of the experiment. It was calculated as:

$$Survival\ Rate\ = \frac{Number\ of\ fish\ at\ the\ end\ of\ the\ experiment}{Number\ of\ fish\ at\ the\ beginning\ of\ the\ experiment} \times 100$$

3.6.6 Weight Gain (g)

$$Weight\ Gain\ = Final\ weight - Initial\ weight$$

Source: Ahmad *et al*., 2011.

3.6.7 Feed Efficiency Ratio (FER)

Feed efficiency ratio is the inverse of the FCR. It is given as:

$$FER = \frac{Weight\ gain\ (kg) by\ the\ fish}{Amount\ of\ feed\ fed\ (kg)}$$

Source: Ahmad *et al*., 2011.

3.6.8 Feed Intake (FI)

This was to determine the amount of feed taken per fish per day in grams. It refers to the total feed intake per fish over the number of days. It is given by:

$$Feed\ Intake = \frac{Total\ feed\ intake\ per\ fish}{Number\ of\ days}$$

Source: Agbo *et al*., 2011.

3.7 Physicochemical parameters

In situ data on dissolved oxygen (DO), total dissolved solids (TDS), conductivity, temperature, and pH were collected using the Hanna (HI 9828) multi parameter probe (Plate 8) on weekly basis throughout the study period.

3.7.1 Secchi depth

Secchi readings were measured in each pond by the use of a Secchi-disk (Plate 9) every week throughout the study period. These readings were measured at the shallow, middle and deeper portions of the pond. The mean weekly value for each pond was also calculated.

Plate 8: Hanna (model: HI 9828) Multi-parameter probe.

Plate 8: Secchi disk used during the study.

3.7.2 Chlorophyll-a determination

Chlorophyll-a was used as a proxy for primary productivity. Water samples for Chlorophyll-a analysis were collected between February and July, 2013 fortnightly. Sampling materials used include 500ml plastic bottles covered with a black polyethylene to prevent light penetration. The sampling bottles were rinsed with distilled water, followed by rinsing with water from the pond to be sampled before use. Samples were collected at a depth of about 30cm (Plate 10) and placed on ice at a temperature of about 4^0C and transported to the laboratory for chlorophyll-a analysis.

The Chlorophyll-a level in the pond water were determined at the Department of Pharmaceutics Laboratories at KNUST. Chlorophyll-a was measured according to the standard procedure described in HMSO (1983). About 50ml of the pond water was filtered under vacuum through a Whatman GF/C filter paper to collect the phytoplankton. The filter paper was placed in a centrifuge tube containing 10ml of methanol. The loosely capped tube was briefly heated in a water bath at 65-70˚C in a fume cupboard. The tube was removed and left for 5 minutes in the dark. The filter paper was removed from the tube after pressing it against the side of the tube to drain as much methanol as possible. The tube was then centrifuged for 8 minutes at 3500 rpm to obtain a clear extract for spectrophotometric determination. Absorbance was measured after a baseline correction for methanol at wavelengths of 665nm and 750nm before and after acidification with 0.1M HCl to determine the chlorophyll-a concentration.

Chlorophyll-a concentration in the pond water was determined using the equation below:

$$\textbf{Chlorophyll-a } (\mu g l^{-1}) = \left(\frac{13.9\ x\ 3(Ah-Aj)\ x\ v}{d\ x\ V}\right)$$ Source: HMSO, 1983.

Where Ah = absorbance at 665nm

Aj = absorbance at 750nm

v = initial volume of methanol in ml (10ml)

d = cell length of cuvette in cm (1cm)

V = sample volume in litres (1L)

Plate 10: Student collecting water for analysis.

3.9 Fish Sales and Marketing

At the end of the study, fish were harvested and marketed every Friday at the premises of the Faculty of Renewable Natural Resources, KNUST (Plate 11). Fish was mainly patronized by the lecturers and staff of the faculty, some students and a few local people from Ayeduase, a nearby community. Fish patronage was not encouraging for the first two weeks but gradually improved till all ponds were completely harvested. Fish were sold in two categories as large (260-330g) or small (200-250g) per piece in accordance with the local market price.

Plate 9: A customer buying fish from the sales point at the Faculty of Renewable Natural Resources, KNUST.

3.10 Cost-Benefit Analyses

The effectiveness and efficiency of experimental feeds was ascertained by developing an enterprise budget that compared the cost of production basically in terms of cost of fingerlings, fertilizer use, feed fed and labour, and the revenue accrued from the sales of fish from ponds fed the experimental feed with that from those fed full ration. Prices of items were based on the prevailing local market price.

3.11 Statistical Analyses

The student t-test was used to test for significance difference at $p < 0.05$ for the following variables: growth, specific growth rate, weight gain, feed conversion ratio, feed intake, survival rate, gross yield, net yield, and the physicochemical variables. Correlation methods were used to evaluate the relationship between chlorophyll-a, growth, and physiochemical variables. All analysis were done with GraphPad Prism version 5.01 Software for Windows and presented in graphs and tables as means ±SD.

CHAPTER FOUR

RESULTS

4.1 Growth performance of Nile Tilapia (*Oreochromis niloticus*)

Growth performance was assessed by the following indicators; Final weight (FW), Weight gain (WG), Specific growth weight (SGR), Survival rate (SR), Gross yield (GY) and Net yield (NY). Generally, there was a steady increase in fish weight from January to March but growth slowed slightly between March and April. Thereafter, a gradual increase in growth was recorded from May till the end of the grow-out period in both treatments but a slowed growth occurred again for the full ration between June and July as shown in Figure 4.1.

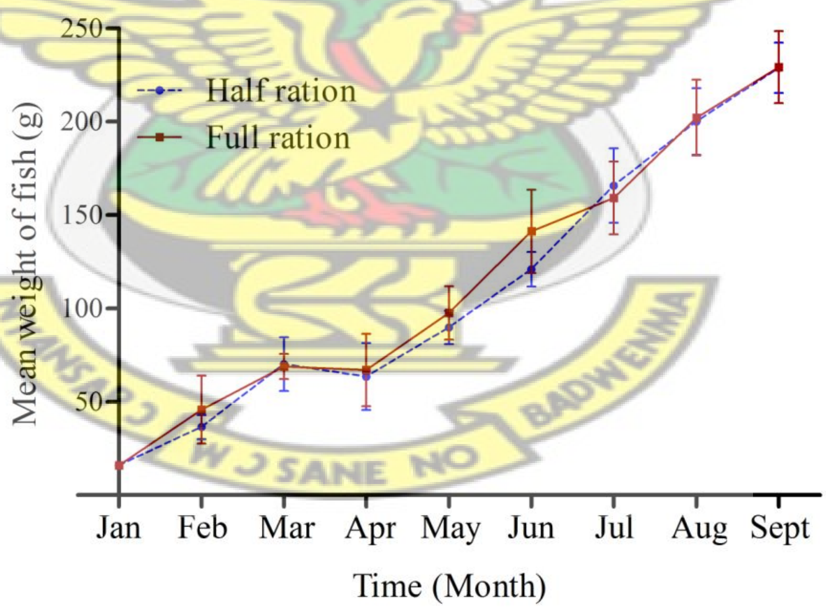

Figure 4.1: Growth performance of Nile Tilapia fed at full ration and half-ration with fertilization in ponds.

The SR was similar and estimated at 62.6 ± 20.3% and 63.9 ± 12.9% for full ration and half ration treatments, respectively (Table 4.1). Fish weight increased from an initial mean weight of 25.0 ± 8.0g and 25.8 ± 8.5g at the start of the trial to 229.1 ± 33.5g and 228.7 ± 23.3g for full ration and half ration treatments, respectively (Table 4.1). The SGR in both treatments were similar with the full ration recording mean value of 1.2 ± 0.2%/day and 1.2 ± 0.3%/day for half ration. Mean WG was also similar at 204.2 ± 36.3g for the full ration while the half-ration was 202.9 ± 23.8g as shown in Table 4.1. There were no significant differences (Appendix B) between the two treatments for all the growth parameters assessed.

4.1.1 Predation in ponds

Predators such as frogs and birds, and sometimes snakes were observed to be present in all experimental ponds almost throughout the study period (Plate 12).

Plate 12: Predators observed: (A) captured frog with fish in mouth (B) snake entangled in predator net and (C) a bird trapped by net.

4.2 Feed Utilization of Nile Tilapia

Feed utilization in this trial was assessed as Feed Conversion Ratio (FCR), Feed Efficiency Ratio (FER) and Feed Intake (FI). The FCR were similar for the two treatments at 1.1 ± 0.2 and 1.2 ± 0.3 for the full ration and half ration treatments, respectively. The other indices had a similar trend as shown in Table 4.2. All the parameters assessed for feed utilization did not show any significant difference (Appendix C) between the two treatments.

Table 4.1 Growth Performance of Nile Tilapia fed at full ration and half-ration from January–September 2013 in ponds (n=3).

	Treatment	
Parameter	**Full Ration**	**Half Ration**
Mean initial weight (g)	25.0 ± 8.0	25.8 ± 8.5
Mean final weight (g)	229.1 ± 33.5	228.7 ± 23.3
Mean weight gain (g)	204.2 ± 36.3	202.9 ± 23.8
Initial total weight (kg)	13.3 ± 6.7	13.7 ± 6.6
Final total weight (kg)	115.2 ± 40.4	115.42 ± 41.40
Total weight gain (kg)	101.9 ± 35.0	101.7 ± 35.6
Specific growth rate (%/day)	1.2 ± 0.3	1.2 ± 0.2
Survival rate (%)	62.6 ± 20.3	63.9 ± 13.0
*Gross yield (kg)	115.2 ± 40.4	115.4 ± 41.4
Net yield (kg)	84.7 ± 38.2	87.3 ± 41.2

n = 3.
*This includes estimated losses due to mortalities.

Table 4.2 Feed Utilization of Nile Tilapia fed at full and half ration from January – September 2013 in ponds.

	Treatment	
Parameter	**Full Ration**	**Half Ration**
Feed conversion ratio	1.1 ± 0.2	1.2 ± 0.3
Feed efficiency ratio	1.4 ± 0.9	0.9 ± 0.2
Feed fed (Kg)	116.4 ± 53.0	113.9 ± 28.3
Feed intake (g)	0.7 ± 0.5	0.6 ± 0.3

n = 3

4.3 Physicochemical Parameters and Chlorophyll-a concentration in the Half ration and Full ration ponds

4.3.1 Temperature

Temperature recorded over the study period for both the full ration and half ration treatments did not show any significant differences ($p = 0.7754$). Ponds on the full ration treatment recorded mean temperature of 27.8 ± 0.3°C ranging from 26.9°C - 28.4°C while the half ration treatment recorded a mean temperature of 28.0 ± 0.3°C with a range from 26.8°C - 28.6°C over the study period as shown in Table 4.3.

4.3.2 pH

There was no significant difference (p-value = 0.6987) in pH between the treatments with the full ration recording 8.1 ± 0.3 while the half ration was 7.9 ± 0.3. The pH ranged from 7.0 to 9.0 in full ration treatments and from 6.9 to 8.7 in half ration treatments (Figure 4.2).

4.3.3 Dissolved Oxygen (DO)

DO concentrations recorded over the study period were generally low (Figure 4.3). DO recorded for the half ration treatment ranged from 2.1 to 6.2mg/l whereas, the full ration treatment ranged from 1.8 to 7.7mg/l. The highest DO values for each treatment were recorded in the month of April, although there was a sharp decline thereafter, whereas the lowest was recorded in February. There were no significant differences in DO between treatments ($p = 0.6744$).

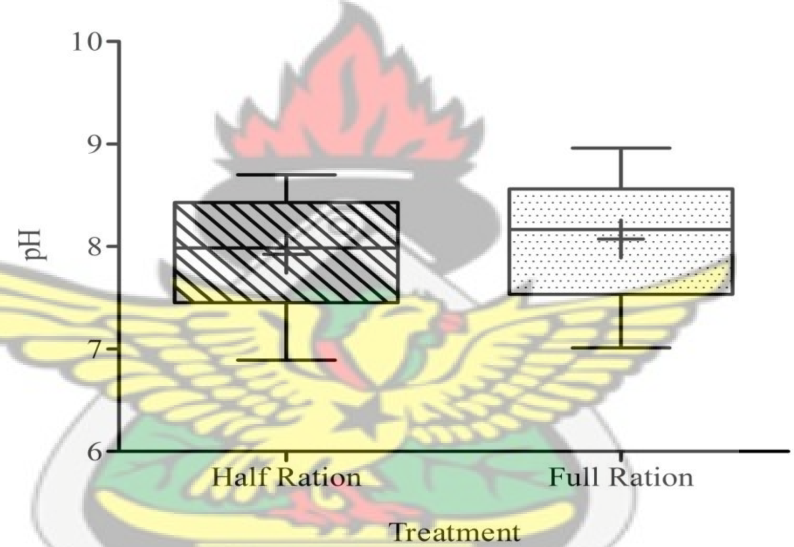

Figure 4.2: pH recorded in full and half ration ponds from January – September 2013.

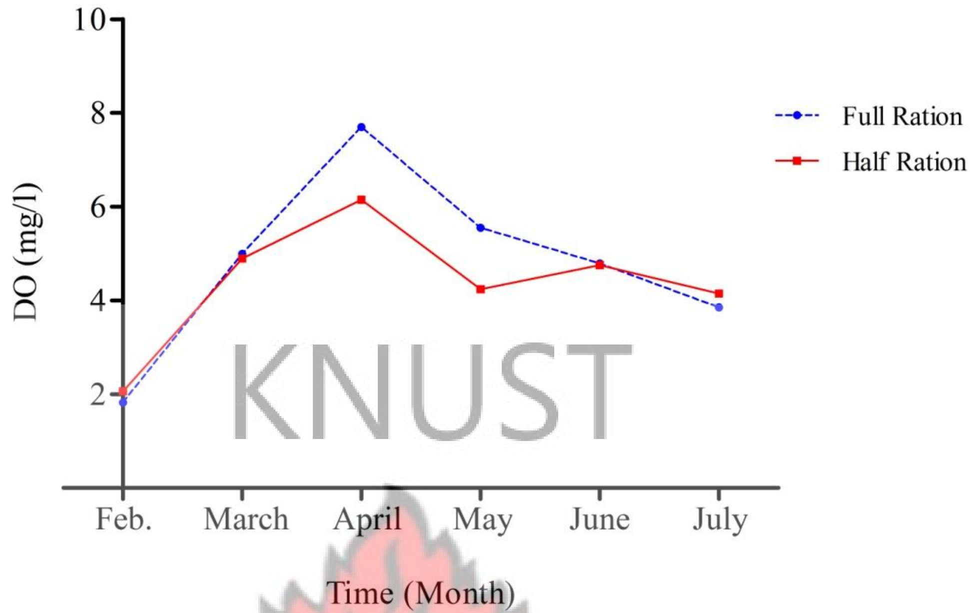

Figure 4.3: Dissolved oxygen recorded in full and half ration ponds from February – July, 2013.

4.3.4 Conductivity

Conductivity of half ration ponds was relatively higher, recording an average of 174 ± 17µS/cm as compared to an average of 150 ± 21µS/cm for full ration ponds. The lowest conductivity readings of 102 and 123µS/cm, and highest readings of 239 and 250µS/cm (Table 4.3) were recorded in the full ration and half ration treatments, respectively. The results however, did not show any significant differences ($p = 0.3962$) between the treatments.

4.3.5 Total Dissolved Solids

Total dissolved solids followed a similar trend as that of the conductivity, with half ration treatments recording higher TDS values with an average of 86 ± 8mg/l and a range of 61 to 119mg/l. Full ration treatments recorded an average of 74 ± 9mg/l from a range of 51 to 117mg/l (Table 4.3). The results also did not show any significant differences ($p = 0.3488$).

4.3.6 Secchi Depth

The half ration treatment recorded mean Secchi depth reading of 14.2 ± 1.5cm ranging from 11.2 to 19.2cm whereas the full ration treatment recorded a mean value of 13.5 ± 1.6cm with a range of 10.8 to 20.5cm (Table 4.3). There was no significant difference between the two treatments (p-value = 0.7621).

4.3.7 Chlorophyll-a concentration

Chlorophyll-a concentration was highest in the full ration ponds with a mean of 2286 ± 258µg/L and ranged from 1842µg/L to 2573µg/L. The chlorophyll-a concentration in full ration ponds increased from February to March but showed a sharp decline between March and April, however, concentrations increased steadily over the study period as shown in Figure 4.4. The half ration ponds however, recorded lower concentrations with a mean of 1374 ± 239µg/L and ranged from 1008µg/L to 1607µg/L (Table 4.3). Trends were similar to that of the full ration although the rate of change was slower than that of the full ration (Figure 4.4). Overall, full ration treatment had significantly higher chlorophyll-a concentration than the half ration treatment ($p < 0.0001$).

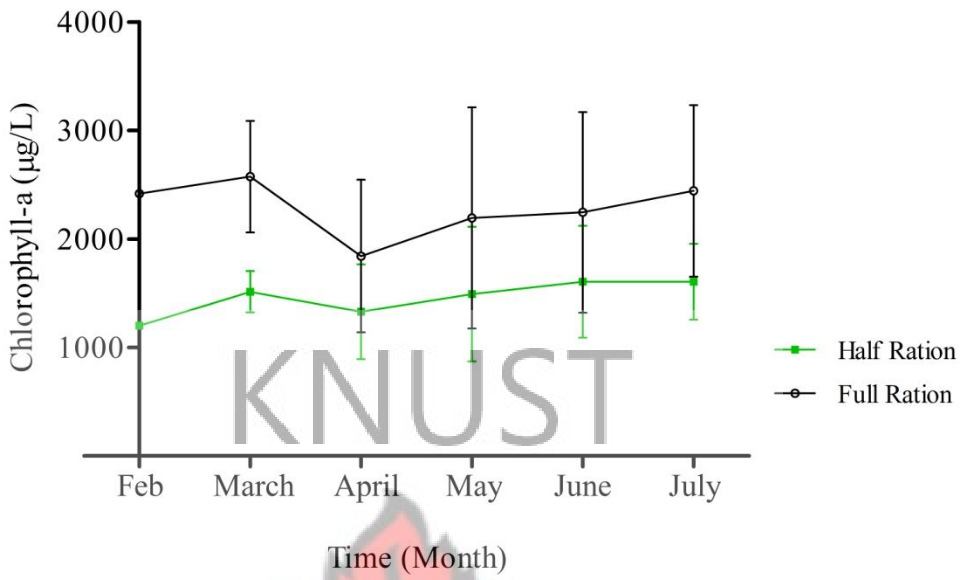

Figure 4.4: Chlorophyll-a concentration recorded in full and half ration ponds from February – July, 2013.

Table 4. 3: Physicochemical parameters and Chlorophyll-a concentration in the half ration and full ration ponds from February to July, 2013.

	Mean readings		**Range**	
Parameter	**Full Ration**	**Half Ration**	**Full Ration**	**Half Ration**
Temperature (°C)	27.9 ± 0.3	28 ± 0.3	27.0 - 28.4	26.8 - 28.6
pH	8.1 ± 0.3	7.9 ± 0.3	7.0 - 9.0	6.9 - 8.7
DO (mg/l)	4.8 ± 0.8	4.4 ± 0.6	1.8 - 7.7	2.1 - 6.2
Conductivity(µs/cm)	150 ± 21	174 ± 17	102 - 250	123 - 239
TDS (mg/l)	74 ± 9	86 ± 9	51- 118	62 - 119
Secchi Depth (cm)	13.5 ± 1.6	14.2 ± 1.5	11.2 - 19.2	10.8 - 20.5
Chlorophyll-a (µg/L)	2286 ± 258	1374 ± 239	1843 - 2574	1008 - 1607

n = 3

4.4 Total costs and earnings for Half and Full ration treatments by the end of the grow-out period.

The total cost of production, the revenue generated after sale of fish, and the profit or loss incurred after the trial for both treatments is shown in Table 4.4. The costs of all inputs as well as the prices of fish were based on local market prices in Kumasi (January to December, 2013). The economics of fish production in this study indicated that the total cost of production was slightly higher (GH₵ 1,621.13) for the half ration treatment compared to the full ration treatment (GH₵ 1,615.82). A similar result was observed for the pond preparation and treatment which showed the half ration recording a total cost of GH₵ 652.90 compared to GH₵ 630.40 for full ration treatment. The cost of pond preparation and treatment also showed a slightly higher cost for the half ration treatment compared to the full ration treatment.

At harvest, fishes were grouped into two categories, large (250-300g) and small (200-249g) according to size before sales. Small size fish were sold at GH₵ 2.00 and the large at GH₵ 2.50 per piece as indicated in Table 4.4.

Table 4.4: Enterprise budget for full and half feed treatments for one production cycle in Ghana. Cost and price information is given in Ghana Cedis (GH₵).

ITEM (Unit)	FULL RATION Number	FULL RATION Unit price (GH₵)	FULL RATION Total Expenses (GH₵)	HALF RATION Number	HALF RATION Unit Price (GH₵)	HALF RATION Total Expenses (GH₵)
VARIABLE COSTS						
Fingerlings (/piece)	1550	0.256	396.8	1550	0.256	396.8
Pond Rent (/month)	18	6.25	112.5	18	6.25	112.5
Subtotal A			**509.3**			**509.3**
Feed						
Juvenile (2.5mm) (kg)	31.99	2.25	71.9775	23.16	2.25	52.11
Growout (4.5mm) (kg)	299.12	2	598.24	300.40	2	600.8
Growout (6.0mm) (kg)	18.15	2	36.3	18.21	2	36.42
Subtotal B			**706.52**			**689.33**
Pond Preparation and treatment						
Lime (kg)	35	2	70	35	2	70
MAP (kg)				3	6	18
UREA (kg)				4.5	1	4.5
Others						
Fuel (filling water)	6	10	60	6	10	60
Labor (/day)	180	1.5	270	180	1.5	270
Subtotal C			**400**			**422.5**
FIXED COST			**0**			**0**
Total (A+B+C)			**1,615.82**			**1,621.13**
REVENUE (FISH SALES)						
Fish (Large) (/piece)	485	2.5	1,212.5	458	2.5	1,145.0
Fish (Small) (/piece)	500	2	1,000.0	554	2	1,108.0
Total	**985**		**2,212.5**	**1,012**		**2,253.0**
Net income (Profit)			**596.68**			**631.87**

CHAPTER 5

DISCUSSION

5.1 Growth Performance of Nile Tilapia

It was expected that fish that received the full ration would perform better than those receiving the half ration, however, that was not the case. The growth of Nile Tilapia in both the full and half ration treatments was similar in terms of their mean final weight, weight gain, and specific growth rate. The growth in the half ration treatment could be as a result of the fish ability to utilize the abundant natural food available in the ponds. The fertilizer promoted growth of plankton, and so though only half of the formulated feed was used, the fish were forced to make use of the natural food available in the pond.

It was observed during the study period that fish in the full ration ponds responded poorly to the feed and this could be because the full ration ponds might have received part of their recommended daily requirement from the natural food and thus, were unable to consume their full daily ration. The uneaten food also resulted in continuous fertilization of the pond although that was an unintended consequence. The results of this study are in agreement with Diana *et al* (1994), who found that no significant differences in fish growth were observed between ponds that were fed a full ration and those that were fertilized and fed at half the recommended daily ration. Moreover, Diana *et al*. (1994) indicated that feeding rates at 50% was most efficient even though feeding at 75% gave comparable results. Due to the lower cost of fertilizer compared to feed; the addition of complete supplemental feed to fertilized ponds could be a big advantage to tilapia pond farmers.

The decline in tilapia growth in both treatments in April was not different from what was reported by Diana *et al*. (1994) who observed a decline in fish growth in February in his study at the Ayutthaya Freshwater Fisheries Station at Bang Sai in Thailand. The decline in fish growth in this study could be linked to several factors such as high water temperatures, thus, the fish's reluctance to swim up to the surface to pick up feed; low D.O. concentration as a result of decomposing organic materials might have resulted in low fish metabolism thereby depressing growth (Brett, 1979), and the presence of predators which threaten and scare the fish away from the feed. Nonetheless, growth continued to increase linearly until the end of the experiment although the average growth rate (1.1 ± 0.3g/day) observed in the present study is lower than was reported (2.0-3.1g/day) by other studies under fertilized pond conditions (Green, 1992 and Diana *et al*. 1994).

Survival rate in this experiment was generally low, but was higher in the half ration treatment compared to the full ration although the difference was not statistically significant. This is contrary to what was observed by Diana *et al.* (1994) who recorded a lower survival in the feed and fertilizer treatment in his experiment. However, since no empirical evidence of mortality was observed throughout the grow-out period, the lower survival rate in this experiment is likely due to the presence of predatory animals like snakes, birds and frogs in all the experimental ponds with the latter being the major predator. According to Diana *et al*. (1994) predators affected the yield of fish in both treatments resulting especially in the variable survival among treatment replicates.

5.2 Feed utilization of Nile Tilapia

Feed utilization in this study was mainly assessed as the Feed Conversion ratio (FCR), Feed Efficiency Ratio (FER), and Feed Intake (FI). There was no difference between the treatments with respect to the FCR. This confirms the report by Hepher and Pruginin (1982) and Diana *et al.* (1994), who recorded similar FCR for ponds receiving feed only or feed and fertilizer input in their study. The half ration treatment in this study had a FCR near one (1) suggesting that the fish benefited from the natural food available in the ponds which was boosted by fertilization. Shroeder (1980) reported that natural food could account for as much as 50-70% of total available food for tilapia in pond culture even when complete diet is provided. Other authors like Green (1992) further emphasized that natural productivity influenced by pond fertilization was enough to promote accelerated fish growth in tilapia pond culture. Certainly, one might expect the total quantity of feed applied to be far lower in the half ration treatment than in full ration, however, feed utilised by the half ration treatment was slightly more than the full ration. This was due to the fact that the quantity of feed given to fish in the treatments was adjusted based on the average body weight after the monthly sampling. Moreover, fish were also fed strictly according to their response to feed. It was observed that full ration ponds responded poorly to the feed thus, consumed less feed overall. The poor response cannot be attributed to low DO levels as water quality was similar for the two treatments. A possible reason was the availability of natural food indicated by the high chlorophyll-a level to fish on the full ration hence their poor response to the feed.

5.3 Water quality

The water quality parameters monitored were generally in the favourable range for tilapia culture (Boyd, 1990). The temperature of the water in both treatments was within the optimal range of 26-30°C for tilapia production (Lazur, 2007). This was expected since all ponds were exposed to similar environmental conditions such as sunlight and wind (Diana *et al.*, 1994). However, wider variations in DO concentrations observed could be as a result of the relatively high chlorophyll-a concentration which usually results in wider fluctuations in D.O. concentration. Diana *et al.* (1994) suggested that wide variation in D.O levels could be as a result of the high oxygen demand and nutrient loading on pond bottom. Similar variation was also reported by Thakur *et al.* (2007). The pH range (6.89 - 8.96) recorded for all ponds in this study were similar to the range of 6.5 to 8.5 recorded by Diana *et al*. (1994). The Secchi disk depth revealed lower visibility for the full ration treatment, however, with no significant difference between the two treatments. The lower visibility in the full ration treatment is supported by the high chlorophyll-a level found in the full ration treatment that suggests high phytoplankton abundance. The higher visibility in the half ration treatment suggests high utilization of phytoplankton by fish. Although, natural food utilization in the full ration was possible continuous fertilization from the left over feed contributed to abundant algae impeding visibility. Diana *et al.* (1994) reported no significant difference in Secchi depth among treatments (fertilized and unfertilized ponds) and attributed this to the similar amount of light (and heat) penetration among treatments. Chlorophyll-a concentration increased in the first month of the study and showed a relatively stable concentration in the last half of the study as reported by Thakur *et al.* (2007). Contrary to what was reported by Thakur *et al.* (2007) who fertilized ponds throughout the cultural period and started feeding Nile tilapia from day 80 (half way through the culture period), fertilization plus feeding in this study recorded the lowest chlorophyll-a concentration. Moreover, chlorophyll-a concentration differed significantly between treatments. The lower amount of chlorophyll-a was an indication of the low abundance of phytoplankton which was probably due to the fish's reliance and effective grazing on the available phytoplankton. The lower chlorophyll-a level also agrees with the smaller fluctuation in the dissolved oxygen concentrations in the half ration compared to that of the full ration treatment.

5.4 Total costs and earnings for Half and Full ration treatments by the end of the grow-out period.

The economic analysis (Table 4.4) suggests that both treatments would be profitable with the half ration treatment being the most profitable. This agrees with Diana *et al.* (1996) who also observed that the one-half (0.5) *ad libitum* and fertilization treatment in their experiment was the most profitable. Contrary to Diana *et al.* (1996), the total amount of food applied in this study did not differ significantly among the treatments. This could be attributed to the fact that feeding in this study was done strictly according to response to minimize feed wastage (Thakur *et al.* 2007), and fish in the full ration treatment were observed to respond poorly to feed. This contributed to the total amount of feed fed to both treatments being almost equal. Thakur *et al.* (2007) indicated that better economic returns in fertilized tilapia ponds could be attributed to improved growth performance of the fish due to the presence of natural food in ponds.

The cost of production (Table 4) was slightly higher in the half ration treatment and could be attributed to the cost of fertilizer input. This is because, the feed management strategy (strictly by response to feed) adopted in this study contributed to both treatments having almost the same quantity of feed used. Hence, the gross revenue and profit generated after sales of fish did not reveal any difference between the two treatments even though the half feed treatment generated higher revenue than the full ration treatment. This could be ascribed to the higher survival rate in the half ration treatment since harvested fish were mainly sold per piece and not per kilogram. Although, from Table 4.3, the full ration treatment produced a higher number (485 pieces) of larger fish, the higher number (554 pieces) of small fish coming from the half ration treatment contributed more revenue to nullify the effect of the revenue coming from the larger fish in the full ration treatment. Even though both treatments made profit the half ration treatment made the most profit with a margin of approximately 6% over the full ration treatment. A study by Thakur *et al*. (2007) which assessed the culture of tilapia under fertilization plus feeding compared to culturing tilapia under feeding only reported an increase in net income for the former.

Finally, the strict administration of the supplemental feed accounted for the feed input contributing 43.7% and 42.5% to the total cost of production for the full ration and half ration treatments, respectively. This suggests that when natural food is readily available or well utilized the amount of feed required for good growth might be close to 45 % of the recommended rate thus, production cost in pond tilapia farming can be reduced when an efficient fertilization programme is applied.

Overall, this study agrees with Diana *et al*. (1994) and Diana *et a*l. (1996) that fertilizing tilapia ponds and supplementing at half ration is profitable. Furthermore, this is corroborated by Thakur *et al*. (2007) who demonstrated that fertilization plus formulated diet produced higher yields and was cost-effective.

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

Based on the results, it can be concluded that the growth of fish in the two treatments was similar. All the growth parameters (weight gain, specific growth rate, gross yield and net yield) and survival rate were not statistically different. The mean final weight recorded was 229.1 ± 33.5 and 228.7 ± 23.3 for full ration and half ration treatments, respectively. Feed utilization indicators such as the FCR, FER and FI for full ration and half ration were also not significantly different between the two treatments.

The heavy presence of predators such as frogs, birds, and snakes in most of the experimental ponds contributed to the lower survival rate in this study, and hence the lower net yield recorded. Additionally, the poor response of fish in the full ration treatment also resulted in the slower growth of fish in that treatment.

Supplementing at half ration plus fertilization combined with feeding strictly according to response appeared to be an effective way of managing feed and reducing production cost whilst maximizing profit.

Overall, the water quality measures for the two treatments were not different with the exception of Chlorophyll-a. The addition of inorganic fertilizer did not adversely affect the water quality but resulted in the abundance of natural food.

The half ration treatment recorded higher profit than the full ration treatment as a result of the relatively lower production cost and slightly higher survival. This study has provided pond management guidelines which will aid efficient aquaculture production in Ghana.

6.2 Recommendation

- Tilapia pond farmers could increase their yield and therefore profits by fertilizing their ponds to enhance the natural food production whilst feeding with formulated feeds at half ration.
- Further studies should be carried out at the same study area and at other pond farms at the following feeding levels (40-80%) to further assess varied feed management regimes to optimise tilapia production in ponds.
- A higher survival rate could be achieved if tilapia pond farmers screen ponds with predator nets to protect fish from being preyed on by predators (birds, snakes and frogs).

REFERENCES

Agbo, N. W., Adjei-Boateng D. and Jauncey, K. (2011). The Potential of Groundnut (*Arachis hypogaea L.*) By-Products as Alternative Protein Sources in the Diet of Nile Tilapia (*Oreochromis niloticus*). Journal of Applied Aquaculture, 23 (4): 367-378. Taylor & Francis Group, LLC. ISSN: 1045-4438.

Agbo, N.W. (2008). Oilseed Meals as Dietary Protein Sources for Juvenile Nile Tilapia (*Oreochromis niloticus* L.), PhD Thesis, Institute of Aquaculture University of Stirling, Scotland, UK. 210pp.

Aggrey-Fynn, E. (2001). The contribution of the fisheries sector to Ghana‘s economy. A paper prepared on behalf of the FAO as an input into the Sustainable Fisheries Livelihoods Study. April 2001.

Ahmad, M. H., El Mesallamu, A. M. D., Samir, F. and Zahran, F. (2011). Effect of Cinnamon (*Cinnamomum zeylanicum*) on Growth Performance, Feed Utilization, Whole-Body Composition, and Resistance to *Aeromona hydrophila* in Nile Tilapia**.** Journal of Applied Aquaculture, 23 (4): 367-378. Taylor & Francis Group, LLC. ISSN: 1045-4438.

Almazan, G. and Boyd, C. E. (1978). Plankton production and tilapia yield in ponds. Aquaculture 15: 75–77.

Anane-Taabeah, G. (2012). Harnessing the opportunities and overcoming constraints to widespread adoption of cage aquaculture in Ghana. MSc Thesis. Virginia Polytechnic Institute and State University, Blacksburg, Virginia. 124pp.

Annongu, A. A., Termeulen, U. and Atteh, J. O. (1996). Response of broilers to dietary treated and untreated Shea butter cake supplemented with molasses. Landbauforschung Volkenrode, Sonderheft, 169: pp 295 - 300.

Asamoah, E. K., Nunoo, F. K. E., Osei-Asare, Y. B., Addo, S. and Sumaila, U. R. (2012). A Production Function Analysis of Pond Aquaculture in Southern Ghana, Aquaculture Economics & Management, 16:3, pp 183-201.

Asmah, R. (2008). Development potential and financial viability of fish farming in Ghana. Institute of Aquaculture, PhD Thesis. University of Stirling, Stirling, UK.

Assiah van Eer, Ton van Schie, and Aldin Hilbrands, (2004). Small-scale freshwater fish farming. Agrodok 15- Second edition Agromisa Foundation. Digigrafi, Wageningen, the Netherlands.

Awity, L. (2005). Prospective analysis of future aquaculture development. National Aquaculture Sector Review. Ghana.

Balarin, J.D. 1988. National reviews for aquaculture development in Africa**.** 18. Ghana. FAO Fisheries Circular No. 770.18. FIRI/C770.18. Rome, Italy, Food and Agriculture of the United Nations.

Bardach, J. E., Ryther, J. H. and McLarney, W .O. (1972). Aquaculture: the farming and husbandry of freshwater and marine organisms. Wiley Interscience, New York, 100pp.

Beveridge, M. C. M. (1984). Cage and pen fish farming. Carrying capacity models and environmental impact. FAO Fisheries Technical Paper. No. 255. Rome, 131pp.

Blow, P. and Leonard, S. (2007). A review of cage aquaculture: sub-Saharan Africa. Pages 188-207 in M. Halwart, D. Soto, and J. R. Arthur (eds.). Cage aquaculture – Regional reviews and global overview, FAO Fisheries Technical Paper. No. 498. Rome, 241pp.

Board of Directors Fisheries Associations Members (BODFAM) (2003). Aquaculture. In: Background of Ghana fishery. [Online] Available at: http://www.nafagfish.org/aboutus-htm (Accessed: 13 July, 2009).

Bowen, S.H. (1982). Feeding, digestion and growth - qualitative considerations. In: R.S.V. Pullin and R.H. Lowe-McConnell (eds) The Biology and Culture of Tilapias. International Center for Living Aquatic Resources Management, Manila, Philippines, 141–156pp.

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

Boyd, C. E. and Tucker, C.S. (1998). Pond Aquaculture Water Quality Management. Kluwer Academic Publishers. Boston, U.S.A.

Brett, J. R. (1979). Environmental factors and growth: In W. S. Hoar, D. J. Randall and J. R. Brett, editors. Fish physiology, volume VIII. Academic Press, New York, New York, USA, 599-677pp.

Brunson, M. W., Stone, N. and Hargreaves J., (1999). Fertilization of Fish Ponds. Southern Regional Aquaculture Center (SRAC), SRAC Publication No. 471, Stoneville, MS. USA.

Chenyambuga S.W., Madalla N., And Mnembuka B., (2012). Management and Value Chain of Nile Tilapia Cultured in Ponds of Small-Scale Farmers in Morogoro Region, Tanzania.

Cobbina, R. (2010). Aquaculture in Ghana: Economic Perspectives of Ghanaian Aquaculture for Policy Development. Ministry of Food and Agriculture, Fisheries Commission. United Nations University - Fisheries Training Programme. 47pp.

Cocker, M. L. (2014). Strategic Review on African Aquaculture feeds. Partnership for African Fisheries Aquaculture Working group (Report), 9 pp.

Dankwa, H.R., Abban, E.K. and Teugels, G.G. (1999). Freshwater fishes of Ghana: In Identification, Distribution, Ecological and Economic Importance. Koninklijk Museum Voor Midden-Afrika Tervuren, Belgie. Royal Museum for Central Africa and the authors. Vol. 283, 4-6pp.

De Graaf, G. and Janssen, H. (1996). Artificial reproduction and pond rearing of African catfish *Claris gariepinus* in sub-saharan Africa – A handbook. FAO Fisheries Technical Paper. No.362. Rome, FAO. 1996.

De Silva, S.S. & Hasan, M.R. (2007). Feeds and fertilizers: the key to long term sustainability of Asian aquaculture. In M.R. Hasan, T. Hecht, S.S. De Silva & A.G.J. Tacon, eds. Study and analysis of feeds and fertilizers for sustainable aquaculture development, FAO Fisheries Technical Paper No. 497, 19–47pp. Rome.

Diana, J. S. (2012). Some Principles of Pond Fertilization for Nile Tilapia Using Organic and Inorganic Inputs. In: *Aquaculture Pond Fertilization: Impacts of Nutrient Input on Production.* First Edition. Edited by Mischke. C. C. John Wiley & Sons, Inc. 163-177pp.

Diana, J. S., Lin C. K. and Jaiyen K. (1994). Supplemental feeding of tilapia in fertilized ponds. Journal of the World Aquaculture Society 25:497-506pp.

Diana, J. S., Lin, C. K. and Yang, Y. (1996). Timing of Supplemental feeding for tilapia production. Journal of the World Aquaculture Society 27:410-419pp.

Diana, J.S., Dettweiler, D. and Lin, C.K. (1990). Effect of Nile tilapia (*Oreochromis niloticus*) on the ecosystem of aquaculture ponds, and its significance to the trophic cascade hypothesis. Canadian Journal of Fisheries and Aquatic Sciences 48: 183–190pp.

Directorate of Fisheries (DOF) (2007). Report on pond and reservoir survey in Ghana. Ministry of Fisheries, Ghana.

Directorate of Fisheries (DOF) (2009). Annual Report for Fisheries Commission of the Ministry of Food and Agriculture. Ministry of Food and Agriculture, Ghana.

Edwards, P. (1993). Environmental issues in integrated agriculture–aquaculture and wastewater fed fish culture systems. In: R.S.V. Pullin, H. Rosenthal, and J.L. Maclean (eds) Environment and Aquaculture in Developing Countries. International Center for Living Aquatic Resources Management, Manila, Philippines, 139–170pp.

Egna, H.S. and Boyd, C.E. (1997). Dynamics of Pond Aquaculture. CRC Press, FL, USA.

El-Saidy, D.M.S.D. and Gaber, M.M.A. (2003). Replacement of fish meal with a mixture of different plant protein sources in juvenile Nile tilapia, *Oreochromis niloticus* (L.) diets. Aquaculture Research 34 (13):1119-1127pp.

El-Sayed, A. -F. M. (2004). Protein Nutrition of Farmed Tilapia: Searching for Unconventional Sources. In: Bolivar, R.B., Mair, G.C. and Fitzsimmons, K., (Eds.) 'New Dimensins on Farmed Tilapia' Proceedings of the Sixth International Symposium on Tilapia in Aquaculture 12-16 September 2004. Manila, Philippines: ISTA Publications: pp 364-378.

El-Sayed, A.-F.M. (2013). Tilapia feed management practices in sub-Saharan Africa. *In* M.R. Hasan and M.B. New, eds. *On-farm feeding and feed management in aquaculture.* FAO Fisheries and Aquaculture Technical Paper No. 583. Rome, FAO. pp. 377–405.

Engle, C. R. and Neira, I. (2005). Tilapia Farm Business Management and Economics: A Training Manual. Aquaculture/Fisheries Center, University of Arkansas at Pine Bluff, Pine Bluff, Arkansas.

Fitzsimmons, K. (2000). "Tilapia: the most important aquaculture species of the 21st century". *In*: K. Fitzsimmons and J. Carvalho Filho (Eds.), Tilapia Aquaculture in the 21st Century, Proceeding from the Fifth International Symposium on Tilapia Aquaculture. Rio de Janeiro, Brazil, 3-8pp.

Fontainhas-Fernandes, A., Gomes, E., Reis-Henriques, M.A. and Coimbra, J. (1999). Replacement of Fish Meal by Plant Proteins in the Diet of Nile Tilapia: Digestibility and Growth Performance. Aquaculture International 7 (1):57-67.

Food and Agricultural Organisation (FAO) (1990). CWP Handbook of Fishery Statistical Standards - Section J. Aquaculture. Rome, Italy: FAO Coordinating Working Party on Atlantic Fishery Statistics (CWP).

Food and Agricultural Organisation (FAO) (2007). The State of World Fisheries and Aquaculture (SOFIA) 2006. World review of fisheries and aquaculture. Rome, Italy: Food and Agriculture Organization of the United Nations.

Food and Agricultural Organisation (FAO) (2009). National Aquaculture Sector Overview. Ghana. In: Fisheries and Aquaculture. Fisheries and Aquaculture Department. [Online] Available at:www.fao.org/fi/website/FIRetrieve Action/ Ghana.

Food and Agricultural Organisation (FAO) (2010). Report of the FAO Expert Workshop on on-farm feeding and feed management in aquaculture. Manila, the Philippines, 13–15 September 2010. FAO Fisheries and Aquaculture Report No. 949. Rome. (Also avallabile at www.fao.org/docrep/013/i1915e/i1915e00.pdf). 37pp.

Food and Agricultural Organisation (FAO) (2011). National Aquaculture Sector Overview. Ghana. National Aquaculture Sector Overview Fact Sheets. http://www.fao.org/fishery/countrysector/naso_ghana/en. Updated 10 October, 2005.

Food and Agriculture Organization (FAO) (2014). The State of World Fisheries and Aquaculture 2012. Food and Agricultural Organization of the United Nations. Rome, Italy. Available at: www.fao.org/3/a-i3720e.pdf.

Food and Agriculture Organization of the United Nations (FAO) (2000). The State of World Fisheries and Aquaculture 2000. Rome, Italy.

Food and Agriculture Organization of the United Nations (FAO) (2012). Republic of Tanzania - National Aquaculture sector overview. http://www.fao.org/fishery/countrysector/naso_tanzania/en.

Food and Agriculture Organization Statistics (FAOSTAT) (2013). Food and Agricultural Organisation of the United Nations, Fisheries and Aquaculture Statistics Database. http://faostat.fao.org/site/629/default.aspx.

Francis, G., Makkar, H.P.S. and Becker, K. (2001). Anti-nutritional factors present in plant-derived alternate fish feed ingredients and their effects in fish. *Aquaculture* 199 (3-4):197-227pp.

Gitonga, N.K., Mbugua, H.M., and Nyandat, B. (2004). New approach to aquaculture extension in Kenya. Department of Fisheries, Nairobi Kenya.

Grammer, G., Slack, W., Peterson, M. and Dugo, M. (2012). Nile tilapia *Oreochromis niloticus* (Linnaeus, 1758) establishment in temperate Mississippi, USA: multi-year survival confirmed by otolith ages. Aquatic Invasions: Volume 7, Issue 3.

Green, B. W. (1992). Substitution of organic manure for pelleted feed in tilapia production. Aquaculture 101: (2) 13-222pp.

Hall, S., Delaporte, A., Phillips, M., Beveridge, M. and O'Keefe, M., (2011). *Blue* Frontiers: Managing the Environmental Costs of Aquaculture. The World Fish Centre, Penang, Malaysia.

Hasan, M. and New, M. (2013). On-farm feeding and feed management in aquaculture. FAO Fisheries and Aquaculture Technical Paper No. 583. FAO, Rome.

Hasan, M. R. (2007). Economics of aquaculture feeding practices in selected Asian countries. FAO Fisheries Technical Paper No. 505. Rome, FAO, 205pp.

Hepher, B. (1962). Primary production in fish ponds and its application to fertilization experiments. Limnology and Oceanography 7: 131–136pp.

Hepher, B. and Pruginin, Y. (1982). Tilapia culture in ponds under controlled conditions. In R. S. V. Pullen and R. H. Lowe-McConnell, editors. The biology and culture of tilapias. International Center for Living Aquatic Resources Management, Manila, Philippines. 185-204pp.

Her Majesty's Stationary Office (HMSO) (1983). The Determination of Chlorophyll-a in Aquatic Environments 1980. Her Majesty's Stationery Office. London.

Hiheglo, P.K. (2008). Prospects, challenges, antidotes and future prospects of aquaculture in Ghana. Department of Social Science and Marketing Studies, Norwegian College of Fishery Science, University of Tromso, Norway. 88pp.

Isyagi, N., Veverica, K., Asiimwe, R., and Daniels, W., (2009). Manual for the Commercial Pond Production of the African Catfish in Uganda. Waficos, Kampala, Uganda.

Jobling, M., Gomes, E. and Dias, J. (2001). Feed types, manufacture and ingredients. In: Houlihan, D., Boujard, T. and Jobling, M., (Eds.) Food intake in fish. Oxford, UK: Blackwell Science. 25-48pp.

Kassam, L. (2014). Aquaculture and food security, poverty alleviation and nutrition in Ghana: Case study prepared for the Aquaculture for Food Security, Poverty Alleviation and Nutrition project. WorldFish, Penang, Malaysia. Project Report: 2014-48. 47pp.

Knud-Hansen, C.F., T.R. Batterson, and C.D. McNabb. (1993). The role of chicken manure in the production of Nile tilapia, *Oreochromis niloticus* (L). Aquaculture and Fisheries Management 24: 483–493pp.

Kumasi Metropolitan Assembly (KMA) (2006). About this Metropolis. Physical Characteristics. www.kma.ghanadistricts.gov.gh. Accessed on 31/07/2014.

Lazur, A. (2007). JIFSAN Good Aquacultural Practices Manual: Grow-out Pond and Water Quality Management. Section 6. University of Maryland. 18pp.

Lin, C.K., Teichert-Coddington, D. R., Green, B. W. and Veverica, K. L. (1997). Fertilization regimes. In: H. Egna and C.E. Boyd (eds) Dynamics of Pond Aquaculture. CRC Press, Boca Raton, FL. 73–107pp.

Ling, S.W. (1977). Aquaculture in South East Asia. A Historical Review. University of Washington press, Seattle.

Machena, C. and Moehl, J. (2001). Sub-Saharan African aquaculture: regional summary. In R. P. Subasinghe, P. Bueno, M. J. Phillips, C. Hough, S. E. McGladdery, and J. R. Arthur (eds.). Aquaculture in the Third Millennium. Technical Proceedings of the Conference on Aquaculture in the Third Millennium, Bangkok, Thailand, 20-25 February. NACA, Bangkok and FAO, Rome. 341-355pp.

Maina, J.G., Beames, R.M., Higgs, D., Mbugua, P.N., Iwama, G. and Kisia, S.M. (2002). Digestibility and feeding value of some feed ingredients fed to tilapia *Oreochromis niloticus* (L.). Aquaculture Research 33 (11):853-862.

Makkar, H.P.S. (1993). Anti-nutritional factors in foods for livestock. In: Gill, M., Owen, E., Pollot, G.E. and Lawrence, T.L.J., (Eds.) Animal Production in Developing Countries. Occasional publication No. 16: British Society of Animal Production. 69–85pp.

Manu, S. (2004). Fish Marketing In South-Western Ghana. "Strengthening the Organizational Capacity of Fish Farmer Groups". FAO. Project TCP/GHA/2904.

Mensah, M.A., Koranteng, K.A., Bortey, A. and Yeboah, D.A. (2006). The state of world fisheries from a fishworkers perspective: The Ghanaian situation. International Collective in Support of Fishworkers (ICSF). Chennai, India, (SAMUDRA Monograph). 104 pp.

Ministry of Fisheries (MoF) (2008). National Fisheries and Aquaculture Policy. Final Draft. 40pp.

Moehl, J., Brummet, R., Boniface, M. K. and Coche, A. (2006). Guiding principles for promoting Aquaculture in Africa: benchmarks for sustainable development. CIFA Occasional Paper No. 28, Accra. 122pp.

Nelson, E. and Wallace, P. (1998). Report on a survey of agro-industrial by-products in Northern Ghana. Aquatic Research Institute Technical Report (Available from WRI, Ghana).

Nilson, H. and Wetengere (1994). Adoption and Viability Criteria for Semi-intensive Fish Farming. Alcom Field Document No. 28. [Online] Available at: www.fao.org/docrep/005/ad001e/AD001EOO.HTM (Accessed: 21/1/10).

Ogunji, J.O. (2004). Alternative protein sources in diets for farmed tilapia. CABI International 2004. Nutrition Abstracts and Reviews: Series *B* 74 (9): 23-32pp.

Olivares, A. E. V. (2003). Design of a cage culture system for farming in Mexico. InstitutoTecnologico Del Mar En Mazatlán Carretera Internacional al Sur, Urías, estero "La Sirena" s/n Mazatlán, Sinaloa, Mexico.

Petr, T. (1994). Intensification of reservoir fisheries in tropical and subtropical countries. Internationale Revue Der Gesamten Hydrobiologie 79(1):131-138pp.

Popma, T. and Masser, M. (1999). Tilapia Life History and Biology. SRAC Publication No. 283

Prein, M., Ofori, J. K., and Lightfoot, C. (1996). Research for future development of aquaculture in Ghana. (Summary Papers of the ICLARM/IAB workshop Accra, No. ICLARM contribution No. 956). Accra: Institute of Aquatic Biology/Council for Scientific and Industrial Research.

Rao, D., Perrino, E.S. and Barreras, E. (2012). The Sustainability of Tilapia Fish Farming in Ghana. University of Southern California Dornsife, Los Angeles CA. (April, 2012). 20pp.

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

Sadiku, S.O.E. and Jauncey, K. (1995). Soybean flour, poultry meat meal blend as dietary protein source in practical diets of *Oreochromis niloticus* and *Clarias gariepinus*. Asian Fish. Sci. 8**:** 159-167pp.

Seini, A. W., Nyanteng, V. K. and Ahene, A. A. (2004). Policy dynamics, trends in domestic fish production and implications for food security in Ghana. International Conference on Ghana at the Half Century July 18-20. Accra, Ghana: Institute of Statistical, Social and Economic Research (ISSER), University of Ghana and Cornell University.

Shang, Y.C. (1990). Aquaculture economic analysis: an introduction. World Aquaculture Society, Baton Rouge. 211pp.

Shipton, T.A. & Hecht, T. (2013). Economic, regulatory and legal review of feed management practices: In M.R. Hasan and M.B. New, eds. On-farm feeding and feed management in aquaculture, pp. 565–585. FAO Fisheries and Aquaculture Technical Paper No. 583. Rome, FAO. 585pp.

Shroeder, G.L. (1980). The breakdown of feeding niches in fish ponds under conditions of severe competition. Bamidgeh 32 (1):20-24pp.

Swann, L. (1992). A Basic Overview of Aquaculture, Purdue University West Lafayette, IN.

Swift, D.R. (1993). Aquaculture training manual. Fishing News books. Oxford, England. Second edition. 46-114pp.

Tacon A.G.J. (1993). Supplementary feeding in semi-intensive aquaculture systems. In: New, M.B., Tacon, A.G.J. and Csavas, I., (Eds.) In: Farm Made Aquafeeds. Proceedings of the FAO/AADCP (Bangkok, Thailand). Rome, Italy. 61-74pp.

Teichert-Coddington, D. R., R.B.W.Green, C.E. Boyd, and M.I. Rodriguez. (1992). Supplemental N fertilization of organically fertilized ponds: variation of the C:N ratio. H.S. Egna, M. McNamara, and N. Weidner (eds) Ninth Annual Administrative Report, Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, OR.

Tetreault, I. (2009). Farmed Tilapia. Seafood Watch, Seafood Report. Monterey Bay Aquarium, 1–68 pp.

Thakur, D. P., Yi, Y., Diana, J. S., and Lin, C. K. (2007). Effects of Fertilization and Feeding Strategy on Water Quality, Growth Performance, Nutrient Utilization and Economic Return in Nile Tilapia.

The Fish Site (2012). FAO State of the World Fisheries. Aquaculture report – Fish Consumption. www.thefishsite.com/articles/1447/fao-state-of-world-fisheries-aquaculture-report-fish-consumption. Accessed on 4/08/2014. Time: 6:15pm.

Tidwell, J.H. and Allan, G.L. (2001). Fish as food: Aquaculture's contribution. EMBO (European Molecular Biology Organization) report 2 (11): 958-963pp.

Trewavas, E. (1983). Tilapiine Fishes of the Genera *Sarotherodon*, *Oreochromis* and *Danakilia*. British Museum (Natural History), London, UK, 583pp.

White, K., O'Neill, B. and Tzankova, Z. (2004). At a Crossroad: Will Aquaculture Fulfill the Promise of the Blue Revolution? A Sea Web Aquaculture Clearing house report.

Yi, Y. and Diana, J. S. (2008). Strategies for Nile Tilapia (*Oreochromis nilticus*) Pond culture. Proceedings of the 8th International Symposium on Tilapia in Aquaculture, Cairo, Egypt, 12-14pp.

APPENDICES

Appendix A: Summary of t-test analysis of the physicochemical parameters and chlorophyll-a of the Half ration and Full ration treatments.

Parameter	P-value	P value Summary	Significant? (P < 0.05)	R squared
Temperature (°C)	0.7754	ns	No	0.008519
pH	0.6987	ns	No	0.01562
Dissolved Oxygen (mg/l)	0.6744	ns	No	0.01839
Conductivity (µs/cm)	0.3962	ns	No	0.07284
Total Dissolved Solutes (mg/l)	0.3488	ns	No	0.08811
Secchi Depth (cm)	0.7621	ns	No	0.009586
Chlorophyll-a (µg/L)	< 0.0001	***	Yes	0.8020

Appendix B: Summary of t-test analysis of the growth parameters of the half ration and full ration treatments.

Parameter	P-value	P value Summary	Significant? (P < 0.05)	R squared
Mean Initial weight (g)	0.9097	ns	No	0.003635
Mean Final weight (g)	0.9868	ns	No	0.00007692
Mean Weight gain (g)	0.9632	ns	No	0.00006023
Initial total weight (kg)	0.9493	ns	No	0.001142
Final total weight (kg)	0.9959	ns	No	0.000007534
Total weight gain (kg)	0.9951	ns	No	0.00001049
Specific growth rate (%/day)	0.9508	ns	No	0.001075
Survival rate (%)	0.9323	ns	No	0.002043
Gross yield (kg)	0.9959	ns	No	0.000007534
Net yield (kg)	0.9396	ns	No	0.001623

Appendix C: Summary of t-test analysis of the feed utilization parameters of the half ration and full ration treatments.

Parameter	P-value	P value Summary	Significant? (P < 0.05)	R squared
Feed conversion ratio	0.8166	ns	No	0.01510
Feed efficiency ratio	0.4409	ns	No	0.1544
Feed fed (Kg)	0.9461	ns	No	0.001293
Feed intake (g)	0.9033	ns	No	0.004166

Appendix D: Correlation analysis between chlorophyll-a and physicochemical parameters of the Half ration

	Physicochemical parameter				
	pH	DO (mg/L)	Secchi Depth (cm)	Conductivity (µS/cm)	TDS (mg/L)
Spearman r	-0.9429	-0.2571	0.4286	-0.9429	-0.9429
P value (two-tailed)	0.0167	0.6583	0.4194	0.0167	0.0167
P value summary	*	ns	ns	*	*
Exact or approximate P value?	Exact	Exact	Exact	Exact	Exact
Is the correlation significant? (alpha=0.05)	Yes	No	No	Yes	Yes

Appendix E: Correlation analysis between Chlorophyll-a and Physicochemical parameters of the Full ration.

	Physicochemical parameter				
	pH	DO (mg/L)	Secchi Depth (cm)	Conductivity (µS/cm)	TDS (mg/L)
Spearman r	-0.2000	-0.3714	-0.7714	-0.4286	-0.4286
P value (two-tailed)	0.7139	0.4972	0.1028	0.4194	0.4194
P value summary	ns	ns	ns	ns	ns
Exact or approximate P value?	Exact	Exact	Exact	Exact	Exact
Is the correlation significant? (alpha=0.05)	No	No	No	No	No