EVALUATION OF FISH FARMING PRACTICES, RICE MILLING BYPRODUCTS AND EFFECTS OF DIETARY PROTEIN LEVELS ON PERFORMANCE OF AFRICAN CATFISH (*Clarias gariepinus*) IN KENYA

BY

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A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR

THE DEGREE OF MASTER OF SCIENCE IN ANIMAL NUTRITION AND FEED SCIENCE

IN THE FACULTY OF AGRICULTURE

UNIVERSITY OF NAIROBI

DECEMBER 2017

DECLARATION

This thesis is my original work and has not been presented for the award of a degree in any other University.

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ACKNOWLEDGEMENTS

I would like to thank my supervisors, Dr J.G. Maina and Prof C.K. Gachuiri, for their dedication and sacrifice in guiding me down the path of knowledge. I thank the Chairman of the Department of Animal Production, Prof J.O. Jung'a, for providing an enabling environment for my studies. I would also like to thank the other academic staff in the department for their advice, the technical staff (Dismon Ambale, Pauline Makenzi, Anne Kimende and Benjamin Kyalo) for their assistance, colleagues for their support, and family members for their emotional and financial support.

I am grateful to the University of Nairobi for awarding me a scholarship to study this degree and the Partnerships for Enhanced Engagement in Research (PEER) Science project "Strengthening institutional capacity for participatory action research in sustainable aquaculture" for funding the project. My regards go to the Kenya Marine and Fisheries Research Institute staff and the Sagana station coordinator, Dr P.S. Orina, based at the National Aquaculture Research Development and Training Centre (NARDTC) in Sagana for providing the labour, advice and facilities to carry out this project.

DEDICATION

I dedicate this work to my family for their support and love during the entire graduate work period.

TABLE OF CONTENTS

LIST OF TABLES

Table No

LIST OF FIGURES

Figure No

LIST OF PLATES

Plate No

LIST OF APPENDICES

Appendix No

LIST OF ABBREVIATIONS AND ACRONYMS

AFCR:	Apparent Feed Conversion Ratio
AFSPAN:	Aquaculture for Food Security, Poverty Alleviation and Nutrition
AOAC:	Association of Official Analytical Chemists
d.f:	degrees of freedom
DO:	Dissolved Oxygen
ESP:	Economic Stimulus Program
EUCORD:	European Cooperative for Rural Development
F pr:	P value
FFEPP:	Fish Farming Enterprise Productivity Program
GoK:	Government of Kenya
HP:	High Protein
KMFRI:	Kenya Marine and Fisheries Research Institute
LP:	Low Protein
MP:	Medium Protein
ms:	mean sum of squares
NARDTC:	National Aquaculture Research Development and Training Centre
OECD:	Organization for Economic Co-operation and Development
PER:	Protein Efficiency Ratio
ss:	sum of squares
SGR:	Specific Growth Rate
TDS:	Total Dissolved Solids
v.r:	variance ratio

ABSTRACT

Two studies were done to evaluate farmed fish management practices and to assess the quality and quantities of rice milling byproducts in Kirinyaga County in Kenya. The effects of protein levels on performance of the African Catfish (*Clarias gariepinus*) cultured in fertilized and unfertilized earthen ponds were also determined.

In the first study, a survey was done to evaluate and document fish farming practices and assess the quality and quantities of rice milling byproducts produced in Kirinyaga County. Semi structured questionnaires were used to collect data from 109 fish farmers and 56 rice millers (6 large and 50 small scale). Over fifty percent (51.6%) of farmers interviewed kept Tilapia in monoculture while 27.7% kept Tilapia and Catfish together in polyculture. Ornamental fish were farmed by 11.4%, while Catfish in monoculture were kept by 9.2% of the respondents. None of the farmers weighed their fish to determine and adjust feeding levels and they also did not follow the recommended pond fertilization regimes. The large scale and small scale rice millers sampled produced a total of 701 and 6388 tonnes of rice bran/ year respectively. Rice bran from large mills had higher levels of crude protein (CP) and rice bran oil/ ether extract (EE) and lower levels of crude fiber (CF) and ash (14.7% CP, 20% EE, 12.1% CF and 10.9% ash) than that from small mills (8% CP, 12% EE, 27.9% CF and 16.4% ash). Large quantities of high quality rice milling byproducts were available in large scale mills all year round. It is recommended that fish farmers in Kirinyaga County should follow efficient feeding and fish pond fertilization strategies with inclusion of rice milling byproducts in the fish diets to reduce feed costs and improve productivity of fish farming.

The second study evaluated the effects of dietary protein levels on performance of *C. gariepinus* cultured in fertilized and unfertilized earthen ponds for 128 days. Mixed-sex *C. gariepinus* fingerlings weighing 1.40± 0.06 g were bought and acclimatized for one week while being fed a control diet having 35% CP without the inclusion of rice milling byproducts. The fish were then randomly selected in groups of 20 fish, average weight 3.29± 0.329 g, and stocked at 10 fish/ m^2 in happas measuring $2m^2$ placed in fertilized and unfertilized earthen ponds. There were twelve (12) happas in each pond measuring $150m^2$. Four isocaloric diets (3000kcal/ kg) with 35% CP (control), 25% CP (Low Protein, LP), 30% CP (Medium Protein, MP), and 35% CP (High Protein, HP) were formulated at a cost of 47.80, 34.50, 38.30, and 42.60 KSh/ kg of diet respectively. All diets, except the control, contained rice milling byproducts. There was no interaction between dietary protein levels and pond fertilization. The average weight of fish at harvest was 234± 18.04 g. Fish fed the HP diet had the highest average final weight, weight gain and Specific Growth Rate (SGR) which were significantly different ($P<0.05$) from those of fish fed the LP diet. The best apparent feed conversion ratio was observed in fish fed the HP diet but this was only significantly ($P<0.05$) different from those fed the control. The highest Protein Efficiency Ratio (PER) was attained by the fish fed the LP diet which was significantly ($P<0.05$) different from that of fish fed the control and HP diets. The fish cultured in the fertilized pond had significantly ($P<0.05$) higher average final weights, weight gains, SGR and feed intake compared to those in the unfertilized pond. Average water temperatures remained above 23.56 °C for both ponds while the average dissolved oxygen, pH, conductivity, salinity and total dissolved solids for the fertilized pond were significantly ($P<0.05$) higher than the unfertilized pond. From this study, it was observed that the growth performance of African Catfish (*Clarias gariepinus*) increased with increasing dietary protein levels up to 35% CP and was better in the fertilized pond compared to the unfertilized pond. In addition, the fish fed the low cost LP diet (25% protein) in the fertilized pond had comparable growth and gross margin to those fed the

other diets. It is therefore recommended that the 25% CP diet having rice milling byproducts can be fed to *C. gariepinus* in fertilized earthen ponds resulting in a specific growth rate of 4.11%/ day that is comparable to fish fed higher protein level diets in fertilized earthen ponds.

CHAPTER 1

1.0 GENERAL INTRODUCTION

1.1 Background information

Fish contribute to food and nutritional security of resource-poor rural households through the provision of omega 3 fatty acids, micronutrients and income (Kaliba *et al.*, 2007; FAO, 2014). The (capture) fisheries and aquaculture industry in Kenya contributes 0.5% of the Gross Domestic Product (GDP) with about 14% of this being contributed through aquaculture (Government of Kenya (GoK), 2014). This is a very small contribution to the country's GDP despite the many Kenyan government initiatives to improve fish production such as the Economic Stimulus Program (ESP) of 2009 (Nyandat and Owiti, 2013; Maina *et al*., 2014). Fish farming in Kenya is mainly practiced under the semi-intensive production system (FAO, 2015a). Under this system, feeds account for approximately 70% of the total variable costs (Ahmed, 2007) and were identified as a main factor that limits aquaculture growth in East Africa (Hecht, 2007).

Agro-processing byproducts have great potential to reduce fish feed cost (Munguti *et al.*, 2012). Kirinyaga County, one of the beneficiaries of the ESP, is the main rice (*Oryza sativa*) growing region in Kenya (GoK, 2009) and thus has abundant inexpensive fish feed resources arising from the milling of rice. However, they have not been fully exploited for that purpose (Munguti *et al.*, 2012) hence the need to document, quantify and analyze their nutritional composition in order to increase their utilization in animal feeds.

The African Catfish (*Clarias gariepinus*) is suitable for aquaculture because it can tolerate adverse water quality conditions. In addition, it has no problem of overpopulating ponds which is common with Nile Tilapia (*Oreochromis niloticus*) (El-Sayed, 2006). Catfish is a predator that feeds on Tilapia fry and fingerlings and is used to control overpopulation in Tilapia ponds. This makes *C. gariepinus* ideal for monoculture or polyculture with *O. niloticus*. Catfish has a higher protein requirement than Tilapia (National Research Council, 1993). This is a major challenge to its sustainable pond culture since the protein fraction of the ration is a more expensive component compared to carbohydrates (Munguti *et al.*, 2012). Most of the trials to establish this requirement have been done under intensive systems. Therefore, there is need to evaluate the protein requirement of *C. gariepinus* under a semi-intensive production system which is the prevalent system in this country.

In addition, adverse water quality conditions are usually experienced in Catfish ponds as the production cycle approaches the end (de Graaf and Janssen, 1996). Fortunately, this can be controlled using pond fertilization because it increases growth of algae that assimilate ammonia produced by decomposing (excess) feed and fish excretion (Knud-Hansen, 1998; Parker, 2002). Therefore in the second study the effects of protein levels on performance of *C. gariepinus* fingerlings in fertilized and unfertilized earthen ponds were investigated.

1.2 Problem statement

Feeds account for a large percentage (about 70%) of the cost of fish production in the semi-intensive systems practiced in Kenya and most of Africa (Ahmed, 2007). Formulated Catfish feeds are costly mainly due to the high levels of protein recommended for its culture. However, these recommendations were made after studies on young Catfish under optimal controlled conditions without considering growth under practical culture conditions (the most common in Kenya) where the objective is to maximize profits and minimize costs. One way of achieving the objective stated above is through the inclusion of agro-processing byproducts to reduce expensive fishmeal used as a protein source in fish diets. Rice milling byproducts are abundant in

Kirinyaga County but their quantities, quality and potential for inclusion in fish diets have not been adequately investigated.

In Kenya, fish culture has largely been dominated by Tilapia species. Tilapia are mostly cultured in ponds in mixed-sex populations. These have the tendency to breed prolifically leading to overpopulation of ponds, competition for food and oxygen and it leads to stunting of fish in a pond. Catfish on the other hand is resistant to poor environmental conditions (FAO, 2015a) and grows faster than Tilapia (Liti *et al.,* 2002; El Naggar *et al.,* 2008). Catfish culture has mainly been promoted in Kenya as a fish for controlling overpopulation in Tilapia ponds (Mbugua, 2002). There is also a lack of low cost feeds (Shitote *et al.,* 2012; Omasaki *et al.,* 2013) which could be a cause for the slow growth of fish farming in Kenya. In addition, the use of pond fertilization to improve the water quality and performance of *C. gariepinus* have not been adequately investigated as seen in Bok and Jongbloed (1984) and Mosha (2015).

1.3 Justification

According to the Agricultural Sector Development Strategy of 2010-2020 (GoK, 2010), the Kenyan aquaculture subsector has great contribution potential to the country’s economy. This is because it can provide employment opportunities, earn foreign exchange, reduce poverty and improve food security. However, there is slow growth of the industry despite many government interventions (Nyandat and Owiti, 2013; Maina *et al.,* 2014) therefore the bottlenecks to the industry’s growth need to be identified. Thus, the first objective aimed to determine the fish feeding and fish pond fertilization strategies in Ndia, Kirinyaga County.

A study by Hecht (2007) identified the high price of fish feeds as a key limit to fish farming development in East Africa. Fish farmers in a study done in Kenya in Kisii, Siaya and Kakamega

Counties identified the high feed cost and its low quality as the key challenges they faced in aquaculture (Shitote *et al.*, 2012; Omasaki *et al.*, 2013). According to Munguti *et al.* (2012), agro-processing byproducts have great potential to reduce fish feed cost and should therefore be explored. The second objective therefore aimed to assess the quantities and quality of the main rice milling byproducts that can be used to formulate diets for African Catfish in Kirinyaga County, Kenya.

A standard dietary crude protein level recommended for African Catfish (*Clarias gariepinus*) has not been established. The National Research Council (1993) recommends a high protein level of 32-36% CP for Channel Catfish (*Ictalurus punctatus*) culture. This was used in this study because they are in the same order, Siluriformes. This recommended high dietary protein level is one of the factors that make Catfish feeds expensive because the protein fraction of the ration is more expensive than carbohydrates (Munguti *et al.*, 2012). This high protein requirement for Catfish was determined using young fish under optimal conditions. The culture of Catfish in semi-intensive production systems can reduce the need for these high protein feeds due to an abundance of natural foods in the water. Water quality in fish ponds also affects the performance of fish. The effects of pond fertilization on the performance of Catfish have not been adequately investigated. The third objective was therefore to evaluate the effects of dietary protein levels on performance of *C. gariepinus* in fertilized and unfertilized earthen ponds.

1.4 Objectives

1.4.1 Broad objective

- To evaluate and document farmed fish management practices and the quality and quantities of rice milling byproducts in Kirinyaga County and determine the effects of protein levels on performance of *C. gariepinus* fingerlings in fertilized and unfertilized earthen ponds.

1.4.2 Specific objectives

1. To determine fish feeding and fish pond fertilization strategies in Ndia, Kirinyaga County, Kenya
2. To document the main rice milling byproducts produced by small and large scale millers and evaluate the quality of rice bran and other feed ingredients used to formulate diets for African Catfish (*Clarias gariepinus*) fingerlings in Kirinyaga County of Kenya
3. To study the effects of protein levels on performance of African Catfish *(Clarias gariepinus*) fingerlings in fertilized and unfertilized earthen ponds

1.5 Research hypothesis

The proposed study was formulated to test the following hypothesis:

1. Null hypothesis: Dietary protein levels have no effects on the performance of African Catfish (*Clarias gariepinus*) fingerlings in fertilized and unfertilized earthen ponds.

The study will also answer the research questions below:

i) What are the main fish feeding and fish pond fertilization strategies currently used by farmers and what are the main challenges?

ii) What are the main rice milling byproducts produced by small and large scale millers, what is their potential for use in fish feeds and what are their nutritional values?

CHAPTER 2

2.0 LITERATURE REVIEW

2.1 Background of aquaculture in Kenya

Aquaculture was introduced in Kenya by the British colonialists in the 1900s and it involved stocking fish into rivers, dams and lakes exclusively for sport fishing (FAO, 2015a). The need for a continuous replenishment of these water bodies with fish led to the culture of fish in static water ponds starting with Tilapia; followed by Common carp, *Cyprinus carpio* (Linnaeus, 1758), African Catfish, *Clarias gariepinus* (Burchell, 1822) and Rainbow trout, *Oncorhynchus mykiss* (Walbaum, 1792; FAO, 2015a). In 1948, fish farms in Kiganjo (cold water fish) and Sagana (warm water fish) were established to supply fingerlings while the Ngomeni Prawn Farm was built in the 1970s for culture of marine aquaculture species (FAO, 2015a). Government efforts to promote fish farming such as the 'Eat more fish' campaigns of the 1960s to 1970s did not show any major increase in fish farming output in the country (Gitonga *et al.,* 2004).

In the year 2009, the government of Kenya renewed its efforts to promote aquaculture in the country. It funded the Fish Farming Enterprise Productivity Program (FFEPP) in 2009/ 2010 financial year which was implemented by government ministries under the Economic Stimulus Program (ESP) (AFSPAN, 2012; NARDTC, 2015). More than 28,000 fish ponds were constructed and stocked (with millions of fingerlings) by the program in 140 constituencies of Kenya. In 2010/ 2011 financial year, the Government funded the Economic Recovery, Poverty Alleviation and Regional Development Program. Under this program construction of 100 more fish ponds in the initial 140 Constituencies was done and 300 ponds were constructed in 20 new constituencies. These programs resulted in increased fish production (from 4,000 MT in 2008 to 20,000 MT in 2011) (GoK, 2013a) to 24,096 MT in 2014 with a farm gate value of 5.6 billion

KSh. (GoK, 2015). This was approximately 7% of the total fish produced in Kenya (AFSPAN, 2012). In 2014, Kirinyaga County produced 701 MT of fish valued at KSh. 169, 111, 000 (GoK, 2015).

Aquaculture contributes to food security through domestic consumption of fish and fish products and the surplus is sold in local and international markets (AFSPAN, 2012). This can reduce poverty levels in the country and also reduce pressure on capture fisheries (GoK, 2010). Aquaculture is practiced countrywide where the government of Kenya subsidized inputs for farmers under the ESP in 160 out of 210 Constituencies in the country (AFSPAN, 2012). The poor quality and high cost of fish feeds currently in the Kenyan market have led to low productivity of fish from aquaculture (GoK, 2015).

2.2 Fish species cultured in Kenya and types of culture systems

The main fish species cultured in Kenya in order of volume of output in 2009 were: Tilapia (3,424 tonnes), Catfish (1,047 tonnes), Common Carp (373 tonnes) and Rainbow Trout (51 tonnes) (FAO, 2017). Other fish species such as Black Bass, Gold Fish and Koi Carp are cultured in lower quantities.

Farmers practicing aquaculture follow three main production systems, namely extensive, semi-intensive and intensive (Mbugua, 2002) depending on the financial ability of the farmer and the species under culture (GoK, 2013b). The extensive production systems have the lowest management level where there is little or no input to enhance production (Ngugi *et al.*, 2007). The fish holding units used are ponds (earthen), cages, water pans and dams where the natural productivity of the pond sustains the fish. This limits the stocking density of fish because it depends on the natural carrying capacity of the pond and consequently leads to low fish yields.

The fish species cultured this way are Tilapia (*O. niloticus*), Catfish (*C. gariepinus*) and Common Carp (*C. carpio*). Under this system, the estimated fish production ranges from 500-1,500 kg/ha/year (Mbugua, 2002).

The semi-intensive production systems have higher management levels because the natural productivity of the pond is enhanced using organic and inorganic fertilizers (Ngugi *et al.,* 2007). Cereal brans and locally available fish feeds are used to supplement the natural pond productivity. Fish cultured under this system are either Tilapia (*O. niloticus*) in monoculture (most common) or various combinations of Tilapia, Catfish and Common Carp in polyculture stocked in earthen ponds and cages. Under this system, fish production is estimated at 1,000-2,500 kg/ha/year which accounts for almost 70% of the total aquaculture production in Kenya (Mbugua, 2002; FAO, 2015a).

Intensive production systems have the highest management levels where the natural productivity of the pond is complemented or completely substituted using nutritionally complete diets (Mbugua, 2002). Good water quality is maintained through aeration and mechanical and bio-filtration thus enabling high stocking densities of fish like rainbow trout (*O. mykiss*) in raceways and Tilapia in tanks or cages. Fish production of 10,000-80,000 kg/ha/year is achieved (FAO, 2015a).

2.3 African Catfish

The African Catfish (*Clarias gariepinus*) is native to Africa and it is omnivorous (Rahman *et al*., 1992). It feeds on a variety of supplemental foods such as plant materials, zooplankton, insects, snails, tadpoles, leeches and smaller fish. The *C. gariepinus* has air-breathing organs that function like lungs thus enabling aerial respiration under conditions of low dissolved oxygen in the water (de Graaf and Janssen, 1996). *Clarias gariepinus* have reduced growth under high stocking densities due to adverse water quality conditions caused by accumulated decomposing uneaten feed and excreta as the production cycle progresses (de Graaf and Janssen, 1996). The poor water quality conditions stress the fish thus causing disease outbreaks and death (Parker, 2002). Generally, Catfish has a fast growth rate, high tolerance to stress during handling, and good consumer acceptance in many African countries (de Graaf and Janssen, 1996).

2.4 Protein levels in *Clarias gariepinus* diets

2.4.1 Introduction

Proteins are made up of amino acids held together by peptide bonds. In fish nutrition, the purposes of dietary protein are to supply amino acids to meet the body's requirements for structural (muscles) and functional (enzymes and hormones) proteins and to provide energy. Therefore the requirement for dietary protein by the fish is basically a requirement for the amino acids present in the proteins (Parker, 2002).

The first nutrient considered when formulating diets is usually protein due to its nutritional importance and relative cost. The dietary protein requirements for *C. gariepinus* have not been adequately documented therefore the dietary protein requirements for Channel Catfish (*Ictalurus punctatus*) were adopted for this study because they are in the same order Siluriformes. The National Research Council (1993) recommends that *I. punctatus* diets should contain 32-36% protein. This recommendation along with those of other nutrients and energy for various fish species were determined mainly using young fish under optimum controlled growth conditions. Also, the diets used were formulated using chemically defined, purified and highly digestible ingredients. In reality, environmental factors, management practices, fish metabolic rate and fish size have an effect on dietary energy and nutrient requirements for optimum growth (National Research Council, 1993). The recommendations are therefore modified when making practical diets using natural ingredients to cater for cost considerations (in order to make least cost diets) and nutrient losses during processing, storage and digestion (bioavailability).

Robinson and Li (2005) found that *I. punctatus* fed on low protein diets performed well when fed to satiation, whereas restricted feeding required diets having high protein to achieve the same performance. They also reported that a diet having 28% crude protein resulted in fast growth when each fish was fed 2g/day or more in grow-out ponds. Higher protein diets of 32-35% increased net production and weight gain when fed on alternating days but it was not economical. Feeding on alternating days improved feed efficiency in the study quoted above but it reduced the dressed weight compared to daily feeding of fish; live weight was high due to fat deposition therefore dressed weight was low when this fat was discarded. They therefore concluded that Catfish grow well on low protein diets but it reduced the dressed weight of the fish due to fat deposition.

Parker (2002) recommended that practical Catfish diets for growers could have 25-36% crude protein (as-fed basis). According to Li and Lovell (1991), Catfish diets having 32-36% protein gave highest gains with restricted feeding while those fed on diets containing 24% crude protein had maximum weight gain when fed to satiation. Many farmers practicing Catfish culture restrict the feeding of fish to reduce wastage. Formulated diets for Catfish culture usually aim to provide a protein level of 32% and an energy level of 2800-3000 kcal DE/kg (Robinson and Li, 2005).

2.4.2 Effects of crude protein level on Catfish performance

Ahmad (2008) reported a significant increase in dressed weight and other indicators of growth and feed utilization by *C. gariepinus* when either the protein level (25, 30 and 35% CP), lipid level (6, 9 and 12% lipid) or both were increased. Ali and Jauncey (2005) observed that *C. gariepinus* fingerlings in a recycling water system fed diets having 33% and 43% CP with either 4, 8 or 12% lipid levels had higher growth and FCR with the higher protein level diet. Degani *et al.* (1989) found that *C. gariepinus* fingerlings fed diets having 25, 30, 35, and 40% dietary protein levels at 23, 25 and 27 °C recorded increasing %weight gain/ day as the protein level increased. That is, ranging from 0.63% weight gain/day at 25% CP and 23°C to 4.26% weight gain/ day at 40% CP and 27°C.

Machiels and Henken (1985) did an experiment where *C. gariepinus* were kept in open circuit balance respirometers and fed diets having 2000, 3000 and 4000 kcal/kg of metabolizable energy and 20, 25, 30, 35 and 40% CP. The highest growth rate and protein gain were recorded at 3000 kcal/kg and the growth rate increased as the protein level increased. However, under pond conditions, Robinson and Li (2005) observed that Catfish fed on a diet containing 28% protein grew faster while higher protein diets of 32-35% increased net production and weight gain when fed on alternating days but the latter was not economical because the feed was expensive due to the high protein level.

Work done by Giri *et al.* (2003) on crosses of *C. gariepinus* with *Clarias batrachus* found that body weight gain increased while FCR decreased as crude protein in the diet increased. Jantrarotai *et al.* (1998) researched on a cross of *C. gariepinus* with *Clarias macrocephalus* and reported that fish growth increased as crude protein in the diet increased. Garling and Wilson (1976) researched on Channel Catfish (*Ictalurus punctatus*) fingerlings and observed that the diet containing the lowest level of CP (24%) and the lowest DE 2.75 kcal/g diet had the best protein utilization efficiency.

2.5 Pond fertilization

2.5.1 Introduction

The growth of phytoplankton in a pond are limited by phosphate availability in water and to a lesser extent nitrogen and potassium (de Graaf and Janssen, 1996). Pond fertilization increases nitrogen and phosphorous which are used by phytoplankton (microscopic plants) for growth (Parker, 2002). These are the primary producers in the aquatic food chain because they use carbon dioxide, water and sunlight to carry out photosynthesis to produce food energy and release oxygen into the water (Knud-Hansen, 1998). They also serve as food for zooplankton, bacteria, fungi and herbivorous fish in the pond: these represent the secondary productivity of the pond.

The amount of zooplankton in the diet of *C. gariepinus* increases with age because as the mouth gape increases, its filter feeding capability increases (de Graaf and Janssen, 1996). Pond fertilization increases phytoplankton growth which in turn increase zooplankton growth as they feed on phytoplankton. In most parts of Africa, the use of organic and inorganic fertilizers to fertilize ponds used for rearing *C. gariepinus* fry and fingerlings is common (FAO, 2015b). This reduces the need for feeding the fish with nutritionally complete feeds because fish get nutrients from natural foods in the pond (FAO, 2015b). The rate of fish pond fertilization is determined by the qualities and pH of pond water and soil. Since these parameters vary from place to place, there are no specific pond fertilization schedules recommended for *C. gariepinus* (FAO, 2015b). Research is also not conclusive on whether fertilization is beneficial in Catfish grow-out ponds.

2.5.2 Effects of pond fertilization on fish performance

In Kenya, Omondi *et al*. (2001) carried out an experiment to investigate the use of inorganic fertilizers and rice bran in the polyculture of Tilapia and Catfish. They recorded the highest net profit when 4 kg and 16 kg/ha of phosphorous and nitrogen respectively were provided by the inorganic fertilizers weekly.

In Nigeria, a study by Fagbenro and Sydenham (1988) fertilized ponds using dry poultry sweepings that also served as feed for African mud Catfish (*Clarias isheriensis*). It was concluded that the fertilizer encouraged phytoplankton growth resulting in zooplankton blooms which were consumed by the *C. isheriensis*.

2.6 Water quality for fish culture

When protein is metabolized in fish, nitrogen end products are produced (e.g. ammonia) which are eliminated through the gills, faeces and urine (Parker, 2002). This results in deterioration of water quality which can be minimized by algae growth in the pond. Growth of algae is stimulated by pond fertilization using inorganic fertilizers and manures. The algae hasten the breakdown of ammonia thus improving the water quality of the pond (Knud-Hansen, 1998). On the down side, the algae are plants and therefore respire at night, thus using up the dissolved oxygen in the water and releasing carbon dioxide that mixes with water to form carbonic acid thus lowering pond water pH (Knud-Hansen, 1998; Parker, 2002). Therefore at dawn, fertilized ponds have lower pH and dissolved oxygen levels than unfertilized ponds.

2.6.1 Dissolved oxygen levels in fish ponds

Dissolved Oxygen (DO) is the level of oxygen molecules found in water and other liquids resulting from diffusion of atmospheric oxygen and production from photosynthesis by aquatic plants (Svobodova *et al.,* 1993; Water Action Volunteers, 2006). Fish take up oxygen in the water through the gills and partly through the skin (de Graaf and Janssen, 1996). Low dissolved oxygen level (dependent on the fish species) in the pond water will lead to death through suffocation. Prolonged exposure to low dissolved oxygen levels leads to increased disease incidence and stunted growth due to stress and reduced feed intake (Pichavant *et al.,* 2001; Breitburg, 2002; Flint *et al.* 2014). High dissolved oxygen concentration in water (super-saturation) above 126% causes abnormality of eggs and larva of fish and gas bubble disease in larger fish (Liang *et al.,* 2013). *Clarias gariepinus* has special air breathing apparatus that enable it to take in oxygen directly from the atmosphere. Therefore, *C. gariepinus* can tolerate up to zero mg/l DO; this usually occurs at dawn. However, maximum warm water fish performance is achieved at 5 mg/l DO (Parker, 2002; Floyd, 2014).

The DO concentration is affected by total dissolved solids, atmospheric pressure and water temperature (Lewis, 2006). It increases as water temperature, salinity and altitude decrease. Dissolved oxygen in water increases through absorption from the atmosphere and photosynthesis of aquatic plants (Lewis, 2006; Water Action Volunteers, 2006). It is removed from the water through respiration of aquatic organisms and chemical processes such as decay of organic matter in the water (Water Action Volunteers, 2006).

Some of the studies done on the effect of pond fertilization on dissolved oxygen of pond water are summarized in Table 2.1. These studies show that pond fertilization increases average dissolved oxygen levels in pond water due to the growth of phytoplankton which add oxygen to the pond water as a byproduct of photosynthesis.

Table 2.1: Effect of pond fertilization on dissolved oxygen levels

Fish cultured	Dissolved oxygen (mg/l)		SEM	P value	Country	Reference
	Fertilized pond	Unfertilized pond				
Catfish	4.5	4.4	0.1	P>0.05	Tanzania	Mosha (2015)
Catfish	6.2	6.0	-	-	Tanzania	Mosha (2015)
Tilapia	3.6	3.3	0.16	0.1839	Pakistan	Zahid *et al.* (2013)
Carp	5.8	5.6	-	P>0.05	India	Suresh *et al.* (2013)

SEM- Standard Error Mean

2.6.2 Water pH in fish ponds

Acute exposure to low pH leads to production of mucus on the gills and skin of the fish leading to stress and eventual slowed growth (Parker, 2002). Prolonged exposure to low pH causes poor absorption of calcium from the pond water leading to weak and poor bone formation. The ideal water pH for aquaculture ranges between 6 to 9.5 (Wurts and Durborow, 1992; Stone and Thomforde, 2006). Some of the studies done on the effect of pond fertilization on water pH are shown in Table 2.2. Pond fertilization increases phytoplankton growth which in turn absorb carbon dioxide from the water during photosynthesis therefore increasing the average pH of pond water (Knud-Hansen, 1998).

Table 2.2: Effect of pond fertilization on water pH

Fish cultured	Water pH		SEM	P-value	Country	Reference
	Fertilized pond	Unfertilized pond				
Catfish	6.00-9.00	7.00-9.00	-	-	Tanzania	Mosha (2015)
Tilapia	8.67	8.57	0.09	0.3215	Pakistan	Zahid *et al.* (2013)
Carp	7.80-8.20	7.80-8.20	-	P>0.05	India	Suresh *et al.* (2013)

SEM- Standard Error Mean

2.6.3 Ammonia in fish ponds

Ammonia in fish ponds originates from organic sources such as fish excretion, agricultural wastes and nitrate reduction by bacteria or from inorganic sources such as industrial effluents

(Svobodova *et al.,* 1993). It occurs in pond water in ionized (NH_4^+ $_{(aq)}$) and un-ionized (NH_3 $_{(g)}$) form depending on the water pH (Knud-Hansen, 1998) and temperature (Eddy, 2005).

Un-ionized ammonia is more toxic to fish and occurs more in high pH and warm temperature conditions (Wurts and Durborow, 1992; Getchis, 2014). It is lethal at 0.5 mg/l but is only stressful to fish at lower concentrations up to 0.1 mg/l (Parker, 2002). The desirable range for total ammonia in fish ponds is 0-2mg/l with an acceptable range of less than 2mg/l whereas the desirable level of un-ionized ammonia is 0 mg/l while the acceptable range is below 0.4mg/l (Stone and Thomforde, 2006). Schram *et al.,* (2010) found that feed intake, specific growth rate and gill morphology of *C. gariepinus* were severely affected as ammonia concentrations increased in pond water. The toxicity of ammonia to fish depends on the water pH and temperature and the fish species (Eddy, 2005).

Algae use ammonia as a nitrogen source during photosynthesis therefore fish ponds with phytoplankton blooms have low ammonia levels (Knud-Hansen, 1998). Ammonia accumulation can also be prevented by avoiding overcrowding and overfeeding, adding fresh water, controlling pond weeds, and monitoring water pH (Parker, 2002).

2.6.4 Nitrites and nitrates in fish ponds

Ammonia dissolved in water can be oxidized by bacteria in the pond to produce nitrites and nitrates (Svobodova *et al.,* 1993). Ammonia undergoes nitrification by *Nitrosomonas* bacteria in the pond water to form nitrates which can be lost as nitrogen gas to the atmosphere or oxidized by Nitrobacter bacteria to form ions (NO_3-) that are taken up by phytoplankton for growth (Knud-Hansen, 1998; Parker, 2002). Presence of nitrates can be observed by the presence of stringy algae in the ponds. Nitrites (NO_2) are products of the intermediate stage of conversion of ammonia to nitrates (Svobodova *et al.,* 1993). If oxygen is present, it quickly converts to nitrates. Most warm water fish can tolerate nitrite levels of 0.1 to 1 mg/l in the water, depending on chloride ion level. Nitrite tolerance level rises as chloride ions in water increase (Eddy and Williams, 1987). This is because nitrites and chlorides compete for absorption sites in fish through the branchial chloride/bicarbonate uptake exchange at the gills (Eddy and Williams, 1987; Durborow *et al.,* 1997). Nitrite toxicity decreases with increase in chloride ions, calcium ions and pH of pond water (Eddy and Williams, 1987; Kroupova *et al.*, 2005). The desirable range for nitrite levels in pond water is 0-1mg/l with an acceptable range of less than 4mg/l whereas nitrates are only toxic to fish at levels higher than 90mg/l (Stone and Thomforde, 2006).

2.6.5 Water temperature

Water temperature of a pond determines the amount of oxygen that can be held by the water (Minnesota Pollution Control Agency, 2009) and this determines the fish species that can be cultured in the pond, fish growth and fish health (Section 2.6.1). Water temperature also influences the rate of biochemical reactions in the pond such as decay of organic matter. In addition, it is an important aspect in aquaculture because fish are ectotherms (Castell, 2000), that is, water temperature influences their metabolic activities. The recommended temperatures for Catfish culture range between 20-30°C (Isyagi *et al.,* 2009; Water Research Commission, 2010).

2.6.6 Total dissolved solids, salinity and electrical conductivity

Total dissolved solids (TDS), salinity, and electrical conductivity (EC) are parameters used to measure dissolved inorganic and organic compounds in water, dissolved inorganic compounds alone and the ability of water to conduct electricity (correlated with salt content) respectively (Republic of South Africa, 1996; Stone and Thomforde, 2006). The concentration of TDS in freshwater rivers is constantly checked in order to monitor toxic metals and organic pollutants that can affect aquatic life and humans: fish can tolerate a TDS of up to 2000mg/l (2ppt) (Weber-Scannell and Duffy, 2007). Some results of studies done around the world are shown in the Table 2.3. Zahid *et al.* (2013) observed high TDS and salinity in fertilized compared to unfertilized ponds. However, the EC of fertilized and unfertilized ponds was not compared. Britz and Hecht (1989) found that the optimal salinity range for *C. gariepinus* larva rearing was 0-2.5ppt with short term exposure to salinities between 2.5-7.5 ppt effectively treating ecto-parasite infestation. In a study on freshwater aquatic biota, Nielsen *et al*. (2003) found that the biota could tolerate salinity levels of up to 1000mg/l (1ppt). Weber-Scannell and Duffy (2007) stated that the average salinity of freshwater rivers in the world is 120mg/l. A study done by Borode *et al.* (2008) found that *C. gariepinus* optimum salinity for hatching and development was 0-2ppt with acceptable growth observed up to 6ppt. As for EC, 100-2000 µS/cm is desirable in fish ponds (Stone and Thomforde, 2006). In addition, the acceptable range for EC in fish ponds is 30-5000µS/cm.

Table 2.3: Effect of pond fertilization on total dissolved solids, salinity and electrical conductivity

Parameter	Fertilized pond	Unfertilized pond {Mean± (Std Dev)}	SEM	P value	Fish cultured	Country	Reference
TDS (ppm)	900.85	892.77	15.89	0.6269	Tilapia	Pakistan	Zahid *et al.* (2013)
Salinity (mg/ l)	0.733	0.700	0.02	0.8476	Tilapia	Pakistan	Zahid *et al.* (2013)
	-	0.64 ± (0.05)	-	-	-	-	Palm *et al.* (2014)
EC (µS/cm)	-	1245.45 ± (106.95)	-	-	-	-	Palm *et al.* (2014)
	84.40-86.53	-	-	-	African Catfish	Western Kenya	Charo-Karisa *et al.* (2013)

TDS- Total Dissolved Solids; EC- Electrical Conductivity; ppm- parts per million; mg/l- milligrams per liter; µS/cm- micro Siemens per centimeter; Std Dev- Standard Deviation; SEM- Standard Error Mean; ±- plus or minus

2.6.7 Effects of water quality on fish performance

The major challenges faced in the intensive monoculture of *C. gariepinus* are poor water quality and predation (de Graaf and Janssen, 1996). The water environment where the fish are cultured serves several functions including being a source of oxygen and food, an excretory site, body temperature regulator, and a source of infections and disease to the fish (Parker, 2002). The water quality therefore directly affects fish performance.

The effects of pond fertilization on water quality specifically for *C. gariepinus* monoculture have not been adequately documented therefore the work done by other authors on other fish species in monoculture or in polyculture with *C. gariepinus* are reviewed. El Naggar *et al.* (2008) observed that the quality of pond water of earthen ponds stocked with *O. niloticus, C. gariepinus* and Silver carp (*Hypophthalmichthys molitrix*) in polyculture depended on the type of fertilizer used and not the fish biomass in the pond. In another study, Koi carp (*Cyprinus carpio vr. koi*) larvae cultured in tanks (concrete) fertilized with cowdung and poultry manure at 0.39 kg/m^3 every 10 days had significantly lower dissolved oxygen values than the other treatments of 0.13 and 0.26kg of manure/m^3 every 10 days.

2.7 Rice (*Oryza sativa* L.)

2.7.1 Background information

Rice (*Oryza sativa* L.) is in the family Gramineae (Poaceae) and is consumed worldwide (OECD, 1999). However, it is the only member of this family that tolerates and grows well under water logging conditions (Bouman *et al*., 2007). It has also adapted to grow in diverse conditions in saline, alkali or acid sulphate soils (OECD, 1999) under irrigation, rain-fed and flooding conditions (EUCORD, 2012; Heuze’ *et al.*, 2015).

Rice is a nutritious cereal crop that provides energy mostly in human nutrition, and to a lesser extent protein, zinc and niacin (Government of India, 2011). In terms of true digestibility, rice protein is the best compared to other cereals. In addition, it is high in fiber and minerals but has low quantities of minerals such as Fe and Ca, and vitamins such as B_1, B_2 and β carotene.

2.7.2 Rice production in Kenya

Rice is a staple cereal in Kenya that is only preceded by wheat and maize, in ascending order (Export Processing Zones Authority, 2005; GoK, 2009). Total national production only caters for 20% of the demand yet the demand is rising especially in urban areas as disposable incomes increase (GoK, 2009). In Kenya, irrigated and rain-fed rice have average unit production of 12.5 t/ha and 2 t/ha respectively (Export Processing Zones Authority, 2005). According to Gitonga (2015), approximately 106,000-120,000 Metric Tonnes (MT) of paddy rice were produced in Kenya in 2014 while GoK (2015) estimated 112,263 MT. The irrigation schemes in Kenya are found in lowland areas in the Central region (9,000 ha in Mwea), Nyanza region (3,520 ha in West Kano and Ahero) and Western region (516 ha in Bunyala) (GoK, 2009). Upland rice (rain-fed) is grown in Migori and Kuria in Nyanza region, and Tana Delta and Msambweni in Coast region. In 2014, Kirinyaga County had 10, 465 ha under rice production and produced 68,988.2 tonnes of rice (GoK, 2015).

Irrigated rice production is more profitable than rain fed rice production as reported by Emong'or *et al.* (2009) in a country wide survey. Annual rice consumption is increasing at 12% while that of maize and wheat are increasing at 1% and 4% respectively (GoK, 2009). This will hopefully reduce the reliance on the rain fed maize as a staple crop therefore improving food security and incomes of the citizens. Kenya's rice production has been ranging between 45,000-50,000 tonnes/year compared to a total demand of 110,000 tonnes/year (Export Processing Zones

Authority, 2005). The four major rice mills in Kenya are Mwea Rice Mills, Lake Basin Development Authority, Western Kenya Rice mills and Tana Delta with milling capacities of 24, 3.5, 3 and 3 Metric Tonnes/hr respectively (GoK, 2009). These are complemented by several small, privately owned one-pass mills, especially in Mwea.

Kenya’s Agricultural Sector Development Strategy of 2010-2020 shows the production costs for most crops in the country remain high despite many government efforts (GoK, 2010). This has been attributed to the high cost of inputs like fertilizer, poor and long marketing chains having many middle men, low mechanization level and high transport costs due to rising global fuel prices. Production of the three staple cereal crops, that is, maize, wheat and rice, has therefore remained below the country’s consumption requirements.

2.7.3 Byproducts of paddy rice milling

Paddy rice describes grains of rice having intact hulls after threshing and winnowing (OECD, 2004). They can be processed to produce polished rice or parboiled rice by boiling the paddy rice with the hulls intact. The main byproducts of rice milling are husks/hulls, bran and broken rice (Government of India, 2011; Heuze’ and Tran, 2015). Generally, approximately 20% of rice milling byproducts are rice hulls and 10-11% bran (Tangpinijkul, 2010; Heuze’ and Tran, 2015). The remaining fractions are 3% polishing, 1-17% broken rice and 50-66% polished rice (Heuze’ and Tran, 2015).

Rice husks/hulls are the outermost hard layer of paddy rice that covers rice grains and they have little feeding value due to their high CF and low CP (Heuze’ and Tran, 2015). They constitute the largest portion of byproduct of rice milling and account for one fifth of the paddy rice by weight. It can be used as fuel for boilers and as a rich source of silica. Brown rice is produced by hulling and is mainly used for human consumption because it is too expensive to be used as animal feed. However, it can be used in pet foods because it does not have a significant amount of allergens.

Rice bran is widely used as animal feed (Heuze' and Tran, 2015), either directly or mixed with other ingredients (Lantin, 1999). It is a combination of several components of a rice grain that can be described as the brown layer and should have less than 13% crude fiber (Tacon *et al.*, 2009). Rice bran has high levels of protein, minerals and vitamins, especially vitamin E (Salem *et al.*, 2014), B vitamins (Heuze' and Tran, 2015) and niacin. Fresh rice bran is fairly palatable by most livestock but it usually turns rancid during storage unless heat treated. This is because rice bran oil undergoes hydrolytic rancidity where triglycerides are hydrolyzed to free fatty acids which also form salts thus the bran develops an odor (World Food Logistics Organization, 2008). This process is catalyzed by lipolytic enzymes which are activated during milling (Heuze' and Tran, 2015). Rice bran contains 14-18% rice bran oil (Heuze' and Tran, 2015). This is used as a healthy cooking oil in human food because it has γ-oryzanol fraction, an antioxidant ((Lloyd *et al*., 2000; OECD, 2004).

Broken rice has a similar chemical composition to the polished rice and is separated from the latter at the polishing stage. It is a result of milling dry and brittle paddy rice that break during the milling process (Lantin, 1999). Broken rice is rarely available in large amounts for inclusion in animal feeds because it is usually mixed in different proportions with the polished rice depending on the standard in which it will be sold. Polished rice is rarely used as animal feed because of its high price. Small particles of broken rice, called rice screenings, are used in livestock diets but their nutritional composition varies a lot (OECD, 2004).

2.7.4 Chemical composition of rice bran

Many rice milling byproducts referred to as 'rice bran' have high variation of chemical components because they are a mixture of byproducts from the many milling sections (OECD, 2004; Heuze' and Tran, 2015). Rice bran laboratory analysis from different studies are shown in Table 2.4. According to Tacon *et al.* (2009), rice bran should have less than 13% crude fiber. As shown in Table 2.4, most of the rice bran samples from Kenya had crude fiber values higher than 13% and this had a dilution effect on the % crude protein of these samples. This is because rice mills in Kenya are predominantly small scale mills (GoK, 2009) characterized by one-stage milling where hulls and rice bran are removed (and mixed) together (Heuze' and Tran, 2015).

2.7.5 Use of rice bran in fish diets

The direct use of rice bran by humans is low therefore it has a high potential for use as fish feed (KMFRI *et al.*, 2007). According to Liti *et al*. (2006), cereal brans are inexpensive sources of energy used in semi-intensive fish ponds to increase the dietary energy level in order to prevent the breakdown of dietary proteins to cater for dietary energy deficits. Chemical fertilizers enhance phytoplankton growth in fish ponds thus increasing growth and multiplication of zooplankton and insects which are sources of amino acids that combine well with milling byproducts of cereals for feeding fish (Omondi *et al*., 2001).

A study done at the Sagana Fish Farm, Kenya compared growth rates of Tilapia fed brans from rice, maize and wheat (having 6.4, 11.6 and 14.3% Crude Protein (CP) respectively) (Liti *et al.*, 2006). The lowest growth and FCR was attained by the fish fed rice bran. The economic returns were only positive when the fish were sold at USD 1.79 kg/fish. It was therefore concluded that rice bran was not cost-effective for Tilapia culture in earthen ponds.

Table 2.4: Chemical analysis of rice bran samples from various studies on dry matter basis

SR No.	% DM	% CP	% CF	% EE	% Ash	Country	References
1	88.70	15.40	8.30	14.30	8.50	Uruguay	Gallinger *et al.* (2004)
2	88.60	13.80	7.40	13.40	7.70	Uruguay	Gallinger *et al.* (2004)
3*	92.10± 0.60	6.40± 0.13	42.30± 2.06	6.90± 0.06	22.00± 0.04	Kenya	Liti *et al.* (2006)
4*	92.30± 0.42	7.00± 0.38	30.90± 0.24	4.10± 0.16	22.90± 0.22	Kenya	Munguti (2007)
5	-	11.90	9.10	17.60	11.10	Kenya	Njuguna (2007)
6	91.00	13.50	13.00	5.90	11.00	USA	Batal and Dale (2011)
7	91.33	10.83	8.32	16.09	10.15	Kenya	Maina *et al.* (2013)
8	91.90	5.69	31.88	3.90	11.64	Kenya	Maina *et al.* (2013)
9*	85.80± 0.78	10.53± 0.55	6.30± 0.50	16.80± 1.60	10.76± 1.05	India	Singh *et al.* (2013)
10*	91.42± 0.69	12.45± 0.86	-	26.59± 1.38	8.57± 0.57	China	Wang *et al.* (2015)

- mean value plus or minus standard error; SR No.- Serial Number; % DM- Percent Dry Matter; % CP- Percent Crude Protein; % CF- Percent Crude Fiber; % EE- Percent Ether Extract

Liti *et al.* (2002) compared the growth of Tilapia and Catfish in polyculture when fed either a pig finisher pellet, test diet pellet and rice bran (having 12.5%, 12.5% and 6.5% CP respectively) in fertilized earthen ponds at Sagana Fish Farm, Kenya. The rice bran treatment recorded the highest values of afternoon dissolved oxygen (9.9 mg/l), pH (8.3) and feed conversion ratio (5.1± 0.31). It was also the least profitable at a market price of USD 1.56 and the fish fed on it had the lowest growth (0.9± 0.06g/day for *O. niloticus* and 1.5± 0.27 g/day for *C. gariepinus*). However, compared to the other two diets, its break-even price was low. Rice bran is therefore suitable for semi-intensive culture of Tilapia and Catfish.

2.7.6 Use of broken rice in fish diets

The broken rice separated from whole grain after the polishing stage of the rice milling process is rarely used as animal feed as it's usually remixed with the whole grains and sold as low-grade rice (Heuze' and Tran, 2015). However, in cases of surplus broken rice with low market price for human consumption, chicken farmers and to a lesser extent fish farmers are known to utilize it. Broken rice has a similar chemical composition to polished rice.

Jantrarotai *et al.* (1994) evaluated the effects of raw broken rice as a source of carbohydrate on the performance of hybrid Catfish. Five isocaloric and isonitrogenous (33% protein) semipurified diets were formulated with 30.0, 37.0, 45.0, 52.5 and 60.0% inclusion levels of raw broken rice. They observed that the fish performed well on diets containing raw broken rice at inclusion levels of 37-50% of the diet.

A study by Chau Thi Da (2012) on Striped Catfish, *Pangasianodon hypophthalmus* (Sauvage, 1878) investigated the effect of replacing fishmeal, among other ingredients, with local feed resources on fish growth performance and nutrient utilization. Broken rice was one of the feed resources found to have high digestibility. It also had more than 70% digestibility of most essential amino acids. It was concluded that the locally available ingredients, including broken rice, could replace part of fishmeal and other ingredients in striped Catfish diets without compromising growth, nutrient utilization and carcass traits.

CHAPTER 3

3.0 STUDY 1: EVALUATION OF FISH FARMING PRACTICES AND RICE MILLING BYPRODUCTS IN KIRINYAGA COUNTY

Abstract

A study was done to evaluate management practices for farmed fish in Kirinyaga County (from 15th-19th July, 2013) and assess the quality and quantities of rice milling byproducts produced in the County (from 5th-9th August, 2013). Data was collected from fish farmers and all rice millers using semi-structured questionnaires. The sample size was determined using data from Ndia Division Fisheries offices (290 active fish farmers) and a statistical formula (Yamane, 1967) for small sample sizes. A total of 109 fish farmers owning 184 fish ponds were interviewed and they kept Tilapia in monoculture (51.6%), Tilapia and Catfish in polyculture (27.7%), Ornamental fish culture (11.4%) and Catfish in monoculture (9.2%). All the farmers interviewed (100%) did not feed their fish at rates based on body weight and 86% complained of expensive feeds. Some of the respondents (27.4%) fertilized their ponds using inorganic fertilizers before stocking while 38% fertilized with organic fertilizers once a month. Most of the respondents (56.3%) reported expensive inorganic fertilizers as a major challenge. Six large scale and 50 small scale rice millers were also interviewed. Total rice bran produced by large scale and small scale rice mills were 701 and 6388 tonnes/year respectively. Rice bran produced from large mills had a higher quality (14.7% CP and 12.1% CF) compared to that from small mills (8% CP and 27.9% CF). The difference was attributed to mixing of rice bran with rice hulls in the one stage milling process used by small scale mills. Paddy rice was available for milling all year round in Kirinyaga County. Therefore, it was recommended that fish farmers in Kirinyaga County should follow efficient feeding and fish pond fertilization strategies with inclusion of rice milling byproducts in the fish diets to reduce feed costs hence increasing their profits.

3.1 Introduction

The fisheries and aquaculture industry in Kenya accounts for 0.5% of the Gross Domestic Product (GDP); aquaculture contributes 14% while the fisheries sector contributes the rest (GoK, 2014). This is a small portion of the country's GDP despite the heavy investment in fish farming in the country (Maina *et al*., 2014). An initiative implemented under the Economic Stimulus Program (ESP) of 2009 (AFSPAN, 2012) distributed fingerlings and feeds to farmers in order to increase the country's fish farming output. The post-ESP fish management practices of farmers need to be evaluated to identify the challenges and opportunities that farmers are experiencing after the end of the program.

Agro-processing byproducts, such as those obtained from the milling of rice (*Oryza sativa* L.), have great potential for lowering the cost of feeds (Munguti *et al.*, 2012). Kirinyaga County, one of the beneficiaries of the ESP, is the main rice growing region in Kenya (GoK, 2009) and thus has abundant rice milling byproducts for use in feeds for fish. However, these byproducts have not been fully exploited for that purpose hence the need to evaluate, quantify and analyze their nutritional composition in an effort to increase their utilization in fish feeds. The objectives of this study were to do the following:

i) To determine fish feeding and fish pond fertilization strategies in Ndia, Kirinyaga County, Kenya
ii) To document the main rice milling byproducts produced by small and large scale millers and evaluate the quality of rice bran and other feed ingredients used to formulate diets for African Catfish (*Clarias gariepinus*) fingerlings in Kirinyaga County of Kenya

3.2 Materials and methods

3.2.1 Study site

This study was done in Kirinyaga County (Figure 3.1) in Kenya which lies between 0° 1' and 0° 40' Southings and 37° and 38° Eastings, covers 1,478.1 km^2 and lies between 1,158-5,380 meters above mean sea level (County Government of Kirinyaga, 2014). The study targeted a random sample of fish farmers (from 15th-19th July, 2013) and all rice millers (from 5th-9th August, 2013) in the county. Fish farmers from the following locations of Ndia, Kirinyaga County were interviewed using a semi structured questionnaire: Mwerua (50), Kariti (38), Kiine (11) and Mukure (10). Small scale rice millers in five locations of Kirinyaga County namely, Mutithi (15), Mwerua (8), Nyangati (13), Tebere (11) and Thiba (3) were interviewed. Large scale rice millers in two locations namely, Mutithi (1) and Tebere (5) were also interviewed.

3.2.2 Sampling procedure

The study targeted a random sample of fish farmers in Ndia, Kirinyaga County and all rice millers in Kirinyaga County. Data on the total number of fish farmers in Ndia was provided by the Divisional Fisheries Development offices in Ndia. A total of 325 fish ponds were constructed under the ESP (one pond per farmer) but only 290 were active at the time of the survey. This number was used in the Yamane formula of 1967 ((1) below) to determine the required sample size of farmers. The farmers were then identified using stratified random sampling.

$$n = \frac{N}{1+Ne^2} \qquad (1)$$

Where n= Required number of farmers; N= Total number of farmers (290 active farmers); e= Precision level

$$n = \frac{290}{1+290(0.05^2)} = 169\ fish\ farmers$$

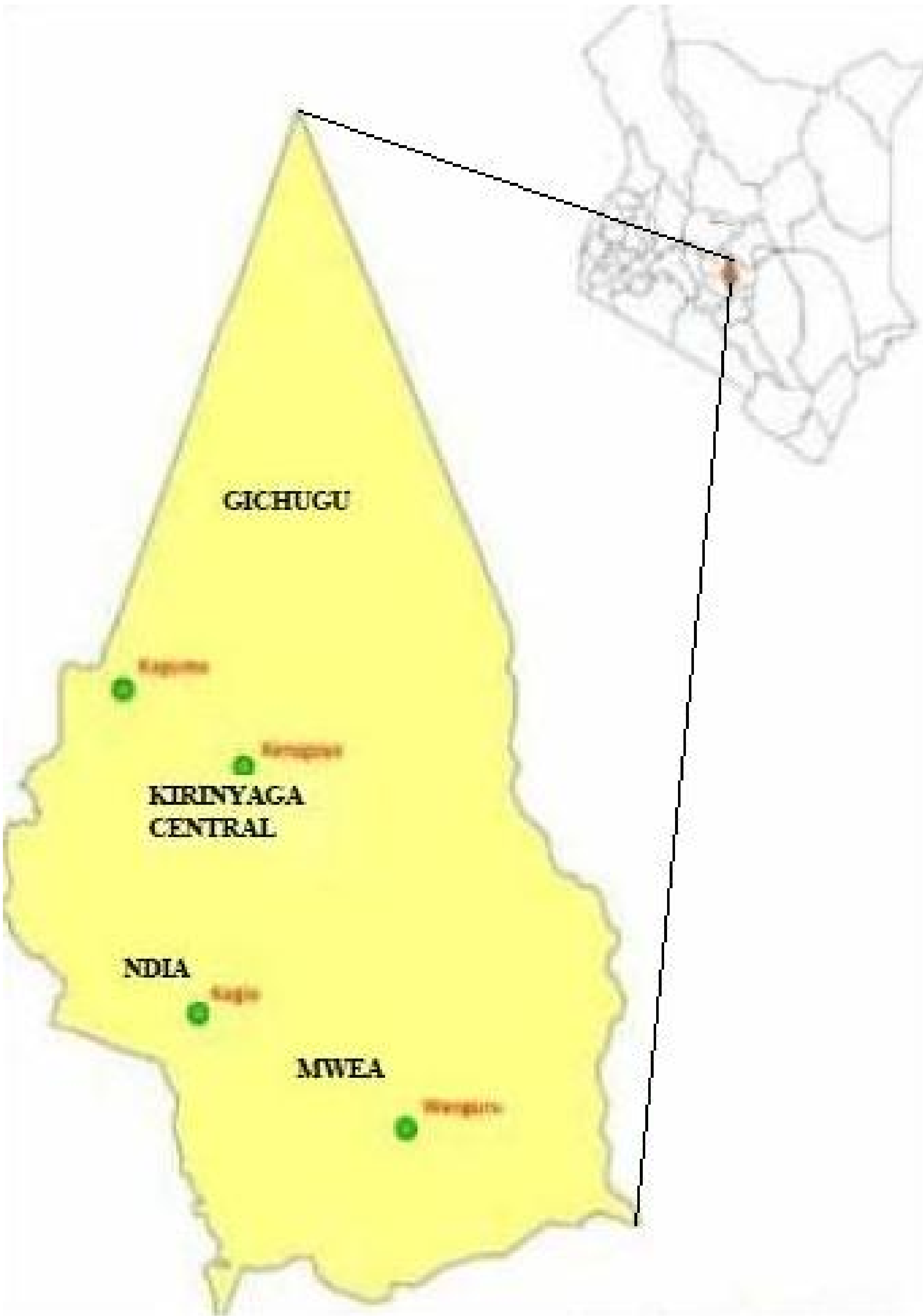

Figure 3.1: Ndia, Kirinyaga County of Kenya (***Source:***

http://www.kenyampya.com/index.php?county=Kirinyaga)

3.2.3 Data collection and chemical analysis

Semi structured questionnaires were used to collect data from fish farmers (Appendix 1) and rice millers (Appendix 2) in the County. Among the information collected were fish farming management practices and the challenges faced by respondents, who either owned the fish pond or managed it. Questionnaires were administered through face to face interviews to the fish farmers and rice millers by trained enumerators supervised by the researcher.

The rice millers were categorized as small scale (single-pass rice mills) and large scale (multiple-pass rice mills) for purposes of the study. Data collected included the amounts of rice milling byproducts produced throughout the year and the challenges faced. Rice bran samples were collected from randomly selected small scale mills (four) and large scale mills (three) in Mwea and Ndia of Kirinyaga County. They were analyzed for CP, CF, EE, ash and moisture according to AOAC (1998) procedures at the University of Nairobi, Department of Animal production.

3.2.4 Data analysis

Data collected was cleaned, sorted and entered into the computer program Microsoft Excel of Windows 7 Professional and exported to the software, Statistical Package for Social Sciences (SPSS) for analysis. This generated descriptive statistics consisting of frequencies, means, standard deviations and percentages that facilitated inferential analysis using t-test to compare large scale and small scale mills.

3.3 Results and discussion

3.3.1 Location of fish farmers in Ndia, Kirinyaga County

Only 109 out of the 169 targeted fish farmers were interviewed. This is because most farmers had abandoned fish farming when the study commenced.

Majority of the fish farmers interviewed (45.9%) were located in Mwerua location as shown in Table 3.1. The rest were located in Kariti (34.9%), Kiine (10.1%) and Mukure (9.2%) locations. A fish farmer being interviewed in Kiine location is shown on Plate 3.1.

Table 3.1: Location of interviewed fish farmers in Ndia, Kirinyaga County

Location of respondents	Frequency	Percentage
Mwerua	50	45.9
Kariti	38	34.9
Kiine	11	10.1
Mukure	10	9.2
Total	109	100

3.3.2 Social and economic factors affecting fish farming practices in Ndia, Kirinyaga County

Table 3.2 shows the gender, relationship to household head, age, education levels, other sources of income and source of start-up capital (to start fish farming) of the respondents. Majority of the respondents (70.6%) were male with 29.4% being female. A similar trend was observed in a study done by Kimathi *et al.* (2013) in Meru County where 72.7% of the respondents were male while 27.3% were female and Oloo (2011) in Kisumu County where 84.1% of the respondents were male and 15.9% were female. In the current study, most of the respondents (66.1%) were household heads therefore most of the household heads were male. Studies done by Maina *et al.* (2014) in Mwea, Kirinyaga County and Ngwili *et al.* (2015) in Machakos and Kiambu Counties in Kenya also found that most of the household heads were male. According to World Bank

Plate 3.1: Researcher (on the right) interviewing a fish farmer in Kiine location.

Table 3.2: Social and economic factors influencing fish farming practices in Ndia, Kirinyaga County

Gender of the respondents	Frequency	Percentage (%)
Male	77	70.6
Female	32	29.4
Total	109	100
Relationship to household head		
Household head	72	66.1
Spouse	21	19.3
Child	2	1.8
Employee	14	12.8
Total	109	100
Age of the respondents		
18-35 years	20	20.6
36-60 years	48	49.5
Over 60 years	29	29.9
Total	97	100
Education level		
Below primary	2	1.9
Primary	31	30.1
Secondary	45	43.7
College	20	19.4
University	5	4.9
Total	103	100
Other sources of income		
None	3	2.8
Fish trader	3	2.8
Livestock/ crop farmer	96	88.1
Business person	3	2.8
Factory worker	2	1.8
Casual labourer	2	1.8
Total	109	100
Source of start-up capital		
Own saving	13	11.9
ESP	86	78.9
Own saving and ESP	10	9.2
Total	109	100

ESP- Economic Stimulus Program

(2009), the rights to land in many countries worldwide are determined by socio-cultural frameworks such as rights attained through spouses, the community allocating the land to an individual, or individuals inheriting land from parents. In many communities, it is the men who inherit land and will therefore have more fish ponds. In Kirinyaga County, most of the land (except leasehold land in Mwea) is ancestral land (County Government of Kirinyaga, 2013) resulting in a higher number of men owning fish ponds.

Majority of respondents (49.5%) were aged between 36 and 60 years (Table 3.2). Oloo (2011), Omasaki *et al.* (2013), Maina *et al.* (2014) and Ngwili *et al*. (2015) observed that fish farming was mainly practiced by farmers of less than 50 years of age. Gachucha *et al.* (2014) attributed this to the energy levels and willingness to take risks by the people under 50 years of age leading to higher adoption of the relatively new enterprise of fish farming.

Over 43% of the fish farmers (43.7%) had attended secondary school while only 1.9% had not completed primary level education (Table 3.2). Ngwili *et al.* (2015) observed that only 8.8% of fish farmers in Kiambu and Machakos Counties had not completed primary level education while Omasaki *et al.* (2013) observed 11.8% of fish farmers in Kakamega, Kisii and Siaya Counties had not attended school. In other studies, Kimathi *et al.* (2013) and Oloo (2011) reported that in Meru and Kisumu Counties respectively, all the farmers had completed primary level education. Fish farming adopters have high levels of education because it enables them understand the complex nature of this new technology (Gachucha *et al.*, 2014).

Farmers had other sources of income as shown in Table 3.2. The major source of income (88.1%) was from mixed livestock and crop farming. Ngwili *et al.* (2015) reported similar findings for fish farmers in Kiambu and Machakos Counties.

The start-up capital for majority of fish farmers (78.9%) was through funding by the Government of Kenya (Table 3.2) under the Economic Stimulus Program (ESP). The other farmers either used their own savings (11.9%) or they used their own savings in addition to the ESP subsidy (9.2%). Kirinyaga County was one of the beneficiaries of the ESP, therefore most of the fish farmers in the County received their start-up capital, in form of inputs (AFSPAN, 2012), from the ESP. Yongo *et al.* (2011) in Gucha, Meru and Taita-Taveta Counties documented a similar trend where 92% of the respondents had individually owned ponds in an area of communal land ownership, attributed by the authors to the ESP. Ngwili *et al.* (2015) observed a similar trend in Kiambu and Machakos Counties where 85.3% and 75% of fish ponds respectively were owned by fish farmers recruited through the ESP. The ESP fully funded the Fish Farming Enterprise Productivity Program (FFEPP) and the Economic Recovery, Poverty Alleviation and Regional Development Program that constructed more than 48,000 fish ponds in 160 constituencies countrywide (AFSPAN, 2012; NARDTC, 2015).

3.3.3 Types of ponds

Table 3.3 shows the types of fish ponds owned by farmers in the study area. The majority (77.1%) used ultra violet (UV) treated polyethylene lined ponds while the rest of the farmers (22.9%) used earthen ponds. Most of the fish ponds in the study area were located in the midland and highland areas of Kirinyaga County where the soil has a low percentage of clay (County Government of Kirinyaga, 2014). In such areas, fish ponds are lined with ultra violet (UV) treated polyethylene in order to prevent/reduce seepage (Bureau of Indian Standards, 2009; Kamau and Baumgartner, 2012). The polyethylene is UV treated to reduce its rate of degradation when exposed to the UV rays of the sun. In addition, the polyethylene used to line ponds prevents growth of aquatic weeds (Federal Government of Nigeria, 2005). These are plants that

Table 3.3: Types of ponds owned by fish farmers in Ndia, Kirinyaga County

Pond type	Frequency	Percentage
Earthen	25	22.9
Liner	84	77.1
Total	109	100

grow in the pond and deplete dissolved oxygen in the pond water, increase water loss by evapo-transpiration, and restrict fish farming management practices such as sampling and harvesting.

A few of the ponds were earthen ponds (22.9%). These were located in lowland areas of Kirinyaga County where the soil has higher amounts of clay compared to midland and highland areas of the County (County Government of Kirinyaga, 2014). According to Ngugi *et al.* (2007), earthen ponds are suitable where the soil has a high percentage of clay (approximately 20%) because such soils have a high water retention capacity. In Kiambu and Machakos Counties, Ngwili *et al.* (2015) found that earthen ponds were the most utilized fish holding structures. Earthen ponds have the advantage of nutrient cycling, such as the nitrogen cycle, in the fish pond due to the contact of pond water with soil (Federal Government of Nigeria, 2005). However, earthen ponds have the disadvantage of nutrient losses during pond fertilization due to binding of compounds such as phosphorous with organic matter and soil (Knud-Hansen, 1998).

3.3.4 Fish species cultured

Table 3.4 shows the fish species cultured in Ndia, Kirinyaga County. The culture of mono-sex Tilapia was the most common (51.6%) among the farmers interviewed whereas 27.7% kept mixed-sex Tilapia and Catfish together in polyculture. A few farmers (11.4%) kept Ornamental fish and a small percentage (9.2%) kept Catfish in monoculture. The total number of ponds recorded (184 fish ponds) was higher than the number of farmers interviewed (109 fish farmers)

Table 3.4: Fish species cultured in Ndia, Kirinyaga County

Fish culture	Number of ponds	Percentage
Tilapia monoculture	95	51.6
Tilapia and Catfish polyculture	51	27.7
Ornamental fish culture	21	11.4
Catfish monoculture	17	9.2
Total	184	100

because some farmers had more than one pond on their farms due to different sources of start-up capital (Table 3.2). Maina *et al.* (2014) observed the same tendencies in Mwea area of the same County (The culture of mono-sex Tilapia was the most common). Omasaki *et al.* (2013) observed that in Kakamega, Kisii and Siaya Counties, Tilapia culture was the most dominant (56.8%) followed by Tilapia and Catfish polyculture (37.3%).

During the initial stages of the Economic Stimulus Program (ESP), the Government of Kenya, through its extension workers, distributed mixed-sex Tilapia to farmers. Tilapia reach sexual maturity before reaching market weight and quickly reproduce thus overpopulating the pond (El-Sayed, 2006). This leads to increased competition for feed and oxygen among the fish resulting in stunted growth of the fish. The government then attempted to offset this challenge by introducing the African Catfish (*Clarias gariepinus*) to control Tilapia numbers by feeding on the unwanted Tilapia fingerlings and fry (de Graaf and Janssen, 1996).

Mono-sex Tilapia have better growth rates than mixed-sex Tilapia (Dagne *et al.*, 2013; Githukia *et al.*, 2015). Later in the ESP project cycle, the Government distributed mono-sex Tilapia obtained through sex reversal resulting in the high numbers of mono-sex Tilapia observed in this study (51.6% of farmers interviewed). Under the ESP, the Government of Kenya did not distribute Catfish and Ornamental fish resulting in the low numbers of these fish species among the farmers. A study done in Kiambu and Machakos Counties of Kenya found that the large numbers of farmers keeping Tilapia in monoculture was due to Tilapia fingerlings being supplied by the government through the ESP. In addition, Tilapia had high consumer acceptability (Ngwili *et al.*, 2015). This was also observed by Yongo *et al.* (2011) in Gucha, Meru and Taita-Taveta Counties of Kenya where 99% of respondents preferred culturing Tilapia compared to 0.5% who preferred Catfish. This was again attributed to market preference and the supply of mono-sex Tilapia by the government of Kenya under the ESP.

The *C. gariepinus* is a popular fish species in Africa, only second to Tilapia with the exception of Nigeria where the reverse is true (Ponzoni and Nguyen, 2008). This is despite the fact that *C. gariepinus* grows faster and is more tolerant to poor water quality conditions than *O. niloticus* (Liti *et al.*, 2002; El Naggar *et al.*, 2008; FAO, 2015a).

3.3.5 Fish pond size and stocking density

The average pond sizes used by fish farmers for Tilapia culture were around 300 m^2 (Table 3.5). This can be related to the Government, under the ESP, constructing fish ponds for farmers measuring 300 m^2 (AFSPAN, 2012). This pond size was also adopted by some farmers who were not beneficiaries of the ESP, especially those who farmed Catfish and Ornamental fish. A study done by Yongo *et al.* (2011) found that 300 m^2 fish ponds were the most common (94.3%) pond sizes constructed in Gucha, Meru and Taita Taveta Counties of Kenya. This size was reported to have been recommended by the Ministry of Fisheries under the ESP.

The average stocking density of fish in these ponds depended on the initial source of capital and fingerlings (Table 3.2). The Government of Kenya aimed to have a Tilapia stocking density of 3fish/ m^2 for farmers under the ESP. It therefore distributed 1000 Tilapia fingerlings (either

Table 3.5: Pond size and stocking density of fish in Ndia, Kirinyaga County

	N	Minimum	Maximum	Mean	Standard deviation
Catfish monoculture					
Pond size (m^2)	17	2.0	300.0	199.2	128.65
Stocking density (fish/m^2)	14	1.0	6.3	2.8	1.59
Tilapia monoculture					
Pond size (m^2)	95	73.0	300.0	274.5	67.59
Stocking density (fish/m^2)	90	1.0	6.7	3.8	1.28
Tilapia and Catfish polyculture					
Pond size (m^2)	51	21.0	300.0	294.5	39.06
Stocking density (Tilapia) (fish/m^2)	50	2.3	6.7	3.5	0.82
Tilapia: Catfish ratio	50	2.0	6.7	3.4	0.88
Ornamental fish culture					
Pond size (m^2)	21	2.0	300.0	95.5	85.85
Stocking density (fish/m^2)	13	0.3	6.5	2.7	1.96

N- number of fish ponds; m^2- square meters

mono-sex or mixed-sex) to the farmers, accounting for 10% mortality (the surviving 900 fish cultured in a 300m^2 pond results in a stocking density of 3fish/ m^2). Catfish (in monoculture) and Ornamental fish were stocked at stocking densities of approximately 3 fish/m^2. Yongo *et al.* (2011) reported stocking densities as high as 10 gold fish (Ornamental fish) per m^2 in Meru County.

3.3.6 Types of fish feeds, amounts fed and feeding frequency

The different types of feeds used by fish farmers are shown in Table 3.6. For purposes of this study, commercial feeds were defined as complete diets purchased from retailers while home-made feeds were feeds formulated on the farm. Single ingredient feeds were defined as fish feed that consisted of only one ingredient such as wheat bran. Most of the respondents (70% of those who stocked Catfish in monoculture, 58.2% of farmers who stocked Tilapia in monoculture, 73.5% of those who stocked Tilapia and Catfish together and 70% of Ornamental fish farmers) fed their fish on commercial feed. This could be attributed to commercial feeds being one of the

Table 3.6: Types of feeds used by fish farmers in Ndia, Kirinyaga County

Feed type	Catfish		Tilapia		Tilapia and Catfish		Ornamental fish	
	N	%	N	%	N	%	N	%
Commercial	7	70.0	39	58.2	25	73.5	7	70.0
Home-made	3	30.0	12	17.9	7	20.6	3	30.0
Single ingredient	-	-	4	6.0	1	2.9	-	-
Commercial and single ingredient	-	-	7	10.4	1	2.9	-	-
Commercial and home-made	-	-	5	7.5	-	-	-	-
Total	10	100	67	100	34	100	10	100

N- number of farmers; %- percentage

inputs distributed to fish farmers under the ESP (AFSPAN, 2012). Ngwili *et al.* (2015) also reported that all fish farmers under the ESP in Kiambu and Machakos Counties used commercial feeds to feed their fish.

The second most popular feeds were home-made feeds used by 30% of Catfish farmers, 17.9% of farmers keeping Tilapia in monoculture, 20.6% of farmers who kept Tilapia and Catfish together and 30% of Ornamental fish farmers. This was also observed by Yongo *et al.* (2011) who reported 93.4% of respondents fed their fish commercial feeds while 6.6% made their own feeds. Home-made rations are inexpensive compared to commercial feeds but they are nutritionally incomplete.

Only 6% and 2.9% of farmers keeping Tilapia in monoculture and Tilapia and Catfish in polyculture respectively used single ingredient feeds to feed their fish. A total of 10.4% of Tilapia monoculture and 2.9% of Tilapia and Catfish polyculture farmers used a combination of commercial and single ingredient feeds. Only 7.5% of farmers keeping Tilapia in monoculture bought commercial feeds and made home-made feeds for their fish. Fish farmers turn to home-made and single ingredient feeds in order to bring down their cost of production because feeds account for approximately 70% of total variable cost (Ahmed, 2007).

Farmers keeping Tilapia alone or together with Catfish in polyculture fed their fish 2.6g and 2.2g commercial feed/fish/day respectively, 3.5g and 1.4g home-made feed/fish/day respectively and 1.1g and 0.4g single ingredient feed/fish/day respectively. This is shown in Table 3.7. Fish weights in the study area were not known because the farmers never weigh the fish fortnightly in order to adjust the feeding rate according to the fish weights. It is therefore difficult to tell whether they are over-feeding or under-feeding the fish. According to Jauncey and Ross (1982) and Kubaryk (1980), Tilapia weighing between 1-100g should be fed at 4-10% of body weight (0.1-4g of feed/fish/day) and those weighing more than 100g should be fed at a lower percentage of body weight (3%).

Catfish in monoculture were fed commercial feed (an average of 2.5g of feed/fish/day) and an average of 13.6g of home-made feed per fish daily. Feeding based on body weight is also practiced in Catfish culture but this was not done and farmers did not know the weights of their fish. Recommendations of amounts of feed fed to fish varies depending on fish size and species, the environmental conditions and the management practices on the farm (National Research Council, 1993).

Table 3.7: Amount of feed offered daily to fish in Ndia, Kirinyaga County

Amount of feed/fish/day (g)	N	Minimum	Maximum	Mean	Standard deviation
Catfish monoculture					
Commercial feed	7	0.7	5.0	2.5	1.42
Home- made feed	3	4.0	26.7	13.6	11.74
Tilapia monoculture					
Commercial feed	51	1.0	27.0	2.6	3.76
Home- made feed	17	0.1	26.7	3.5	6.68
Single ingredient feed	11	0.1	3.0	1.1	0.83
Tilapia and Catfish polyculture					
Commercial feed	26	1.0	5.0	2.2	1.07
Home- made feed	7	1.0	2.0	1.4	0.60
Single ingredient feed	2	0.2	0.5	0.4	0.21

g- gram; N- number of farmers

Table 3.8 shows the daily feeding frequencies of fish in the study area. The farmers having Tilapia alone or together with Catfish or Catfish alone fed their fish either once or twice per day. Yongo *et al.* (2011) observed that most fish farmers (46%) in Gucha, Meru and Taita Taveta Counties of Kenya fed their fish twice daily. This is the daily feeding frequency recommended by several authors (Pantazis and Neofitou, 2003; Zeinhom *et al*., 2010).

Table 3.8: Daily feeding frequency of fish in Ndia, Kirinyaga County

Feeding times per day	N	Minimum	Maximum	Mean	Std. Deviation
Commercial feeds					
Catfish monoculture	6	1	2	1.8	0.40
Tilapia monoculture	46	1	2	1.8	0.41
Tilapia and Catfish polyculture	25	1	2	1.8	0.43
Home-made feeds					
Catfish monoculture	3	2	2	2.0	0.00
Tilapia monoculture	12	1	2	1.6	0.51
Tilapia and Catfish polyculture	6	1	2	1.7	0.51
Single ingredient feeds					
Tilapia monoculture	11	1	2	1.3	0.46

N- number of farmers; Std- Standard

3.3.7 Cost of fish feed

The cost of fish feeds is shown in Table 3.9. Commercial feeds were the most expensive at 73.1 KSh/kg followed by home-made feeds at 45.9 KSh/kg and the least cost were single ingredient feeds at 13.8 KSh/kg. Home-made feeds consisted of simple mixtures that were made on the farm (Table 3.10). The single ingredient feeds consisted of a single feedstuff (Table 3.11).

The type of feeds used by fish farmers depended on the type of fish kept, production system used, fish selling price and the financial position of the farmer (Shipton and Hasan, 2013). In the study area, the resources available to farmers determined the type of feed they selected because most of them could not afford the expensive commercial feeds so they used home-made feeds or single ingredient feeds.

Table 3.9: Cost of fish feeds in Ndia, Kirinyaga County

Feed cost/kg (KSh)	N	Minimum	Maximum	Mean	Standard deviation
Commercial feed	57	43	100	73.1	9.66
Home-made feed	7	20	75	45.9	20.90
Single ingredient feed	14	5	30	13.8	6.51

Kg- kilogram; KSh- Kenya Shilling; N- number of farmers

The most expensive home-made feed cost 75 KSh/kg due to the use of expensive ingredients such as fishmeal at 200 KSh/kg and Cassava chips at 100 KSh/kg as shown in Table 3.10. The least expensive home-made feed cost 20 KSh/kg and this consisted of low cost ingredients such as sweet potato chips at 15 KSh/kg and cereal milling byproducts, that is, maize bran at 20 KSh/kg and rice bran at 25 KSh/kg. Home-made feeds are usually used to grow fish consumed in the homestead or sold to neighbours (Shipton and Hasan, 2013).

Table 3.10: Home-made feeds used by fish farmers in Ndia, Kirinyaga County

S/R No.	Ingredients	Cost/kg of ingredients (KSh)	Percentage of ingredients in feed (%)	Cost/kg of feed (KSh)
1	Freshwater shrimp (*Caridina nilotica*) meal	100	40	46
	Rice bran	10	60	
2	Rice bran	11.67	-	75
	Fishmeal (*Lates niloticus* processing waste)	200	-	
	Cassava chips	100	-	
3	Sweet potato chips	15	33.33	20
	Maize bran	20	33.33	
	Rice bran	25	33.33	
4	Maize bran	30	-	70
	Fishmeal (*Lates niloticus* processing waste)	130	-	
	Soyameal	25	-	
	Wheat bran	30	-	
	Cassava chips	25	-	
5	Wheat bran	20	-	30
	Maize germ	20	-	
	Cotton seed cake	36	-	
6	Wheat bran	20	-	30
	Maize germ	20	-	
	Cotton seed cake	40	-	
7	Rice bran	-	-	50
	Fishmeal (*Lates niloticus* processing waste)	-	-	

SR No.- Serial Number; KSh- Kenya Shilling; %- Percentage

The most expensive single ingredient feed was sweet potato vines at 30 KSh/kg (Table 3.11). It was also the most common single ingredient feed (35.7%) used by farmers. The vines were planted on the dykes (banks) of fish ponds in order to prevent soil erosion and also to be used as a cheap supplementary feed for the fish (the vines are chopped into small pieces). According to Munguti *et al.* (2012), the vegetative part of sweet potatoes and cassava can be used to feed fish because they are usually discarded after harvesting the tubers. Other single ingredient feeds such

Table 3.11: Costs of single ingredient feeds used by fish farmers in Ndia, Kirinyaga County

Single ingredient feeds	Cost/ kg (KSh)							N	%
	5	10	11	12	15	20	30		
Sweet potato vines	2	1	-	-	1	-	1	5	35.7
Rice bran	-	1	-	-	-	1	-	2	14.3
Maize germ	-	1	-	-	-	-	-	1	7.1
Wheat bran	-	-	1	1	1	-	-	3	21.4
Cassava leaves	-	-	-	-	2	1	-	3	21.4
								14	100

kg- kilogram; KSh- Kenya Shilling; N- number of fish farmers; %- percentage

as cereal milling byproducts are currently used as supplementary feed in the semi-intensive production of fish (Munguti *et al.,* 2012; FAO, 2015a). Rice bran was one of the cereal milling byproducts used in home-made and single ingredient fish feeds in Kirinyaga County. However, Tilapia fed with either rice bran, maize bran or wheat bran having CP of 6.4%, 11.6% and 14.3% respectively recorded the poorest growth in the fish fed rice bran (Liti *et al.,* 2006). It should therefore be used in combination with other ingredients in fish feeds so that the fish can receive all the nutrients they require.

3.3.8 Feeding challenges faced by fish farmers in Ndia, Kirinyaga County

Table 3.12 below shows the feeding challenges faced by the fish farmers. The main challenge (86%) was the high cost of feeds. This was also identified as a challenge by 33.6% of farmers in Siaya County, Kenya as documented by Shitote *et al.* (2012). In Kakamega, Kisii and Siaya Counties, the high cost of feeds was identified by fish farmers as the main challenge (compared to lack of finances, expertise and high quality fingerlings) that they faced in fish farming (Omasaki *et al.,* 2013). Other challenges reported in the current study were unavailability of feeds (8%) and low quality feeds (6%).

Table 3.12: Feeding challenges faced by fish farmers in Ndia, Kirinyaga County

Feeding challenges	Frequency	Percentage
Expensive feeds	43	86
Unavailability of feeds in the market	4	8
Low quality feeds	3	6
Total	50	100

Feed related challenges such as high cost, unavailability in the market and low quality impact heavily on fish farming because feeds account for approximately 70% of total variable cost of semi-intensive culture of fish (Ahmed, 2007). According to Shipton and Hasan (2013), profitability of fish farming can be enhanced if there is availability of high quality, low cost feeds accompanied by appropriate management practices.

3.3.9 Fish pond fertilization

The types of fertilizers used by fish farmers for pond fertilization are shown in Table 3.13. The majority of farmers (49.5%) used both organic and inorganic fertilizers while 28.4% used organic fertilizers and 9.2% used inorganic fertilizers alone. Only 12.8% of the farmers did not use any fertilizer in their ponds. Inorganic fertilizers used, such as Di-ammonium Phosphate (DAP), Urea, Calcium Ammonium Nitrate (CAN), and Nitrogen: Phosphorous: Potassium (N: P: K), were purchased from local shops.

Farmers obtained organic fertilizers (manure) from cattle, goats, poultry, pigs and rabbits on their farms or bought the manure from neighbouring farms. Farmers under the ESP were trained by extension workers on the use of both organic and inorganic fertilizers in their fish ponds. Inorganic fertilizers dissolve faster, have a higher concentration of phosphorous and nitrogen (the limiting nutrients in a fish pond) and do not use up oxygen (due to decomposition) compared to organic fertilizers (Fintrac, 2012).

Table 3.13: Types of fertilizers used by fish farmers in Ndia, Kirinyaga County

Fertilizer type	Frequency	Percentage
Inorganic	10	9.2
Organic	31	28.4
Both	54	49.5
None	14	12.8
Total	109	100

On the other hand, organic fertilizers increase zooplankton population in ponds more than inorganic fertilizers (Knud-Hansen, 1998). Zooplankton become more important feed components as Catfish grow because of increasing mouth gape and gill rakers for filter feeding (de Graaf and Janssen, 1996). The organic fertilizers used by fish farmers in Kirinyaga County depended on their availability on the farm while inorganic fertilizers were purchased from nearby shops.

Fertilization of ponds is important in order to increase growth of phytoplankton (Morris and Mischke, 1999). Phytoplankton serve as food for zooplankton and some herbivorous fish species such as Tilapia. In addition, they increase oxygen level in ponds due to photosynthesis by algae during the day which produces oxygen. Increase in phytoplankton lead to an increase in zooplankton which are the preferred feeds for larvae of most fish species (Knud-Hansen, 1998; FAO, 2015a). According to Knud-Hansen (1998) and FAO (2015a), the main production system practiced by Kenyan fish farmers is semi-intensive, where production of the natural pond food for the fish is enhanced using fertilizers. Organic fertilizers are either animal manures or compost and should only be used if they are readily available and inexpensive (Knud-Hansen, 1998). This is because of cost-benefit considerations. In addition, when phytoplankton die and decompose, they deplete dissolved oxygen in the fish pond. They also increase ammonia and hydrogen sulfide concentrations in pond water (Knud-Hansen, 1998).

The fertilizer application frequency in fish ponds is shown on Table 3.14. Most (27.4%) of the fish farmers used inorganic fertilizers in their fish ponds before stocking them with fish. They did not weigh the amount of inorganic fertilizer used. Most farmers (38%) used organic fertilizers once a month while 28% of the farmers applied them when the fish pond water was clear (little algal growth). The fish farmers did not weigh the amount of organic fertilizer used. This was also observed by Nyandat (2007) who pointed out that most farmers in Kenya monitored algal blooms instead of applying manure at the rate of 100-500kg dry weight/ha/week (Boyd and Massaut, 1999). There are also recommended manuring schedules for specific sources of manure such as chicken manure which should be applied two weeks before stocking at 25 kg dry weight/100 m^2 and thereafter 3 kg dry weight/100 m^2 every 10 days (Tacon, 1988). The fish farmers under the Economic Stimulus Program (ESP) were using fertilization rates (based on monitoring algal blooms) recommended by government extension officers.

Table 3.14: Frequency of fertilizer use in fish ponds in Ndia, Kirinyaga County

Frequency of use	Inorganic fertilizer		Organic fertilizer	
	N	%	N	%
Before stocking	32	27.4	12	12
When the water clears	29	24.8	28	28
Daily	-	0	1	1
Once a week	-	0	4	4
Every two weeks	8	6.8	1	1
Once a month	28	23.9	38	38
After more than a month	20	17.1	16	16
Total	117	100	100	100

N- number of fish farmers; %- percentage

Table 3.15 shows the challenges associated with fish pond fertilization. The main challenge (56.3%) was the high cost of inorganic fertilizer. The fish farmers did not follow the recommended fertilization rates of Boyd and Massaut (1999) and Nyandat (2007). As a result,

Table 3.15: Fish pond fertilization challenges in Ndia, Kirinyaga County

Fertilizer use challenges	Frequency	Percentage
Expensive inorganic fertilizers	9	56.3
Too much algae growth	6	37.5
Fish diseases	1	6.3
Total	16	100

the ponds had water quality problems such as too much algae growth (37.5%) and fish diseases (6.3%) due to over-fertilization.

Evaluation of rice milling byproducts

3.3.10 Location of rice millers in Kirinyaga County

A total of 56 questionnaires were administered to rice millers with 50 of these administered to small scale rice millers and six administered to large scale rice millers in Ndia and Mwea in Kirinyaga County. All the questionnaires had a 100% response rate. Most of the small scale rice millers (30%) were in Mutithi location of Mwea, Kirinyaga County whereas the majority of large scale rice millers (83.3%) were located in Tebere location as shown in Table 3.16. Plates 3.2 and 3.3 below show the researcher in a small scale and large scale rice mill respectively in Mutithi Location of Mwea, Kirinyaga County.

Table 3.16: Location of rice mills in Kirinyaga County

Location	Small scale millers		Large scale millers	
	Frequency (N)	Percentage	Frequency (N)	Percentage
Mutithi	15	30	1	16.7
Mwerua	8	16	-	-
Nyangati	13	26	-	-
Tebere	11	22	5	83.3
Thiba	3	6	-	-
Total	50	100	6	100

Plate 3.2: Researcher (on the left) interviewing a small scale rice miller in Mutithi Location

Plate 3.3: Researcher in a large scale rice mill in Mutithi Location

3.3.11 Availability and quality of rice milling byproducts in Kirinyaga County

Paddy rice was available all year round to the large scale rice millers and only to 42% of small scale mills (Table 3.17). Suppliers of paddy to large scale mills were middlemen who bought the paddy rice from farmers all over the County and milled it in bulk at the large scale rice mills. On the other hand, small scale rice mills depended on individual farmers and local small scale traders who were severely affected by seasonal supply of paddy rice for milling. Gitau *et al.* (2010) reported that large scale rice traders in Kenya handle approximately 57.3 tonnes of paddy rice per month compared to small scale rice traders who handle 4.5 tonnes per month. The year round milling of paddy rice by large scale mills can provide a constant supply of milling byproducts for use in animal feeds in the study area and neighboring Counties.

Table 3.17: Paddy rice availability in Kirinyaga County

Paddy rice available all year	Small scale mills		Large scale mills	
	Frequency	Percentage	Frequency	Percentage
Yes	21	42	6	100
No	29	58	0	0
Total	50	100	6	100

The peak milling month for small scale rice mills was December (24.5%) while that for large scale rice mills was November and December (20% each) as shown in Table 3.18. This coincides with the end of the short rainy season in Kirinyaga County (County Government of Kirinyaga, 2014). Most farmers therefore mill their rice in the dry season following the short rains in December as they depend on sun drying of the paddy rice prior to milling as it is cheaper compared to using mechanical dryers (Lantin, 1999). This indicates the time of year when there is an abundant supply of rice bran as a rice milling byproduct.

Table 3.18: Peak rice milling months in Kirinyaga County

Month of year	Small scale mills		Large scale mills	
	Number of respondents	Percentage	Number of respondents	Percentage
January	17	16.0	3	15
February	14	13.2	2	10
March	9	8.5	1	5
April	7	6.6	-	-
May	6	5.7	-	-
June	6	5.7	-	-
July	5	4.7	-	-
August	4	3.8	2	10
September	4	3.8	2	10
October	2	1.9	2	10
November	6	5.7	4	20
December	26	24.5	4	20
Total	106	100	20	100

The high cost of transport of paddy rice from the farms to the millers (49.1%) was the main challenge faced by small scale rice mills as shown in Table 3.19. Other challenges included inadequate drying of paddy rice (43.4%) and frequent outbreaks of rice blast disease (7.6%). Inadequate drying of paddy rice (60%) was the main challenge faced by large scale rice mills. The other challenges were expensive transport of paddy rice from the farms and frequent outbreaks of rice blast disease (all at 20%). The high cost of transport of paddy rice is mostly caused by the poor road infrastructure and the black cotton soils which are good for irrigated rice production in the lower regions of the County (County Government of Kirinyaga, 2014) but bad for transportation of paddy to the mills located in urban centers. In Nigeria, Ibitoye *et al.* (2014) reported the challenge of expensive transport from the farms to the mills as the third most important challenge.

Freshly harvested paddy rice usually has a moisture content of 24-26% and therefore in order to avoid qualitative and quantitative losses due to micro-organisms, storage pests and poor milling,

Table 3.19: Challenges faced by millers in the supply of paddy rice in Kirinyaga County

Challenges	Small scale mills		Large scale mills	
	Frequency	Percentage	Frequency	Percentage
Expensive transport of paddy rice from the farm	26	49.1	1	20
Inadequate drying of paddy rice	23	43.4	3	60
Rice blast disease	4	7.6	1	20
Total	53	100	5	100

it must be dried to 14% moisture content within 24 hours (Lantin, 1999). Immediately after the paddy rice in Kenya is harvested, it is purchased by traders who dry the paddy rice in trading centers in preparation for milling (Gitau *et al.* 2010). This is a challenge due to the small space available for drying the paddy rice in trading centers and the cold weather experienced in some months of the year therefore making sun drying impossible thus the challenge of inadequately dried paddy rice experienced by millers.

Rice blast is a fungal disease caused by *Pyricularia oryzae* Cav. and appears as lesions on the leaves and collars of rice plants (Pandey, 2008). It is spread by infected seeds and it occurs worldwide. The challenge of rice blast disease was also identified in a study done in western Kenya by Mambala (2007) who reported that rice blast disease was ranked by 80% of rice farmers as the most damaging disease.

3.3.12 Production of rice milling by products

Rice milling byproducts are available for use in fish feeds when paddy rice is available for milling as discussed above. The production per year and cost per kg of rice bran and chicken (broken) rice are discussed here because they are the main rice milling byproducts used in fish feeds and were therefore included in the test diets in study 2.

The 6 large scale mills reported a total rice bran production of 701.8 tonnes/year while the 38 small scale mills produced 6388.2 tonnes/year (Table 3.20). However, the average rice bran production by the large scale and the small scale mills was not significantly ($P>0.05$) different. Rice bran from large scale mills had a higher ($P<0.05$) average cost of 13.1 KSh/kg (Table 3.20) and an average CP of 14.7% (Table 3.21) compared to that from small scale mills that had an average cost of 6.9 KSh/kg and an average CP of 8%. This is compared to wheat pollard, a cereal milling byproduct, which costs 27 KSh/kg (Appendix 18) and has a CP of 15.5% (Table 4.3). This shows that rice bran from large scale mills has comparable CP to wheat pollard but is almost half the price. This could be because the rice bran was obtained directly from the rice mills while wheat pollard was purchased from shops which transport it from wheat growing regions of Kenya. This shows that rice bran from large scale mills has better quality (with regard to CP) compared to that from small scale mills and can be used to replace wheat pollard in fish diets (with regard to CP and cost).

The large scale mills produced a total of 38 tonnes/year of chicken rice while small scale mills produced 304.9 tonnes/year (Table 3.20). Chicken rice is a form of broken rice that is mainly fed to chicken (thus the name) because it has very small particle sizes that cannot be mixed with polished rice for human consumption. Chicken rice from large scale mills had an average cost of 32.5 KSh/kg and from small scale mills it had an average cost of 42.7 KSh/kg. Maize, a cereal like rice, had a cost of 35 KSh/kg (Appendix 18) which was slightly higher than the cost of chicken rice from large scale mills. However, maize had a CP of 7.6% compared to that of chicken rice from large scale mills which had a CP of 7.9% on DM basis (Table 4.3). This shows that chicken rice and maize are substitutes when formulating fish feeds (with regard to CP and cost).

Table 3.20: Rice milling characteristics in Kirinyaga County

Production characteristics	Large scale millers				Small scale millers				P value
	N	Total	Mean	SD	N	Total	Mean	SD	
Rice bran production (tonnes/yr)	6	701.8	117.0	135.50	38	6388.2	168.1	311.80	0.697
Rice bran cost (KSh/kg)	5	-	13.1[b]	2.12	47	-	6.9[a]	2.13	<0.001
Chicken rice production (tonnes/yr)	2	38.0	19.0	26.16	25	304.9	12.2	27.28	0.737
Chicken rice cost (KSh/kg)	2	-	32.5	10.61	28	-	42.7	13.78	0.318

N- number of millers; SD- Standard Deviation; yr- year; KSh- Kenya Shilling; kg- kilogram

3.3.13 Nutrient content of rice bran

The average Crude Fiber (CF) content of rice bran from large scale rice mills was 12.1% (Table 3.21) which was comparable to 13% reported by Batal and Dale (2011). Several other authors such as Gallinger *et al.* (2004), Njuguna (2007), Maina *et al.* (2013) and Singh *et al.* (2013) reported values lower than this ranging from 6.3% to 9.1%. According to Tacon *et al.* (2009), rice bran should have less than 13% CF. The average CF of rice bran from small scale rice mills was 27.9% which was comparable to the value of 30.9% documented by Munguti (2007) but higher than the 13% CF identified as the maximum for rice bran by Tacon *et al.* (2009). Other authors (Liti *et al*, 2006; Maina *et al.*, 2013) found higher CF (42.3% and 31.9% respectively) in their rice bran samples. This CF content (higher than 13%) can be attributed to rice bran from small scale mills being mixed with rice hulls during the less expensive and more common one-stage processing (compared to multi-stage processing) where hulls and bran are removed together (GoK, 2009; Tangpinijkul, 2010; Heuze' and Tran, 2015). On the other hand, the more expensive multi-stage processing of rice in large scale rice mills removes hulls and bran in

Table 3.21: Nutrient content of rice bran from rice millers in Kirinyaga County on dry matter basis

Parameters (%)	Mill scale	N	Minimum	Maximum	Mean	Std. Deviation
Dry matter	Large	3	88.7	91.0	89.7	1.15
	Small	4	89.5	91.8	90.5	1.06
Crude fiber	Large	3	9.8	13.2	12.1	1.90
	Small	4	19.1	33.6	27.9	6.40
Crude protein	Large	3	14.1	15.5	14.7	0.72
	Small	4	3.5	11.5	8.0	3.47
Ether extract	Large	3	16.8	23.7	20.0	3.44
	Small	4	9.3	16.7	12.0	3.23
Ash	Large	3	10.7	11.2	10.9	0.26
	Small	4	14.8	18.1	16.4	1.42
NFE	Large	3	28.4	38.0	32.0	5.22
	Small	4	24.5	27.5	26.2	1.50

N- number of rice bran samples; Std- Standard; NFE: Nitrogen Free Extract

different stages (Heuze' and Tran, 2015) resulting in bran having low crude fiber. Rice hulls are the hard outer layer of paddy (unmilled) rice with little feeding value due to high crude fiber and silica content and low crude protein (Njuguna, 2007; Government of India, 2011; Heuze' and Tran, 2015). This explains the high ash and low CP of rice bran from small scale mills compared to large scale mills. There was also high variability of crude fiber among the small scale mills because of the mixing of hulls and bran in varying proportions by the different machine types in different mills that carry out the one-stage milling resulting in large variations in the chemical composition as observed by OECD (2004).

The mixing of rice hulls with rice bran in small scale mills also lowers the level of oil (ether extract) in rice bran. According to Heuze' and Tran (2015), rice bran contains 14-18% oil. In the current study, rice bran from large scale and small scale mills had 20% and 12% oil (ether extract) respectively (Table 3.21) where the latter had lower levels due to mixing with rice hulls in the one-stage milling of rice in small scale mills (Heuze' and Tran, 2015).

Generally, the mixing of rice hulls and rice bran during the one-stage processing of paddy rice in small scale mills increases the crude fiber and ash contents and lowers the crude protein and oil (ether extract) of the rice bran. This lowers the feeding value of the rice bran making it less suitable for feeding fish. However, this also lowers the cost of the rice bran making fish farmers with limited resources turn to it as an inexpensive fish feed therefore leading to poor fish growth.

3.4 Conclusions

- Tilapia monoculture is the most common culture of fish in Kirinyaga County followed by polyculture of Tilapia with Catfish. Catfish monoculture was the least common.

- Most farmers did not feed their fish with the right feeds and at a percentage of body weight.

- The fish farmers in Kirinyaga fertilized their ponds but did not follow fertilization recommendations.
- Rice bran was the main rice milling byproduct found in large quantities in Kirinyaga County. However, the fish farmers in the County did not adequately utilize this rice milling byproduct to bring down their fish feed costs.
- The quality of rice bran from large scale rice mills was more suitable for use in fish diets due to its lower levels of crude fiber compared to rice bran from small scale rice mills.

3.5 Recommendations

- Capacity building for farmers to know the importance of sampling their fish every two weeks in order to determine their weight. This will enable them to feed the fish at a percentage of their body weight in order to avoid over-feeding or under-feeding the fish.
- The fish farmers should also be trained by government extension officers on better methods of fertilizing their ponds so as to maintain good water quality and natural food available to the fish and thus increase fish growth.
- On feeding, the fish farmers should be encouraged to use the rice milling byproducts that are available in large quantities, that is, rice bran and chicken rice, in home-made feeds to compliment commercial feeds in order to bring down their fish feed costs.
- Fish farmers in Kirinyaga County should also purchase rice bran from large scale mills because it has better quality compared to rice bran from small scale mills.

3.6 Way forward

- A cost-benefit analysis of fish farming in Kirinyaga County should be carried out. This will assist further research on ways of increasing fish production in the County.
- Economic reduction of moisture and oil in rice bran should be investigated in order to increase its shelf life.

CHAPTER 4

4.0 STUDY 2: EFFECTS OF DIETARY PROTEIN LEVELS ON PERFORMANCE OF AFRICAN CATFISH CULTURED IN FERTILIZED AND UNFERTILIZED EARTHEN PONDS

Abstract

A study was done in Kirinyaga County to evaluate the effects of dietary protein levels on performance of *C. gariepinus* cultured in fertilized and unfertilized earthen ponds. The fish were stocked at 10 fish/m^2 in happas placed in a fertilized and unfertilized earthen pond measuring 150m^2 each for 128 days. Four isocaloric diets (3000kcal/kg) with protein levels of 35% (control), 25% (Low Protein, LP), 30% (Medium Protein, MP), and 35% (High Protein, HP) were formulated at a cost of 47.80, 34.50, 38.30, and 42.60 KSh/kg of diet respectively. All diets contained rice milling byproducts (except the control) and were fed to the fish in triplicate. Average water temperature remained above 23.56°C (both ponds) while the average dissolved oxygen for the fertilized pond was significantly ($P<0.05$) higher than the unfertilized pond. There was no interaction between dietary protein levels and pond fertilization. The fish fed the HP test diet had the highest final weight, weight gain and Specific Growth Rate (SGR) which were significant ($P<0.05$) from that of the fish fed the LP diet. The best apparent feed conversion ratio was attained by fish fed the HP diet but the difference was only significant ($P<0.05$) when compared with those fed the control. The highest protein efficiency ratio was attained by the fish fed the LP diet but it was only significantly ($P<0.05$) different from that of fish fed the control and HP diets. The fingerlings in the fertilized pond had significantly ($P<0.05$) higher final weight, weight gain, SGR and feed intake compared to those in the unfertilized pond. The fish fed the low cost LP diet (25% protein level) in the fertilized pond had comparable growth to those fed the other diets and had a positive gross margin (52.80 KSh/ kg). It is therefore suitable for *C. gariepinus* culture in fertilized earthen ponds.

4.1 Introduction

Proteins supply amino acids to meet the (fish) body's requirements for structural proteins (such as muscles) and functional proteins (such as enzymes and hormones) and to provide energy (Parker, 2002). They are usually the first nutrient considered when formulating diets due to their nutritional importance and high cost (Craig and Helfrich, 2002).

The African Catfish (*Clarias gariepinus*) is omnivorous and has relatively better utilization of proteins than carbohydrates (FAO, 2015b). This is a challenge to its sustainable culture because the protein fraction of the ration is a more expensive component of feeds compared to carbohydrates (Munguti *et al.,* 2012). The protein requirements recommended for Catfish (32-36%) (National Research Council, 1993) were determined using young fish under optimum environmental conditions with the objective of achieving maximum growth rates. There was no consideration given to production costs or maximizing profits (Parker, 2002). As such, there is need to evaluate the performance of *C. gariepinus* under varying dietary protein content to assess growth and economics of the growth. In this study, rice milling byproducts, which were abundant in the study area were used to formulate diets for *C. gariepinus* in order to reduce the cost of formulated diets for this fish species.

A major challenge encountered in the culture of fish in ponds is the poor pond water quality (de Graaf and Janssen, 1996) resulting from decomposing left over feeds and fecal material which release ammonia into the water (Parker, 2002). Pond fertilization increases growth of algae which assimilate ammonia and increase dissolved oxygen concentration in the pond water during the day (Knud-Hansen, 1998). There is therefore need to study effects of pond fertilization on the quality of pond water and *C. gariepinus* growth.

The overall objective of this study was to investigate the effects of dietary protein levels and inclusion of rice milling byproducts in diets on the performance of African Catfish (*Clarias gariepinus*) in fertilized and unfertilized earthen ponds.

Specific objectives of this study were therefore to:

i. Determine the effects of dietary protein levels on performance of *Clarias gariepinus* in fertilized and unfertilized earthen ponds.
ii. Evaluate the effects of dietary inclusion of rice milling byproducts on performance and diet cost for *Clarias gariepinus*.

4.2 Materials and methods

4.2.1 Study site

This study was carried out from 15th February, 2014 to 3rd July, 2014 at the National Aquaculture Research Development and Training Center, 2 km outside of Sagana Town (Figure 4.1), Kirinyaga County, Kenya. It is 104 km NE of Nairobi at 0° 39’ Southings, 37° 12’ Eastings and 1230 m above mean sea level (McElwee, 1999). The water source for the farm is the permanent River Ragati.

4.2.2 Feed ingredients

Rice bran was purchased from a large scale rice miller in Kirinyaga County while the other feed ingredients were purchased from suppliers in Nairobi. The raw materials were analyzed at the Department of Animal production, University of Nairobi for their nutritional composition prior to their inclusion in fish diets. The analysis of the feed ingredients for DM, CP, EE, CF and ash was done according to the procedures outlined by the Association of Official Analytical Chemists (AOAC, 1998) prior to the formulations.

4.2.3 Experimental diets and research design

Four isocaloric diets (3000 kcal/kg) having protein levels of 35% (control), 25%, 30%, and 35% were formulated and used in this study. All diets (except the control) contained rice milling byproducts. Other ingredients included maize, wheat pollard, soybean meal and freshwater shrimp (*Caridina nilotica*) meal as shown in Table 4.1. The fish were stocked at 10 fish/m^2 and cultured for 128 days in happas each measuring 2 m^2 placed 1m apart in two earthen ponds each measuring 150m^2. There were four diets fed to fish in the two ponds, one fertilized and the other unfertilized. These were eight treatments with three replicates each (therefore 24 happas used, 12 in each pond) and twenty fish per replicate (Table 4.2).

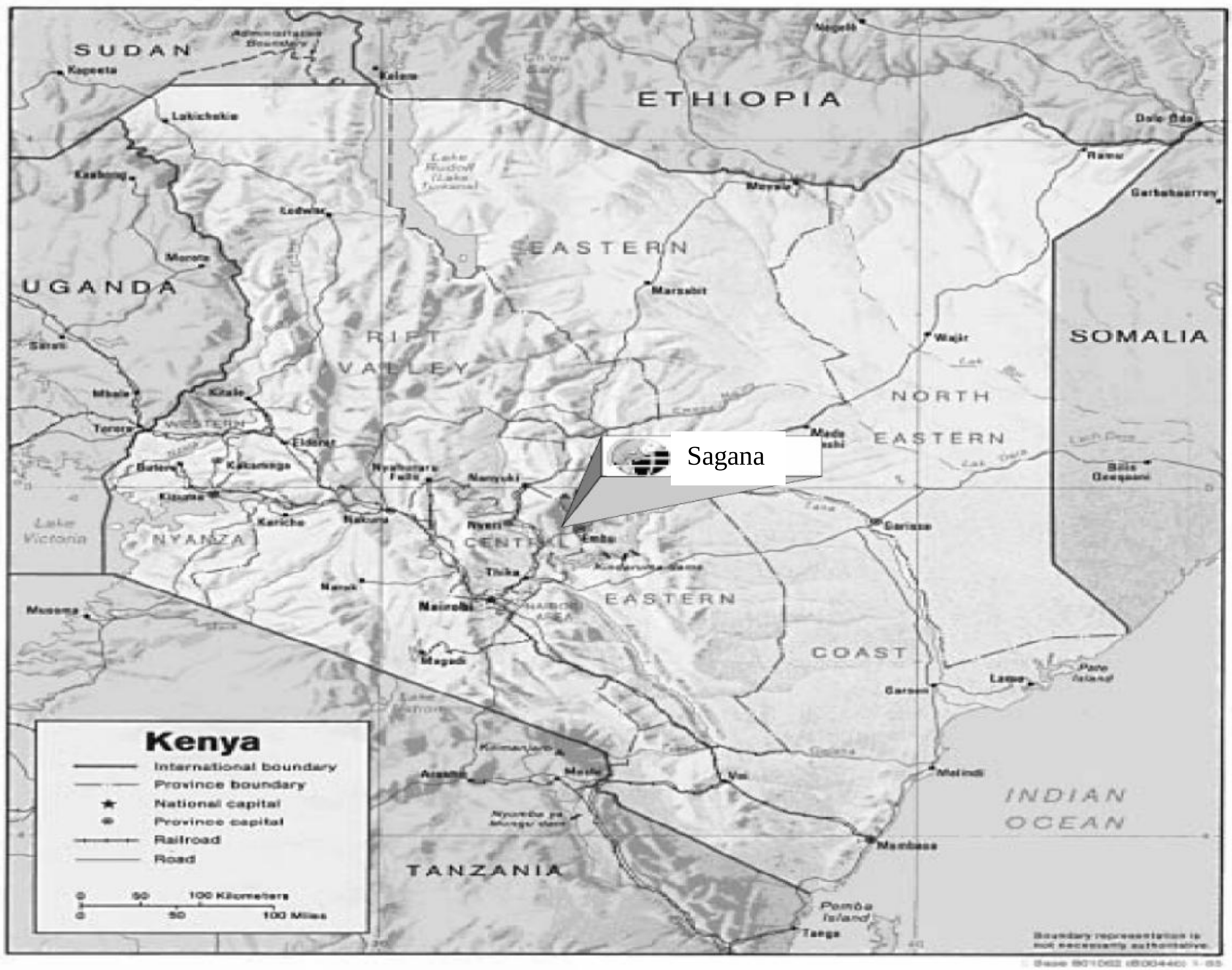

Figure 4.1: Sagana town, Kenya (***Source: McElwee, 1999***)

Table 4.1: Composition of the *Clarias gariepinus* diets used in the study

INGREDIENTS (%)	DIETS			
	Control (35% CP)	25% CP	30% CP	35% CP
Maize grain	22.13	10.00	10.00	10.00
Rice bran (fine)	-	20.00	20.00	20.00
Rice grain (chicken rice)	-	15.80	8.54	0.00
Corn oil	-	4.93	2.18	0.00
Soybean meal, solvent extracted	15.00	15.00	15.00	15.00
Wheat pollard	10.00	10.00	10.00	10.00
Freshwater Shrimp Meal	45.74	22.04	32.18	42.48
Di-calcium Phosphate	0.20	0.13	0.10	0.10
Limestone	3.33	0.00	0.00	0.00
HCL-Lysine	0.30	0.00	0.00	0.00
DL-Methionine	0.30	0.10	0.00	0.00
Ascorbic acid	2.00	1.00	1.00	1.42
Salt	0.50	0.50	0.50	0.50
Vitamin-Mineral Premix	0.50	0.50	0.50	0.50
Total	100	100	100	100
Calculated composition (air-dry basis)				
Digestible Energy (Kcal/ kg)	3000.00	3000.00	3000.00	3023.68
Crude Protein (%)	35.00	25.00	30.00	35.00
Calcium (%)	3.07	0.97	1.36	1.77
Phosphorous (%)	0.62	0.50	0.55	0.59
Crude fiber (%)	3.80	5.07	5.15	5.17
Lysine (%)	2.68	1.55	1.94	2.33
Methionine (%)	1.18	0.64	0.70	0.85
Cost/ kg (Ksh.)	47.80	34.50	38.30	42.60

%- percentage; CP- Crude Protein; kg- kilogram; Kcal/ kg- Kilocalories per kilogram; KSh- Kenya Shilling; The vitamin-mineral premix provided the following per kg of feed: Vitamin A, 5000 IU; Vitamin D_3, 1000 IU; Vitamin E, 150 IU; Vitamin K_3, 3 mg; Vitamin B_1, 10 mg; Vitamin B_2, 15 mg; Vitamin B_6, 7.5 mg; Vitamin B_{12}, 0.025 mg; Niacin, 100 mg; Pantothenic acid, 27.5 mg; Biotin, 0.5 mg; Folic acid, 3 mg; Choline, 500 mg; Vitamin C, 300 mg; Manganese, 75 mg; Iron, 20 mg; Zinc, 22.5 mg; Copper, 2.5 mg; Cobalt, 0.1 mg; Iodine, 0.7 mg; Selenium, 0.06 mg. The cost of corn oil, ascorbic acid, transport of ingredients, pelleting and packaging of the diets are not included in the total cost of the diets because they were inflated compared to market prices due to experimental conditions. Control contains 35% protein without rice milling byproducts.

Table 4.2: Treatments and replicates used in *Clarias gariepinus* feeding trial

Happas	Fertilized pond	Unfertilized pond
1	Control (R1)	30% CP (R1)
2	30% CP (R3)	35% CP (R1)
3	Control (R2)	Control (R2)
4	25% CP (R2)	25% CP (R3)
5	35% CP (R2)	30% CP (R3)
6	25% CP (R1)	25% CP (R2)
7	35% CP (R1)	Control (R1)
8	30% CP (R1)	30%CP (R2)
9	35%CP (R3)	25% CP (R1)
10	Control (R3)	35% CP (R2)
11	25% CP (R3)	Control (R3)
12	30% CP (R2)	35% CP (R3)

CP- Crude Protein; R1- Replicate 1; R2- Replicate 2; R3- Replicate 3

4.2.4 Management of fish

Eight hundred mixed-sex *Clarias gariepinus* fingerlings weighing 1.40± 0.06 g were bought from Jambo fish farm in Kiambu County, Kenya and transported to the study site. They were acclimatized to pond conditions for a week while being fed on the control diet before the feeding trial commenced. After acclimatization, 480 fish were selected, weighed (average weight 3.29± 0.329g), grouped (20 fish/group) and randomly placed in 24 happas in two earthen ponds which constituted two blocks limed two weeks before stocking according to guidelines by Boyd and Massaut (1999) and Ngugi *et al.* (2007), that is, 2,500 kg lime per hectare. Feeding was done thrice daily (Aderolu *et al.,* 2010) instead of the more conventional feeding of twice daily (Pantazis and Neofitou, 2003; Zeinhom *et al*., 2010) to reduce incidences of cannibalism (Baras and Jobling, 2002). The four groups of fish were fed each diet (three replicates) at a percentage of body weight. These percentages were adjusted biweekly after measuring the fish weights (g) and were reduced gradually from 10% (when the fish weighed 1.40± 0.06 g) to 3% of body weight when the fish attained a weight of approximately 36g: this was according to guidelines by Hogendoorn *et al*. (1983), Hecht *et al*. (1988) and de Graaf and Janssen (1996). One pond was fertilized with chicken manure two weeks before stocking at 25 kg dry weight/100 m^2 and thereafter 3 kg dry weight/100 m^2 every 10 days (Tacon, 1988). The other pond was left unfertilized. Parameters used to assess the quality of the pond water were: temperature (°C), dissolved oxygen (mg/l), pH, ammonia (mg/l), nitrates (mg/l), nitrites (mg/l), Total Dissolved Solids, TDS (ppm), salinity (mg/l) and Electrical Conductivity, EC (µS/cm) which were monitored every week. A thermometer was used to measure the water temperature, an oxygen probe was used to measure the DO, while pH was measured using a pH meter, and ammonia, nitrates, and nitrites were measured using chemical test kits 'Colombo Aquatest kits' supplied by

Jambo fish farm, Kiambu County, Kenya. A multi-parameter probe (HI 98282.2) was used to measure the TDS, salinity and EC.

4.2.5 Data collection

Fish weighing was done biweekly and length measurements taken in order to adjust the feeding rates and to calculate the growth performance, percentage survival and feed utilization. The following parameters for measuring fish performance were monitored.

Initial weight, final weight and weight gain

The gain in weight of the fish (g) was calculated as the weight at commencement of the experiment subtracted from the weight at harvest.

Specific growth rate

The Specific Growth Rate (SGR), recorded as a %/day, was calculated as (1) below.

$$SGR = \left(\frac{\log_n W_2 - \log_n W_1}{T_2 - T_1}\right) \times 100 \qquad (1)$$

Where $\log_n W_2$ and $\log_n W_1$ are natural logarithms of final and initial fish weights respectively, and T_2-T_1 is the culture period (days).

Feed intake and apparent feed conversion ratio

Feed intake was reported as the average consumption of feeds/fish for the whole culture period. The Apparent Feed Conversion Ratio (AFCR) was estimated when feed intake/fish was divided by the gain in weight of the fish during the culture period.

Protein efficiency ratio

The Protein Efficiency Ratio (PER) was calculated as shown below.

PER= (W2-W1)/(Protein consumed (g))

Where W2 and W1 are the final and initial fish weights (g) respectively.

Fulton's condition factor

The fish welfare was determined using the Fulton's condition factor (K) which is a non-invasive condition measure described in a review by Blackwell *et al.* (2000) where actual and expected weight-length relationships are estimated. It indicates fatness or well being of the fish. It assumes fish weight-length relationship is linear and that the fish have isometric growth, that is, old fish have the same shape as young fish. It is determined using the formula (3) below.

Fulton's condition factor, $K= (W/L^3)*100$ (3)

Where W is the fish weight (g), L is the fish length (cm), and 100 is a constant used to scale the fish weight-length relationship towards unity (Froese, 2006). Values below 1 are an indication of emaciation or underfeeding while values above 1 are an indication of fatness or overfeeding. A good value is therefore as close to 1 as possible.

Fish mortalities

Fish mortalities were recorded during the biweekly sampling.

4.2.6 Data analysis

Data on performance of *C. gariepinus* were analyzed using two-way Analysis of Variance (ANOVA) in Genstat 13th edition. Differences between treatment means were considered significant at $P<0.05$ and if found to be significant they were separated using Tukey's multiple comparison procedure. T-tests were done to compare the water quality parameters of fertilized and unfertilized ponds.

4.3 Results and discussion

4.3.1 Ingredient nutrient composition

The nutrient percentages in the dietary ingredients are shown on Table 4.3. The maize grain had a CP content of 7.6% which was lower than 8.5% reported by National Research Council (1993). Rice bran (fine) had a CP of 14.4% and CF of 10% which were higher than the CP of 11.9% and 10.8% and CF of 9.1% and 8.32% reported by Njuguna (2007) and Maina *et al.* (2013) respectively in Kenya. However, the CP content was within the range of 13.8-15.4% reported by Gallinger *et al.* (2004) in Uruguay but the CF was higher than that reported (7.4-8.3%). This is acceptable according to the definition of rice bran by Tacon *et al.* (2009) who stated that it should contain CF less than 13%. In this study, rice bran was purchased from a large scale mill where bran and hulls are removed separately. It is also called fine bran because of its high CP (higher than the cited values above) because it mixes with polishings consisting of the starchy kernel or endosperm of milled rice during the polishing stage of rice processing in large scale mills (Heuze' and Tran, 2015).

Chicken rice, which are small sized particles (compared to broken rice) of rice grains that break during the milling process and are mainly fed to chicken (thus the name), were purchased from the same mill as the rice bran and had a CP of 7.9% which is close to 7.1% reported by Chau Thi Da (2012) in Vietnam. Soybean meal, solvent extracted, had a CP of 45.6% which was close to 42.8% (Fagbenro *et al.*, 2010) and 43.7% (Ochang *et al.*, 2014) recorded in Nigeria but lower than 50% reported by Nyandat (2007) in Kenya. Wheat pollard (middlings) had a CP of 15.5% which is close to 15% reported by Nyandat (2007) in Kenya. Freshwater Shrimp Meal had a CP of 59.6% which is close to 55-60% recorded by Munguti *et al.* (2014) and 60.1±0.06% reported by Obwanga (2010) but lower than 63.5±0.33% reported by Munguti *et al.* (2012). The

Table 4.3: Proximate components in percentages of dietary feed ingredients on dry matter basis

Feed ingredients	DM	CP	Ether extract	Ash	CF
Maize grain	90.0	7.6	0.6	1.0	13.1
Rice bran (fine)	90.2	14.4	1.1	12.3	10.0
Rice grain (chicken rice)	88.4	7.9	0.8	2.0	6.5
Soybean meal	87.5	45.6	0.6	8.7	11.1
Wheat pollard	90.1	15.5	0.4	4.3	8.3
Freshwater Shrimp Meal	86.2	59.6	0.5	21.3	13.6

DM- Dry matter; CP- Crude protein; CF- Crude fiber

Freshwater Shrimp (*Caridina nilotica*) is found in Lake Victoria located in East Africa. In this study, *C. nilotica* was the source of animal protein.

4.3.2 Effects of dietary protein levels and pond fertilization on performance of *Clarias gariepinus*

The interactions of dietary protein levels and pond fertilization were not significant (P>0.05) for all the parameters studied as shown in Table 4.4. The effects of dietary protein levels on performance of *C. gariepinus* is shown in Table 4.5. The average initial weight of the fingerlings allocated to the treatments were similar when the feeding trial commenced. The highest average weight at harvest, gain in weight and specific growth rate (SGR) (259.7g, 256.1g and 4.32%/day respectively) were attained by fingerlings fed the 35% protein level diet. This was however only significantly (P<0.05) different from that of the fingerlings fed the 25% protein diet which attained an average weight at harvest, gain in weight and SGR of 200g, 196.5g and 4.11%/day respectively.

Fish on the control diet had the highest average feed intake (429.4g) but the difference from the feed intakes of fish in the other treatments was not significant (P>0.05). The best apparent feed conversion ratio (1.66) was attained by fish fed the high protein diet (35% protein) but the difference was only significant (P<0.05) from that attained by fish fed on the control diet (1.93). The highest protein efficiency ratio of 2.18 was attained by the fish fed on the low protein diet (25% protein) but the difference was only significant (P<0.05) from that of 1.49 attained by fish fed the control diet and the 35% protein level diet (1.73). The condition factor and mortality of the fish fed different protein levels were not significantly (P>0.05) different.

Table 4.4: Performance of *Clarias gariepinus* fed varying protein levels in fertilized and unfertilized earthen ponds for 128 days

[1]Parameters	Fertilized pond				Unfertilized pond				LSD	SEM	Main effects		Interactions
	Control	LP	MP	HP	Control	LP	MP	HP			PL	PF	PL* PF
IW	3.66	4.88	3.72	4.64	2.41	2.30	2.30	2.41	0.99	0.329	0.192	<0.001	0.171
FW	240.00^{ab}	227.80^{ab}	269.70^{b}	298.10^{b}	212.40^{ab}	172.30^{a}	230.20^{ab}	221.30^{ab}	54.07	18.040	0.020	0.001	0.568
WG	236.40^{ab}	222.90^{ab}	266.00^{b}	293.40^{b}	210.00^{ab}	170.00^{a}	227.90^{ab}	218.90^{ab}	53.89	17.980	0.019	0.002	0.584
FI	459.20^{bc}	401.60^{abc}	437.10^{abc}	507.50^{c}	399.50^{abc}	315.60^{a}	383.40^{abc}	347.00^{ab}	86.30	28.800	0.086	<0.001	0.265
AFCR	1.95	1.81	1.64	1.74	1.90	1.90	1.69	1.59	0.23	0.077	0.006	0.771	0.442
PER	1.47^{a}	2.22^{d}	2.03^{bcd}	1.66^{ab}	1.50^{a}	2.13^{cd}	1.98^{bcd}	1.80^{abc}	0.23	0.078	<0.001	0.860	0.460
SGR	4.26^{ab}	4.22^{ab}	4.36^{b}	4.44^{b}	4.17^{ab}	3.99^{a}	4.24^{ab}	4.21^{ab}	0.22	0.072	0.034	0.005	0.652
K	0.78	0.76	0.77	0.77	0.77	0.74	0.78	0.76	0.04	0.015	0.417	0.409	0.606
M	3.59	3.20	2.54	4.45	2.34	4.03	3.82	2.80	2.87	0.959	0.870	0.773	0.352

LSD- Least significant difference; SEM- Standard Error Mean; PL- Protein Level; PF- Pond Fertilization; Control- contains 35% protein without rice milling byproducts; LP- Low Protein diet containing 25% protein; MP- Medium Protein diet containing 30% protein; HP- High Protein diet containing 35% protein; IW- Initial Weight (g); FW- Final Weight (g); WG- Weight Gain (g); FI- Feed Intake (g); AFCR- Apparent Feed Conversion Ratio; PER- Protein Efficiency Ratio; SGR- Specific Growth Rate (%/day); K- Fulton's condition factor; M- Mortality (%); Means with different superscripts in a row are significantly ($P<0.05$) different; [1]Means, n= 480

Table 4.5: Effects of dietary protein levels on *Clarias gariepinus* performance

Protein Level	Control diet	LP	MP	HP	LSD	SEM	P Value
[1]Fish performance							
Initial weight (g/fish)	3.04	3.59	3.01	3.53	0.70	0.232	0.192
Final weight (g/fish)	226.20[ab]	200.00[a]	250.00[ab]	259.70[b]	38.23	12.750	0.020
Weight gain (g/fish)	223.20[ab]	196.50[a]	246.90[ab]	256.10[b]	38.11	12.710	0.019
SGR (%/day)	4.22[ab]	4.11[a]	4.30[ab]	4.32[b]	0.15	0.051	0.034
Feed intake (g/fish)	429.40	358.60	410.20	427.20	61.00	20.300	0.086
AFCR	1.93[b]	1.85[ab]	1.67[a]	1.66[a]	0.16	0.054	0.006
PER	1.49[a]	2.18[c]	2.01[c]	1.73[b]	0.17	0.055	<0.001
K	0.77	0.75	0.77	0.77	0.03	0.010	0.417
Mortality (%)	2.96	3.62	3.18	3.62	2.03	0.678	0.870

LP- Low Protein diet containing 25% protein; MP- Medium Protein diet containing 30% protein; HP- High Protein diet containing 35% protein; SGR- Specific Growth Rate; AFCR- Apparent Feed Conversion Ratio; PER- Protein Efficiency Ratio; K- Fulton's condition factor; Means with different superscripts in a row are significantly (P<0.05) different; [1] Means, n= 480

Ahmad (2008) reported a significant increase in growth of *C. gariepinus* with increase in protein and lipid levels with the highest growth being achieved at 30% and 35% CP having 12% and 9% lipid respectively. Likewise, Ali and Jauncey (2005) observed that *C. gariepinus* fingerlings fed diets having 33% and 43% CP had significantly ($P<0.05$) higher growth rates and FCR as the protein level increased. Other authors (Machiels and Henken, 1985; Degani *et al.,* 1989) reported that *C. gariepinus* performance improved with increasing protein up to 40% CP. It is noteworthy that the literature quoted above is for fingerlings and young fish. Data on the effects of different protein levels for Catfish fed to market weight of approximately 200g is scarce.

Weight gains

The weight gains of the fish in this study increased as the dietary protein levels increased where the fish fed the diets having CP of 25%, 30% and 35% had weight gains of 196.5g, 246.9g and 256.1g respectively. In contrast, those fed the control diet (35% CP) had a lower weight gain of 223.2g. The control diet did not contain rice bran which has high levels of minerals and vitamins, especially vitamin E and B vitamins (Salem *et al.,* 2014; Heuze' and Tran, 2015). Rice bran also contains 14-18% rice bran oil (Heuze' and Tran, 2015) which is used as a healthy cooking oil in human food because it has γ-oryzanol fraction, an antioxidant (OECD, 2004). These could have improved the growth of fish fed the 35% CP test diet compared to those fed the control diet with the same protein level but the difference was not significant.

Specific growth rate

The Specific Growth Rate (SGR) of the fish increased as dietary protein levels increased where the fish fed the diets containing 25% CP, 30% CP and 35% CP had SGRs of 4.11, 4.30 and 4.32%/day respectively. However, the SGR of fish fed the control diet was 4.22%/day which was low compared to 4.32%/day attained by fish fed the same dietary protein level (35% CP diet).

Specific growth rate is a measure of instantaneous growth and therefore increases with increasing growth. The SGR trend was therefore similar to the weight gain trend and just as in the case of weight gain, the poor SGR of fish fed the control diet was attributed to the lack of rice bran in the diet.

Feed intake

The feed intake of the fish increased as the dietary protein level increased where the fish fed the diets containing 25% CP, 30% CP and 35% CP had feed intakes of 358.6, 410.2 and 427.2g/fish respectively. This is because feeding of fish was done at a percentage of body weight, ranging from 10% of body weight when the fish weighed 1.40± 0.06 g to 3% of body weight when the fish attained a weight of approximately 36g. This was according to guidelines given by Hogendoorn *et al*. (1983), Hecht *et al*. (1988) and de Graaf and Janssen (1996) where the higher the weight of the fish, the higher the amount of feed given. In contrast, a feed intake of 429.4g was recorded for the fish fed the control diet which was highest (P>0.05) among the treatments.

Apparent feed conversion ratio

The Apparent Feed Conversion Ratio (AFCR) of the fish decreased with increasing dietary protein levels where the fish fed the diets containing 25%, 30% and 35% CP had AFCRs of 1.85, 1.67 and 1.66. This is because *C. gariepinus* are omnivorous with better utilization of high protein than high carbohydrate diets (FAO, 2015b) therefore they had better utilization of feed as the protein level increased. The fish fed the control diet, having a CP of 35%, had the highest AFCR because they had the highest (P>0.05) feed intake and low weight gain (due to lack of rice bran in the diet).

Protein efficiency ratio

The Protein Efficiency Ratio (PER) of the fish decreased as the dietary protein levels increased where the test diets having 25%, 30% and 35% CP recorded PERs of 2.18, 2.01 and 1.73 respectively of the fish. The efficiency of utilization of protein decreases with increase in protein. The fish fed the control diet (that had 35% CP without the inclusion of rice milling byproducts) had the lowest PER (1.49) compared to the fish fed the test diets. This could be because they had low weight gain due to lack of rice bran in their diet and they also consumed high levels of protein as indicated by their high ($P>0.05$) feed intake.

Fulton's condition factor

The Fulton's condition factor (K) of fish fed the diets having CP of 25%, 30%, 35% and the control was 0.75, 0.77, 0.77 and 0.77 respectively. The K for the fish in this study were less than 1 indicating emaciation of fish which was preferred because the values were close to 1 compared to having values larger than 1 which would indicate fatness (fat deposition).

Mortality

The average mortality of the fish in the current study fed the diets containing 25%, 30% and 35%CP was 3.62%, 3.18% and 3.62% respectively. The fish fed the control diet had an average mortality of 2.96%. The main causes of mortality were cannibalism and bird predators. These mortalities were low compared to those recorded by Ani *et al.* (2013) ranging between 10.00-13.33% in the culture of *C. gariepinus* fed extruded commercial feeds at various allocated times during the day. The protein level and rice bran inclusion in the diet had no effect on the mortality rate in the current study.

4.3.3 Effects of pond fertilization on performance of *Clarias gariepinus*

The effects of pond fertilization on fish performance are shown on Table 4.6. The mean fish weight in the fertilized pond at the start of the experiment was higher than that of fish in the unfertilized pond. An analysis of covariance was done with the initial weights of fish as the covariate. The covariance was not significant (P>0.05) for any of the parameters. Fish reared in the fertilized pond had higher final weights, gain in weight, feed intake and specific growth rates (258.9g, 254.7g, 451g and 4.32%/day respectively) than those in the unfertilized pond (209.1g, 206.7g, 361g and 4.15%/day respectively); the differences were significant (P<0.05). There was no significant (P>0.05) difference in apparent feed conversion ratio, protein efficiency ratio, mortality and Fulton's condition factor of the fish in fertilized and unfertilized ponds.

Weight gains

The fish in the fertilized pond had higher average gain in weight (254.7g/fish) in comparison with those in the unfertilized pond (206.7g/fish) and the difference was significant (P<0.05). This is because pond fertilization increases nitrogen and phosphorous levels in the pond water resulting in increased phytoplankton growth (Parker, 2002). The phytoplankton increase dissolved oxygen concentration in the pond water when they carry out photosynthesis during the day and they also assimilate ammonia from the pond water (Knud-Hansen, 1998). This improves the pond water quality and consequently improves the fish performance.

Specific growth rate

The fish in the fertilized pond had higher Specific Growth Rate, SGR (4.32%/day) in comparison with those in the unfertilized pond (4.15%/day) and the difference was significant (P<0.05). This was due to the improved water quality as described above.

Table 4.6: Effects of pond fertilization on the performance of *Clarias gariepinus*

Pond Fertilization	Fertilized pond	Unfertilized pond	LSD	SEM	P Value
[1]Fish performance					
Initial weight (g/fish)	4.23	2.36	0.49	0.16	<0.001
Final weight (g/fish)	258.90[b]	209.10[a]	27.04	9.02	0.001
Weight gain (g/fish)	254.70[b]	206.70[a]	26.95	8.99	0.002
Specific Growth Rate (%/day)	4.32[b]	4.15[a]	0.11	0.04	0.005
Feed intake (g/fish)	451.00[b]	361.00[a]	43.10	14.40	<0.001
Apparent Feed Conversion Ratio	1.78	1.77	0.12	0.04	0.771
Protein Efficiency Ratio	1.84	1.85	0.12	0.04	0.860
Fulton's condition factor	0.77	0.76	0.02	0.01	0.409
Mortality (%)	3.45	3.25	1.44	0.48	0.773

LSD- Least significant difference; SEM- Standard error mean; g/fish- gram per fish; %/ day- percentage per day; Means with different superscripts within a row are significantly (P<0.05) different; [1]Means, n= 480

Feed intake

The fish in the fertilized pond had higher feed intake (451g/fish) in comparison with those in the unfertilized pond (361g/fish) and the difference was significant ($P<0.05$). This is because fish in the fertilized pond were fed more feed compared to those in the unfertilized pond due to their larger body weight (Hogendoorn *et al*., 1983; Hecht *et al*., 1988; de Graaf and Janssen, 1996).

Apparent feed conversion ratio

The fish in the fertilized pond had a higher average apparent feed conversion ratio (1.78) compared to those in the unfertilized pond (1.77). However, the difference was not significant ($P>0.05$).

Protein efficiency ratio

Fish in the fertilized pond had a lower Protein Efficiency Ratio (PER) (1.84) than the fish in the unfertilized pond (1.85). However, the difference was not significant ($P>0.05$).

Fulton's condition factor

The Fulton's condition factor of fish in the fertilized pond was higher (0.77) than that of fish in the unfertilized pond (0.76). However, the difference was not significant ($P>0.05$).

Mortality

The mortality of fish in the fertilized pond (3.45%) was higher than that in the unfertilized pond (3.25%). However, the difference was not significant ($P>0.05$).

4.3.4 Effects of pond fertilization on water quality of *Clarias gariepinus* ponds

Temperature

The mean water temperature of the fertilized pond (23.88°C) was higher (P>0.05) than that of the unfertilized pond (23.56°C) (Table 4.7). Mosha (2015) in Tanzania cultured *C. gariepinus* fry in concrete tanks and observed no temperature differences between fertilized and unfertilized ponds. Similarly, Suresh *et al.* (2013) in India cultured Indian major carp while Zahid *et al.* (2013) in Pakistan cultured Tilapia in fertilized and unfertilized earthen ponds both observing no difference in water temperatures. Therefore pond fertilization had no effect on water temperature.

The recommended temperature for Catfish culture range between 20-30°C (Isyagi *et al.,* 2009; Water Research Commission, 2010). Water temperature is important because fish are ectotherms (Castell, 2000), therefore water temperature influences their metabolic activities.

Dissolved oxygen

The average dissolved oxygen (DO) of the fertilized pond (2.8mg/l) was higher than that of the unfertilized pond (2.15mg/l) and the difference was significant (P<0.05) (Table 4.7). In contrast, Mosha (2015) working with *C. gariepinus* fry in Tanzania, Suresh *et al.* (2013) working with Indian major carp and Zahid *et al.* (2013) working with Tilapia in Pakistan reported no difference in DO between fertilized and unfertilized ponds.

The recommended dissolved oxygen level for Catfish culture ranges between 3 mg/l (Water Research Commission, 2010) to 5 mg/l (Parker, 2002; Floyd, 2014). The primary productivity of a fish pond, that is, phytoplankton (microscopic plants) growth, is mainly limited by phosphate availability in the water and to a lesser extent nitrogen and potassium (de Graaf and Janssen,

Table 4.7: Water quality parameters of the fertilized and unfertilized ponds used to culture *Clarias gariepinus*

Parameter	Treatment pond	Frequency	Mean	Standard deviation	P value
Temperature (°C)	Fertilized	62	23.88	1.817	0.320
	Unfertilized	64	23.56	1.765	
Dissolved oxygen (mg/l)	Fertilized	63	2.80[b]	1.990	0.037
	Unfertilized	64	2.15[a]	1.462	
pH	Fertilized	62	8.08[b]	0.3073	<0.001
	Unfertilized	64	7.85[a]	0.2737	
Electrical conductivity	Fertilized	62	225.60[b]	38.38	<0.001
(µS/cm)	Unfertilized	64	123.50[a]	23.00	
Salinity (mg/l)	Fertilized	62	0.11[b]	0.019	<0.001
	Unfertilized	64	0.06[a]	0.011	
Total dissolved solids (ppm)	Fertilized	62	112.85[b]	19.30	<0.001
	Unfertilized	64	61.80[a]	11.44	

°C- degrees centigrade; mg/l- milligram per liter; µS/ cm- microsiemens per centimeter; ppm- parts per million; Means with different superscripts within a column are significantly (P<0.05) different

1996). Pond fertilization increases nitrogen and phosphorous levels in the pond water which are used by phytoplankton for growth (Parker, 2002). The phytoplankton carry out photosynthesis during the day resulting in higher DO levels in fertilized ponds compared to unfertilized ponds (Knud-Hansen, 1998). Optimal levels of DO have been found to increase fish growth. A study done in the USA by Torrans (2008) investigated the effect of high, medium and low average DO levels (4.37, 2.68 and 2.32 mg/l respectively) on Channel Catfish, *Ictalurus punctatus* (Rafinesque, 1818) growth in earthen ponds. The fish growth increased with increasing dissolved oxygen levels. The study used paddlewheel electric aerators to regulate the DO levels in the water and recommended a DO level between 2.3-2.5 mg/l to compromise between fish growth and aeration costs. This is because the optimum DO level recommended for *I. punctatus* is 5 mg/l (Parker, 2002; Floyd, 2014).

Water pH

The average pH of the fertilized pond water at 8.08 was higher than that of the unfertilized pond (pH 7.85) and the difference was significant ($P<0.05$) (Table 4.7). Mosha (2015) reported pH ranging between 6-9 in a fertilized pond and pH 7-9 in an unfertilized pond. Suresh *et al.* (2013) recorded pH 7.8-8.2 in both fertilized and unfertilized ponds. Zahid *et al.* (2013) in Pakistan got a water pH of 8.67 and 8.57 from fertilized and unfertilized ponds respectively. None of these observations were significantly different.

The optimum water pH for fish production ranges between 6 to 9.5 (Wurts and Durborow, 1992; Stone and Thomforde, 2006; Water Research Commission, 2010). The pH of pond water has been reported to increase with fertilizer application because manure increases primary productivity of the pond (phytoplankton growth) which carry out photosynthesis during the day thus reducing the amount of dissolved carbon dioxide (carbonic acid) in the water (Knud-

Hansen, 1998). The presence of carbonates and bicarbonates in the manure also make the pond water slightly alkaline and this has been proven to be a suitable environment for aquatic organisms (Parker, 2002). According to Svobodova *et al.* (1993) acute exposure to water having very low or very high pH makes the fish gills and skin produce a lot of mucus. This makes it difficult for the fish to absorb oxygen (Water Research Commission, 2010). Prolonged exposure to low pH leads to poor absorption of calcium from the pond water leading to weak and poor bone formation (Parker, 2002).

Electrical conductivity

The average electrical conductivity (EC) of the fertilized pond (225.6 µS/cm) was higher than that of the unfertilized pond (123.5 µS/cm) and the difference was significant ($P<0.05$) (Table 4.7). Charo-Karisa *et al.* (2013) in western Kenya reported EC of 84.40-86.53 µS/cm in fertilized ponds. Palm *et al.* (2014) in Germany recorded average EC values of 1245.45 µS/cm in an unfertilized pond. The EC is used to measure the ability of water to conduct electricity (Republic of South Africa, 1996). It is correlated with salinity whereby it increases as salinity increases (Stone and Thomforde, 2006). Salinity in a pond increases due to pond fertilization because of the mineralization of the fertilizer and release of inorganic compounds into the water. The desirable amount of EC in fish ponds is 100-2000 µS/cm (Stone and Thomforde, 2006).

Salinity

The mean salinity of the fertilized pond (0.11 mg/l) was higher than that of the unfertilized pond (0.06 mg/l) and the difference was significant ($P<0.05$) (Table 4.7). Zahid *et al.* (2013) in Pakistan got water salinity of 0.733 mg/l and 0.700 mg/l from fertilized and unfertilized ponds respectively and the difference was not significant ($P>0.05$). Palm *et al.* (2014) in Germany reported salinity of 0.64 mg/l in an unfertilized pond.

Salinity is used to measure dissolved inorganic content in water (Republic of South Africa, 1996). Manure added to the fish pond during pond fertilization mineralizes thus releasing organic and inorganic compounds into the water. The inorganic compounds increase the salinity level of the water. The optimal salinity range for *C. gariepinus* culture is 0-2.5mg/l (Britz and Hecht, 1989; Borode *et al.*, 2008). Minimal salinity is required in pond water to enable the fish to maintain osmotic balance (Stone and Thomforde, 2006).

Total dissolved solids

The average total dissolved solids (TDS) of the fertilized pond (112.85 ppm) was higher than that of the unfertilized pond (61.8 ppm) and the difference was significant ($P<0.05$) (Table 4.7). Zahid *et al.* (2013) in Pakistan reported TDS of 900.85 ppm and 892.77 ppm from fertilized and unfertilized ponds respectively and the difference was not significant ($P>0.05$). According to Weber-Scannell and Duffy (2007), TDS concentration in freshwater rivers fluctuates due to industrial effluent, changes to water inflow and outflow in an area and salt-water intrusion. It is used to measure dissolved inorganic and organic compounds in water (Republic of South Africa, 1996). The manure used during pond fertilization mineralizes thus releasing organic and inorganic compounds into the water therefore increasing TDS. A review done on effects of TDS to fish found that TDS has no effect on fish growth up to 2000 ppm (Weber-Scannell and Duffy, 2007).

4.3.5 Cost-benefit analysis of *Clarias gariepinus* culture in earthen ponds

The assumptions made were that the sale price of Catfish is 300 KSh/kg of fish and that all fixed and variable costs are similar for all the treatments except for the feed and cost of pond fertilization as shown in Table 4.8. The fish in the fertilized pond fed the different diets had higher average gross margins compared to those fed similar diets in the unfertilized pond. The

Table 4.8: Cost benefit analysis of *Clarias gariepinus* culture in earthen ponds

	Fertilized pond				Unfertilized pond			
Dietary protein level (%)	Control	25	30	35	Control	25	30	35
Average feed consumed/fish (kg)	0.46	0.40	0.44	0.51	0.40	0.32	0.38	0.35
Feed cost/kg (KSh)	47.80	34.50	38.30	42.60	47.80	34.50	38.30	42.60
[1]Total feed cost/kg/fish (KSh)	21.99	13.80	16.85	21.73	19.12	11.04	14.55	14.91
[2]Manure amount/fish (kg)	0.40	0.40	0.40	0.40	-	-	-	-
[3]Manure cost/kg (KSh)	6.00	6.00	6.00	6.00	-	-	-	-
[4]Total manure cost/kg/fish (KSh)	2.40	2.40	2.40	2.40	-	-	-	-
[5]Gross expenditure/fish (KSh)	24.39	16.20	19.25	24.13	19.12	11.04	14.55	14.91
Final weight of fish (kg)	0.24	0.23	0.27	0.30	0.21	0.17	0.23	0.22
Fish cost/kg (KSh)	300.00	300.00	300.00	300.00	300.00	300.00	300.00	300.00
[6]Gross income/fish (KSh)	72.00	69.00	81.00	90.00	63.00	51.00	69.00	66.00
[7]Gross margin/fish (KSh)	47.61	52.80	61.75	65.87	43.88	39.96	54.45	51.09

%- percentage; KSh- Kenya Shilling; kg- kilogram; [1]Total feed cost/kg/fish= Average feed consumed/fish*Feed cost/kg (KSh); [2]Manure amount/fish (kg) was calculated for 240 fish in the pond fertilized at 25 kg Dry Matter (DM) manure/100 m^2 pond, two weeks before stocking plus 3 kg DM manure/100 m^2 pond, every 10 days (de Graaf and Janssen, 1996) for 120 days; [3]Manure cost/kg (KSh) was calculated from a 50 kg gunny bag of manure costing KSh 300 at farm level; [4]Total manure cost/kg/fish= Manure amount/fish*Manure cost/kg (KSh); [5]Gross expenditure/fish= Total Feed cost/kg/fish+ Total manure cost/kg/fish (KSh); [6]Gross income/fish= Final weight of fish* Fish cost/kg (KSh); [7]Gross margin/fish= Gross Income- Gross expenditure (KSh); Control diet has 35% crude protein and does not contain rice milling byproducts

highest average gross margin (65.87 KSh) was attained by the fish fed the high protein diet (35% CP) in the fertilized pond. The lowest average gross margin (39.96 KSh) was attained by the fish fed the low protein diet (25% CP) in the unfertilized pond. The fish fed the 25% protein diet (the least expensive diet) in the fertilized pond had comparable growth performance to the fish in the other treatments (Table 4.4) and had a positive average gross margin. This makes the 25% protein diet suitable for *C. gariepinus* culture in fertilized earthen ponds. Other authors working with *C. gariepinus*, Charo-Karisa *et al.* (2013) got cost benefits ranging between 112.1-180.7 US$ while Ani *et al.* (2013) got a gross margin of 51.70 Nigerian Naira (NGN), that is, approximately 28.44 KSh at an exchange rate of 1NGN= 0.55 KSh.

According to Ahmed (2007), feeds contribute approximately 70% of the total variable cost of semi-intensive culture of fish while Hecht (2007) identified expensive feeds as a major issue that limits fish farming in East Africa. On the other hand, Okechi (2004) did a profitability assessment of the feasibility of farming *C. gariepinus* in western Kenya using assumptions based on secondary data. The study found that Catfish farming was mainly affected by the stocking rate, % survival and sale price of the fish.

4.4 Conclusions

- The performance of *C. gariepinus* with respect to gain of weight, SGR and apparent FCR improved with increasing protein levels in the diets having inclusion of rice milling byproducts up to 35% protein.

- Pond fertilization improved the gain in weight and SGR of *C. gariepinus.*

- Inclusion of rice bran reduced the cost of *C. gariepinus* feed and improved *C. gariepinus* performance due to improved nutrient content.

- Pond fertilization resulted in improved water quality (with regard to DO, pH, EC, TDS and salinity) resulting in better *C. gariepinus* performance.

4.5 Recommendations

- The fish fed the diet having low protein (25% protein level) in the fertilized pond had comparable performance to the fish fed the other protein level diets. In fertilized ponds, fish farmers can lower production costs and increase gross margins by feeding Catfish with diets containing 25% protein. Farmers can use rice milling byproducts to formulate fish diets. In this study, rice milling byproducts improved the nutrient quality of the fish feed and improved weight gains and other performance indicators of Catfish.

- Fertilization of ponds should be practiced in the culture of *C. gariepinus* to improve water quality and consequently improve fish performance.

4.6 Way forward

- This study should be carried out in large commercial ponds since the small experimental units have high management levels that lead to fish growth performance and cost-benefits that might not be replicated at the farm level.
- Carcass characteristics of the fish should be evaluated because carcass fattiness increases with decreasing protein level thus reducing processed yield and market acceptability.
- Further studies should also document the ‘natural foods’ for the *C. gariepinus* present in both the pond water and the gut of the fish.

CHAPTER 5

5.0 GENERAL DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

5.1 General discussion

Fish farming contribution to the Kenyan economy is still small despite many government interventions. A major impediment to the growth of fish farming is expensive fish feeds (Shitote *et al.,* 2012; Omasaki *et al.,* 2013). In addition, culturing mixed-sex Tilapia is still common in Kenya despite Tilapia having the tendency to breed prolifically leading to overpopulation of ponds and competition for food and oxygen resulting in stunted fish growth. Two studies were therefore done to evaluate fish management practices, assess the quality and quantities of rice milling byproducts as potential fish feed resources, and determine the effects of dietary protein levels on performance of the African Catfish (*Clarias gariepinus*) in fertilized and unfertilized earthen ponds.

The first study was done to evaluate and document farmed fish management practices and the quality and quantities of rice milling byproducts in Kirinyaga County. Nile Tilapia (*Oreochromis niloticus*) in monoculture was the most common fish species cultured (51.6%) in Ndia, Kirinyaga County. Culturing mixed-sex Tilapia in polyculture with Catfish to control overpopulation of the former was also common in Ndia, Kirinyaga County (27.7% of the respondents). Catfish monoculture was the least cultured in the same area (9.2%) despite *C. gariepinus* having faster growth rates and being more tolerant to poor water quality conditions compared to *O. niloticus* (Liti *et al.,* 2002; El Naggar *et al.,* 2008; FAO, 2015a).

All the fish farmers in the study area did not weigh their fish fortnightly in order to calculate the feed requirement of the fish. Hogendoorn *et al*. (1983), Hecht *et al*. (1988) and de Graaf and Janssen (1996) advice that the body weight of fish should be determined and used to feed the fish in order to avoid over-feeding or under-feeding them. In addition, most of the farmers (86%) cited expensive feeds as a constraint. This has also been reported in Kakamega, Kisii and Siaya Counties of Kenya (Shitote *et al.,* 2012; Omasaki *et al.,* 2013).

The pond fertilization schedules followed by fish farmers were not consistent and did not follow guidelines such as weekly application rates advised by Boyd and Massaut (1999) and Nyandat (2007). A total of 27.4% of the fish farmers used inorganic fertilizers in their fish ponds before stocking them with fish while 38% used organic fertilizers once a month. The main challenge faced by fish farmers in fish pond fertilization practices was the high cost of inorganic fertilizer (56.3% of the farmers).

To quantify rice milling byproducts, six large scale and 50 small scale rice millers were interviewed. Large scale rice mills produced a total of 701 tonnes/year of rice bran while small scale mills produced 6388 tonnes/year. Rice bran samples from large scale mills had high CP% and EE% and low CF% and ash% compared to those from small scale mills. The difference was attributed to the fact that in small scale rice milling operations, there was mixing of rice bran with rice hulls in the one stage milling process (Heuze' and Tran, 2015).

A feeding trial was carried out to evaluate the effects of dietary protein levels on performance of *C. gariepinus*. Parameters for growth, nutrient utilization, water quality and cost-benefit were monitored. The fish performance improved as the protein levels in the diet increased and this agreed with work done by Machiels and Henken (1985), Degani *et al*. (1989), Ali and Jauncey (2005) and Ahmad (2008). This is because Catfish are omnivorous fish having relatively better utilization of high protein than high carbohydrate diets (FAO, 2015b). In this study, it was concluded that low protein diets (25% protein level) are suitable for *C. gariepinus* culture in fertilized earthen ponds because the fish fed on it had comparable performance with those fed on the control diet having 35% CP without the inclusion of rice milling byproducts.

In addition, the diet containing 35% protein with rice milling byproducts was cheaper per kg compared to the control diet with a similar protein level and no rice milling byproducts. Fish fed the experimental diet having 35% CP also had better growth performance and higher gross margins than the fish fed on the control diet. Finally, the fish in the fertilized pond had better growth performance and gross margins compared to those fed similar diets in the unfertilized pond. The results are in agreement with work done by Bok and Jongbloed (1984), Jha *et al.* (2004) and El Naggar *et al.* (2008) who found that fish performance improved with fish pond fertilization. This is because pond fertilization increases nitrogen and phosphorous levels in the pond water and these are used by phytoplankton for growth (Parker, 2002). The phytoplankton increase DO concentration in the pond water when they carry out photosynthesis during the day and they also assimilate ammonia from the pond water (Knud-Hansen, 1998). This improves the pond water quality and consequently improves the fish performance. It was therefore concluded that pond fertilization using locally available manure at 100-500 kg dry weight/ ha/ week should be encouraged among fish farmers in Kirinyaga County in order to improve fish growth.

5.2 General conclusions

- Tilapia was the most common species cultured and the farmers had poor feeding and fish pond fertilization strategies.
- Large quantities of rice milling byproducts (rice bran and chicken rice) are available in Kirinyaga County all year round and the best quality for use in fish feeds are those from large scale mills.
- African Catfish (*Clarias gariepinus*) performance increased as the protein level in the diet increased and was better in fertilized ponds compared to unfertilized ponds.

5.3 General recommendations

- Fish farmers should be encouraged to take up *C. gariepinus* monoculture and they should be trained on the best feeding and fish pond fertilization strategies for maximum productivity of their fish farming
- Fish farmers and fish feed manufacturers should be informed of the cost effectiveness of using rice milling byproducts in their fish diets.
- Fish farmers should be trained on the use of pond fertilization and low cost fish feeds having rice milling byproducts in order to bring down the cost of production of *C. gariepinus.*

5.4 General way forward

- A study on defatted rice bran inclusion in fish diets should be done; defatted rice bran has longer storage time (without going rancid) compared to full fat rice bran.
- The effect of γ-oryzanol (found in rice bran oil) on fish growth should be determined because it has been proven to have health benefits in human nutrition.

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APPENDICES

Appendix 1: Questionnaire for farmed fish management practices in Ndia, Kirinyaga County

Questionnaire No. .... Name of respondent............. Name of enumerator...............

Location of the farm.. Date of interview..................

1. Gender of respondent: Male [ ] Female [ ]

2. How old are you? …………

3. Education level? Less than primary [ ] Primary [ ] Secondary [ ]

College [ ] University [ ]

4. Do you have any other work besides fish farming? No [ ] Fish trader [ ]

Livestock/ crop farmer [ ] Services and selling shops [ ] Factory worker [ ]

General worker [ ] Other [ ] Specify …………………..

5. Where did you get the money to start this fish farm? …………………………

6. Briefly describe how your ponds has been constructed (indicate the construction material)

Earth pond [ ] Liner [ ] Concrete [ ]

7. Please fill the table below:

Type of culture	Number of fish ponds currently in use	Average size of fish ponds (m^3)	Average number of fish in each pond
1. Tilapia only			
2. Tilapia & Catfish			
3. Catfish only			
4. Other (specify ...)			

8. Please fill the table below:

Type of feed	Tilapia	Tilapia & Catfish	Catfish	Other (Specify)
1. Commercial feed				
2. Home- made feed				
3. Single ingredient feed				

9. Please fill the table below: (Note: T= Tilapia, T & C= Tilapia and Catfish, C= Catfish, O= Other)

	C feed				H feed				Single feed			
	T	T & C	C	O	T	T & C	C	O	T	T & C	C	O
Total quantity of feed per day (kg)												
Number of times fed per day												
Price per kg (KSh)												

10. List the challenges you encounter when using feeds

i) ---
ii) --
iii) --

11. Do you fertilize your fish ponds? 1) Yes 0) No. If Yes, fill the table below.

Type of fertilizer used in fish pond	Tick appropriate answer	How often do you use it
Inorganic fertilizer		
Organic fertilizer		

12. If you use fertilizers, list the challenges you encounter when using them

i) --
ii) --
iii) --

Appendix 2: Questionnaire for rice millers in Kirinyaga County

Questionnaire no: ………………….. Date: ………………… Location: …………………….

Name of respondent …………………… Name of enumerator ……………………………….

1. Scale of mill: Large [   ]   Small [   ]

2. When did you start milling rice (year)? ------. What is your installed milling capacity ----------- tonnes/ hr and current production level ------- tonnes/ hr?

2. Is paddy rice available for milling all year round? Yes [   ]   No [   ]

3. In the table below, fill in the peak and low seasons of rice milling.

Peak seasons (months)	Low seasons (months)

5. What is the cost of milling 1 kg of paddy rice? KSh ----. List the challenges you encounter in the supply of paddy rice for milling with i) being the most important and iii) the least important

i) ---
ii) --
iii) ---

7. In the table below, write down the main rice milling byproducts, their quantities and prices.

Byproduct	Amount produced per yr (tonnes)	Cost/kg of the byproduct (KSh)
1.		
2.		
3.		

8. Have you received any complaints from your customers about the quality of the byproducts?

1) Yes 2) No

9. If Yes in (19.) above, state the complaints in order of importance (i the most important and iii the least important)?

i) ---
ii) --
iii) ---

Thank you for taking part in the survey.

Appendix 3: Analysis of variance of initial weight of the *Clarias gariepinus* fingerlings cultured in fertilized and unfertilized earthen ponds

Variate: Initial_weight_g

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Protein_level	3	1.7274	0.5758	1.78	0.192
Pond_fertilization	1	20.9833	20.9833	64.70	<.001
Protein_level.Pond_fertilization					
	3	1.8437	0.6146	1.90	0.171
Residual	16	5.1888	0.3243		
Total	23	29.7432			

Appendix 4: Analysis of variance of final weight of the *Clarias gariepinus* cultured in fertilized and unfertilized earthen ponds

Variate: Final_weight_g

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Protein_level	3	12763.6	4254.5	4.36	0.020
Pond_fertilization	1	14904.1	14904.1	15.27	0.001
Protein_level.Pond_fertilization					
	3	2034.8	678.3	0.70	0.568
Residual	16	15614.2	975.9		
Total	23	45316.7			

Appendix 5: Analysis of variance of weight gain of the *Clarias gariepinus* cultured in fertilized and unfertilized earthen ponds

Variate: Weight_gain_g

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Protein_level	3	12843.7	4281.2	4.42	0.019
Pond_fertilization	1	13806.6	13806.6	14.24	0.002
Protein_level.Pond_fertilization	3	1940.0	646.7	0.67	0.584
Residual	16	15511.2	969.4		
Total	23	44101.5			

Appendix 6: Analysis of variance of feed intake of the *Clarias gariepinus* cultured in fertilized and unfertilized earthen ponds

Variate: Feed_intake_g

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Protein_level	3	19558.	6519.	2.62	0.086
Pond_fertilization	1	48575.	48575.	19.55	<.001
Protein_level.Pond_fertilization					
	3	10828.	3609.	1.45	0.265
Residual	16	39749.	2484.		
Total	23	118709.			

Appendix 7: Analysis of variance of apparent feed conversion ratio of the *Clarias gariepinus* cultured in fertilized and unfertilized earthen ponds

Variate: Apparent feed conversion ratio

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Protein_level	3	0.32016	0.10672	6.01	0.006
Pond_fertilization	1	0.00156	0.00156	0.09	0.771
Protein_level.Pond_fertilization					
	3	0.05035	0.01678	0.95	0.442
Residual	16	0.28389	0.01774		
Total	23	0.65596			

Appendix 8: Analysis of variance of protein efficiency ratio of the *Clarias gariepinus* cultured in fertilized and unfertilized earthen ponds

Variate: Protein efficiency ratio

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Protein_level	3	1.65027	0.55009	30.14	<.001
Pond_fertilization	1	0.00059	0.00059	0.03	0.860
Protein_level .Pond_fertilization					
	3	0.04956	0.01652	0.91	0.460
Residual	16	0.29203	0.01825		
Total	23	1.99244			

Appendix 9: Analysis of variance of specific growth rate of the *Clarias gariepinus* cultured in fertilized and unfertilized earthen ponds

Variate: Specific_growth_rate

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Protein_level	3	0.17423	0.05808	3.70	0.034
Pond_fertilization	1	0.16939	0.16939	10.80	0.005
Protein_level.Pond_fertilization					
	3	0.02615	0.00872	0.56	0.652
Residual	16	0.25091	0.01568		
Total	23	0.62068			

Appendix 10: Analysis of variance of mortality of the *Clarias gariepinus* cultured in fertilized and unfertilized earthen ponds

Variate: Mortality

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Protein_level	3	1.950	0.650	0.24	0.870
Pond_fertilization	1	0.237	0.237	0.09	0.773
Protein_level.Pond_fertilization					
	3	9.679	3.226	1.17	0.352
Residual	16	44.106	2.757		
Total	23	55.972			

Appendix 11: Analysis of variance of Fulton's condition factor of the *Clarias gariepinus* cultured in fertilized and unfertilized earthen ponds

Variate: Fulton's_Condition_factor

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Protein_level	3	0.0019370	0.0006457	1.00	0.417
Pond_fertilization	1	0.0004623	0.0004623	0.72	0.409
Protein_level.Pond_fertilization					
	3	0.0012151	0.0004050	0.63	0.606
Residual	16	0.0102885	0.0006430		
Total	23	0.0139030			

Appendix 12: Two-sample t-test of temperature of fertilized and unfertilized *Clarias gariepinus* ponds

Variate: Temperature_°C

Summary

Sample	Size	Mean	Variance	Standard deviation	Standard error of mean
F	62	23.88	3.302	1.817	0.2308
UNF	64	23.56	3.115	1.765	0.2206

Probability = 0.320

Appendix 13: Two-sample t-test of dissolved oxygen of fertilized and unfertilized *Clarias gariepinus* ponds

Variate: Dissolved_oxygen_mg_l

Summary

Sample	Size	Mean	Variance	Standard deviation	Standard error of mean
F	63	2.799	3.962	1.990	0.2508
UNF	64	2.146	2.138	1.462	0.1828

Probability = 0.037

Appendix 14: Two-sample t-test of pH of fertilized and unfertilized *Clarias gariepinus* ponds

Variate: pH

Summary

Sample	Size	Mean	Variance	Standard deviation	Standard error of mean
F	62	8.083	0.09441	0.3073	0.03902
UNF	64	7.853	0.07490	0.2737	0.03421

Probability < 0.001

Appendix 15: Two-sample t-test of electrical conductivity of fertilized and unfertilized *Clarias gariepinus* ponds

Variate: Conductivity_µS_cm

Summary

Sample	Size	Mean	Variance	Standard deviation	Standard error of mean
F	62	225.6	1473	38.38	4.874
UNF	64	123.5	529	23.00	2.875

Probability < 0.001

Appendix 16: Two-sample t-test of salinity of fertilized and unfertilized *Clarias gariepinus* ponds

Variate: Salinity_mg_l

Summary

Sample	Size	Mean	Variance	Standard deviation	Standard error of mean
F	62	0.10613	0.0003651	0.01911	0.002427
UNF	64	0.05797	0.0001276	0.01129	0.001412

Probability < 0.001

Appendix 17: Two-sample t-test of total dissolved solids of fertilized and unfertilized *Clarias gariepinus* ponds

Variate: Total dissolved solids_ppm

Summary

Sample	Size	Mean	Variance	Standard deviation	Standard error of mean
F	62	112.85	372.6	19.30	2.451
UNF	64	61.80	130.8	11.44	1.430

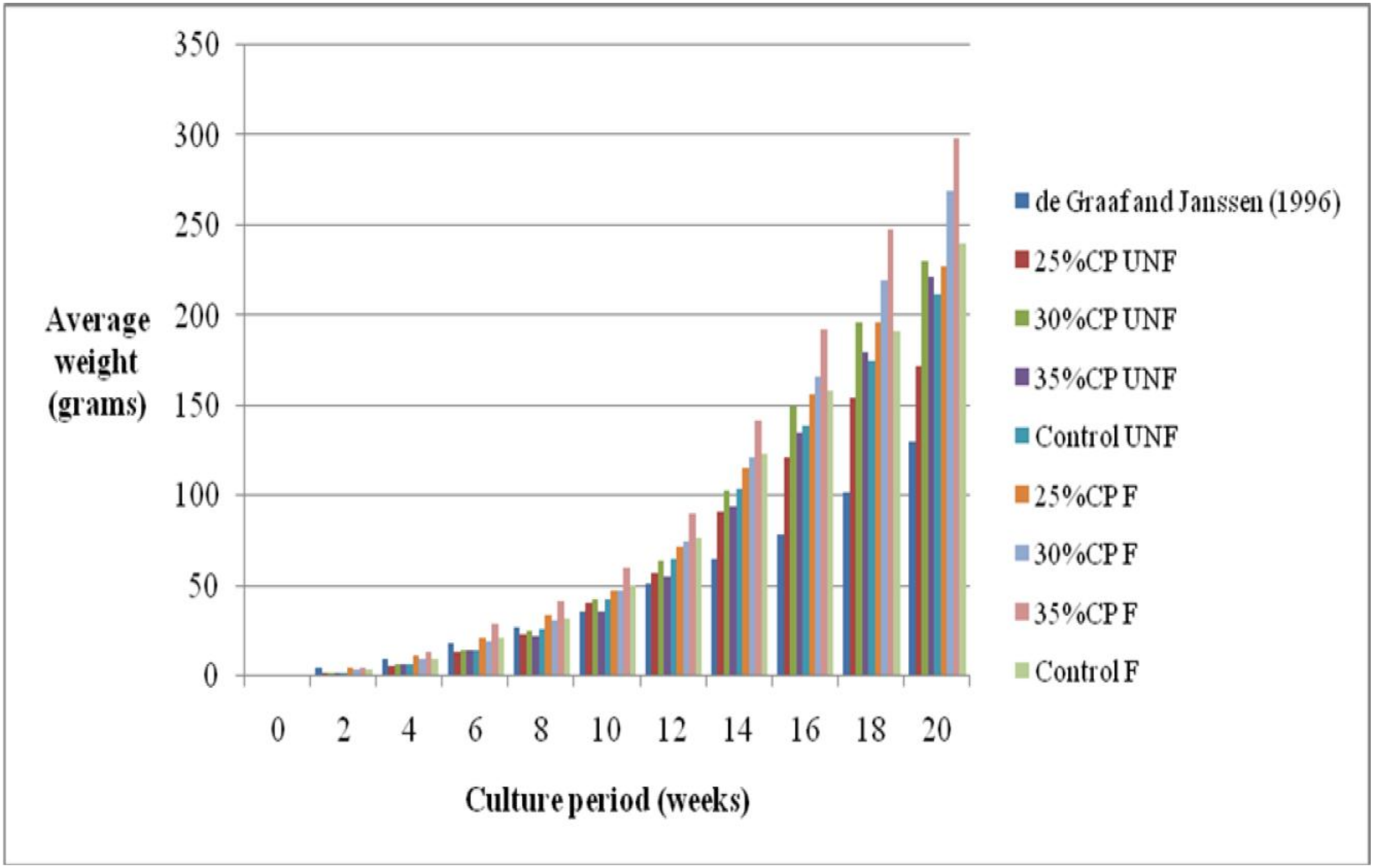
Probability < 0.001

Appendix 18: Cost of ingredients used to make experimental diets

Ingredient	Ingredient cost/ kg (KSh)
Maize	35
Rice Bran	15
Rice grain (broken)	30
Corn oil	280
Soybean meal solvent extracted	93
Wheat pollard	27
Freshwater Shrimp Meal	150
Di-calcium phosphate	85
Limestone	8
HCL-Lysine	350
DL-Methionine	600
Ascorbic acid	1740
Salt	20
Vitamin-Mineral premix	494.16

Kg- kilogram; KSh- Kenya Shilling; HCL- Hydrochloric acid; DL- isomers

Appendix 19: Average weight of African Catfish fingerlings fed varying protein levels in fertilized and unfertilized earthen ponds for 128 days



CP- Crude protein; UNF- Unfertilized; F- Fertilized