University of Natural Resources
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UNESCO-IHE
Institute for Water Education

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# SUITABILITY OF ON-FARM FORMULATED FEEDS AND POND CHARACTERISTICS FOR NILE TILAPIA PRODUCTION IN SEMI-INTENSIVE CULTURE IN SELECTED FARMS OF RIFT VALLEY REGION, KENYA

Master of Science Thesis

by

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**Egerton University, Njoro, Kenya**

APRIL 2017

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This thesis has been submitted with our approval as supervisors for examination according to Egerton University regulations

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Karatina University and Public Service Commission of Kenya

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# DEDICATION

I dedicate this work to The Almighty God whose grace has always been sufficient, and to my family members, who have always been a pillar of strength and hope in my life.

## ACKNOWLEDGEMENT

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# ABSTRACT

High costs and inaccessibility to quality fish feeds in Kenya, have contributed considerably to the aquaculture sector stagnation. Consequently, farmers have opted for cheaper, locally available ingredients to formulate feeds for Nile tilapia in semi-intensive culture systems. In spite of these innovations, farmers continue to incur losses, an indication that the quality of on-farm formulated fish feeds could be compromised. This study therefore investigated proximate composition of on-farm formulated Nile tilapia feeds, the methods of formulation, the cost of these feeds compared to that of commercial feeds. The work also investigated pond characteristics in Bomet, Kericho and Nakuru counties in the Rift valley Region of Kenya. In the study, eighteen farms using semi-intensive method of raising Nile tilapia, were selected from the three counties based on a set of criteria. Fish feeds were collected from the selected farms and prepared for proximate analysis by standard methods. A comparison of proximate composition of the on-farm formulations, the commercial feeds and the Standard for Kenyan Commercial fish feed was done. Feed Cost analyses was also done through pilot surveys, from which best buy technique was used to determine cost per protein. In addition, farm and feed management practices were investigated through use of questionnaires. The results revealed a significant difference ($P< 0.05$) between the sampled feeds' moisture, crude protein and mineral contents with the legislated standard levels and commercial feeds commonly used in the counties. There was also a significant difference between the three counties in terms of crude protein in the feeds, with feeds from Nakuru being significantly different from those used in Bomet and Kericho counties. On-farm formulated feeds recorded lowest cost per unit of nutrient compared to commercial feeds sampled, and the feeds formulated using imported ingredients. Nakuru County recorded the highest cost per gram of feed .The cost regime in Nakuru therefore varied significantly with the observed fish feed cost structure used in Bomet and Kericho counties ($P < 0.05$). Pond water physico-chemical parameters did not vary significantly between the three counties apart from conductivity which was significantly higher in fish ponds in Nakuru County. The study concludes that by using on-farm formulated fish feeds, farmers are able to minimise costs of production. However, the majority of these feeds do not meet the quality standards and nutrient requirements recommended for raising Nile Tilapia.

**TABLE OF CONTENTS**

**DECLARATION AND RECOMMENDATION** .................... i
**DEDICATION** .................... ii
**ACKNOWLEDGEMENT** .................... iv
**ABSTRACT** .................... v
**TABLE OF CONTENTS** .................... vi
**LIST OF TABLES** .................... viii
**LIST OF FIGURES** .................... ix
**LIST OF PLATES** .................... xi
**LIST OF ABBREVIATIONS AND ACRONYMS** .................... xii
**DEFINITION OF TERMS** .................... xiii
**CHAPTER ONE** .................... 1
**INTRODUCTION** .................... 1
1.1. Background Information .................... 1
1.2. Statement of the Problem .................... 3
1.3. Objectives .................... 4
1.3.1. General objective .................... 4
1.3.2. Specific Objectives .................... 4
1.4. Hypotheses .................... 4
1.5. Justification .................... 4
**CHAPTER TWO** .................... 6
**LITERATURE REVIEW** .................... 6
2.1. Aquaculture in Kenya .................... 6
2.2. Nile tilapia (*Oreochromis niloticus*) production in Kenya .................... 7
2.3. Quality of fish feed and Nile tilapia *(O. niloticus*) nutritional requirements .................... 8
2.3.1. Protein .................... 9
2.3.2. Lipids .................... 10
2.3.3. Carbohydrates .................... 11
2.3.4 Minerals .................... 12
2.3.5. Gross Energy .................... 12
2.4. Status of fish feeds in Kenya .................... 13
2.5. Feeding and water quality .................... 15
2.6. The criteria for determining suitable feeds for Nile Tilapia. .................... 15
**CHAPTER THREE** .................... 17
**MATERIALS AND METHODS** .................... 17

3.1. Study area .......... 17
3.2. Study design and field sampling .......... 18
3.2.1. Criteria of farm selection .......... 18
3.2.2. Collection of feed samples .......... 18
3.2.3. Characterisation of farms .......... 19
3.2.4. Feed cost analysis .......... 19
3.3. Proximate analysis .......... 20
3.4. Data collection using questionnaire .......... 23
3.5. Data analysis .......... 23
**CHAPTER FOUR .......... 24**
**RESULTS .......... 24**
4.1. Proximate analysis of on-farm formulated feeds and comparison to Kenya standards. .......... 24
4.1.1. Ingredients commonly used by farmers in on-farm fish feed formulation. .......... 24
4.1.2. Proximate constituents of on-farm formulated feeds and selected commercial feeds .......... 25
4.2. Fish Feed costs .......... 32
4.3. Fish Farm management .......... 34
4.4. Knowledge of the farmer on nutrient requirements of Nile tilapia and level of farmers' training. .......... 35
4.5. Experience of farmer in the industry and training .......... 37
4.6. Feed management practises. .......... 39
4.7. Frequency of fish feeding. .......... 39
4.8. Physico-chemical parameters and pond characteristics. .......... 40
**CHAPTER FIVE .......... 42**
**DISCUSSION .......... 42**
5.1. Ingredients availability and use in on-farm feed formulations .......... 42
5.2. Proximate composition of on-farm fish feeds and their effects on fish production and pond water quality .......... 43
5.3. Fish feed costs .......... 45
5.4. Fish farm management strategies in aquaculture .......... 46
5.5. Fish feed management strategies and their impacts on fish feed quality in aquaculture production .......... 47
5.6. Fish Feeding Frequency .......... 48
**CHAPTER SIX .......... 49**
**CONCLUSIONS AND RECOMMENDATIONS .......... 49**
**REFERENCES .......... 51**

## LIST OF TABLES

Table 1: The Kenyan Standards for commercial fish feed standards for catfish and Nile tilapia fry, fingerlings, growers and brooders (Source: KEBS, 2015)....................................9

Table 2: Major ingredients used in farm-made fish feed formulation in the counties of Nakuru, Kericho and Bomet .........................................................................24

Table 3: Tukey's post hoc output for differences between proximate constituents of fish feeds from the three counties with the standard values.………………………………………………………………………29

Table 4: One way ANOVA output for the differences between proximate constituents of fish feeds from the three counties with the standard values. n = 4..................................32

Table 5: One way ANOVA output for differences between mineral contents of fish feeds from the three counties with the standard values. n = 4 ……………………………26

Table 6: Tukey's post hoc output for differences between proximate constituents of fish feeds from the three counties with the standard values......................................................32

Table 7: The mean values of selected water physico-chemical parameters in the studies fish ponds..................................................................................................................40

## LIST OF FIGURES

Figure 1: Graph showing changes in aquaculture production in Kenya from 1980-2014 (FAO 2016) .......... 6
Figure 2: The relative proportions of cultured fish species in Kenya (FAO 2016). .......... 8
Figure 3: A map of Kenya showing the counties where the study was undertaken. .......... 17
Figure 4: Box plots showing variations in moisture contents of the 18 feeds and the standard value. .......... 25
Figure 5: Box plots showing variations in ash contents of the 18 feeds and the standard value. .......... 26
Figure 6: Box plots showing variations in Crude lipid contents of the feeds in the studied counties and the standard values. .......... 27
Figure 7: Box plots showing variations in protein contents of the feeds in the studied counties and the standard value. .......... 27
Figure 8: Box plots showing variations in crude protein contents of the feeds for the studied counties and the standard values of crude protein. .......... 28
Figure 9: Box plots showing variations in crude fibre contents of the 18 feeds for the studied counties and the standard values. .......... 30
Figure 10: Box plots showing variations in proximate contents of (a) moisture, (b) ash, (c) crude lipid and (d) Crude fibre of the feeds for the three counties and the standard values. .......... 30
Figure 11: Box plots showing variations in minerals contents of the feeds for the three counties and the standard values, where (a) Calcium, (b) Sodium, (c) Iron, (d) Phosphorus and (e) Magnesium .......... 31
Figure 12: A bar graph showing cost per gram of proteins in the 18 feeds analysed from Bomet, Kericho and Nakuru counties.BOFA, KEFA, and NAFA are farm codes. 33
Figure 13: A bar graph showing mean cost per gram of protein in feeds in the counties of Nakuru, Kericho and Bomet. .......... 33
Figure 14: Graphs showing types of farm ownership (a) in combined region of study and (b) in Bomet, Kericho and Nakuru counties. .......... 34
Figure 15: Graphs method of feed formulation used by farmers in the whole region of study (a) and in each of the three counties studied (b). .......... 35

Figure 16: The response of farmers on knowledge on (a) fish nutrient requirements in relation to level of knowledge on fish farming practises and (b) shows farmers' knowledge on fish farming practises, in relation to training attendance and the feed formulation methods they use, in the three counties. ............................................36
Figure 17: Graph showing attendance of training by the farmers and the responsible training providers in Bomet, Kericho and Nakuru Counties. .................................37
Figure 18: Bar graphs showing effects of (a) training and year of operation of the farmer on levels of crude protein in three counties, and (b) effects of farmers training and level of knowledge on crude protein levels in on-farm formulated fish feeds. .......38
Figure 19: The response of farmers to fish feed storage in Bomet, Kericho and Nakuru counties. ...........................................................................................................39
Figure 20: Fish feeding frequency in the counties of Nakuru, Kericho and Bomet. ..........40
Figure 21: Bar graphs showing (a) mean depth (m) and (b) mean pond volume (m3) of sampled ponds taken during the study. ...................................................................41

# LIST OF PLATES

Plate 1: Photograph showing water levels and pond design as observed in selected ponds in (a) Bomet County, and (b) Nakuru County............................................................59
Plate 2: Photograph showing (a) spreading of mash fish feed, and wastage on the pond dykes and (b) excess uneaten feed floating on pond water. .............................................59

## LIST OF ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| AOAC | Association of Official Analytical Chemists |
| b.w | Body Weight |
| BOFA | Bomet Farm |
| CP | Crude Protein |
| DO | Dissolved Oxygen |
| ESP | Economic Stimulus Programme |
| FCR | Food Conversion Ratio |
| GDP | Gross Domestic Product |
| ha | Hectares |
| HUFA | Highly Unsaturated Fatty Acid |
| IU | International Units |
| Kcal | Kilocalories |
| KEBS | Kenya Bureau of Standards |
| KEFA | Kericho Farm |
| KNBS | Kenya National Bureau of Statistics |
| KES | Kenyan shillings |
| MT | Metric Tonnes |
| NAFA | Nakuru Farm |
| ppm | Parts per million |
| PUFA | Poly Unsaturated Fatty Acid |

## DEFINITION OF TERMS

**Aquaculture:** The farming of aquatic organisms in both coastal and inland areas involving interventions in the rearing process to enhance production.

**On-farm formulated fish feeds:** These are small-scale feeds manufactured on the farms, encompassing everything from simple hand-formed dough balls to feed pellets from small feed production units.

**Feed formulation:** The process of quantifying the amounts of feed ingredients that need to be combined to form a single uniform mixture (feed) that supplies all the nutrient requirements of fish.

**Fish feed suitability:** This is the ability of a fish feed to satisfy all the nutritive requirements and appropriate physical qualities for better utilization by a targeted fish species, and which is available at an affordable price.

**Intensive culture system:** A fish farming system in which fish are raised in artificial tanks and raceways at very high densities and are subject to supplemental feeding and fertilization. There is high control of water quality and is characterised with high level of mechanised operations.

**Semi-intensive culture system:** A fish farming practice in which fish feeding is carried out at least two times per week and fertilization of fish ponds is done once per week.

**Extensive culture system:** A fish farming practice carried out in the ocean, natural and man-made lakes, rivers and fiords, where food supply is from natural productivity, with little control applied to feeding, stocking density and fertilization

# CHAPTER ONE

# INTRODUCTION

## 1.1. Background Information

The world population is expected to reach 9 billion inhabitants by 2050 (FAO 2014). This will see an increasing food demand by the ever growing population. For this reason, global focus has shifted to food security and sustainable strategies of food production. Aquaculture tops the list of sectors most governments are currently giving attention to for food security. This sector has over the decades showed high potential in food security, employment creation and growth of national economy especially in developing countries. Aquaculture sector has been recognised as one of the fast-growing food producing sectors in the world (FAO, 2015) mainly due to the increase in fish consumption and production. In 2013, fish represented 16 percent of all animal protein consumed by humans globally (FAO, 2014). China in Asia tops the list of countries in capture fisheries and aquaculture production (FAO, 2015).

Kenya's capture fisheries and aquaculture sectors contribute approximately 0.54 percent to the country's Gross Domestic Product, where total inland fishery and aquaculture production in 2013 amounted to 186, 700 tonnes, with 83 percent coming from inland capture fisheries and 17 percent from aquaculture (FAO, 2013). Growth of the aquaculture sector has been notable in the past two decades, making Kenya one of the fastest growing major producers of cultured fish in Sub-Saharan Africa, with an annual production that increased from about 1,000 tonnes in 2001–2006, to over 25, 000 tonnes in 2014 (FAO, 2014).

Development of aquaculture has been a priority to the Kenya Government (Kenyan Annual fishery statistical report 2015). Various initiatives have been undertaken to encourage farming and consumption of fish and to attract investment in the sector. These ideas gained momentum in 2009-2010 through a government initiative dubbed Economic Stimulus Program (ESP) whose aim was economic development and poverty alleviation. The effort was realized by construction of more than 200 fish ponds in each of 140 constituencies bringing the number to more than 27,000 fish ponds nationally (Abowei *et al.*, 2012). Aquaculture earned fish farmers KES. 5.5 million in 2013 which was four fold the earnings in 2009 (Kenyan Annual fishery statistical report, 2015). In spite of the success stories in the sector, aquaculture in Kenya still faces challenges which have resulted in stagnation of the industry (GoK, 2013). Some of the challenges are lack of readily available and affordable quality fish seed, inadequate good quality and affordable fish feeds, poor adoption of recommended fish husbandry techniques by some farmers and inadequate market information as highlighted in the Annual fishery statistical Report Ministry of Agriculture, livestock and fisheries (FAO, 2015). The problem of inadequate quality and affordable fish feeds tops the list of these challenges. This stands out for the reason that fish feed accounts for more than 40 percent of total fish production cost (Abowei *et al.*, 2012). The small number of certified commercial fish feed producers in the country plus the increased fish feed demand, has resulted to inadequate feeds in the market. Producers are also scattered all over the country and for this reason, farmers travel long distances to obtain the feeds which results in high travel costs and eventually high costs of production (Liti *et al.*, 2009).

Farmers opt to use on-farm made and ingredients to feed fish, in order to avoid high production costs. Ngugi and Manyala (2009) showed that more than 95 percent of Nile tilapia small scale farmers use on-farm formulated diets. Attempts have been made to train farmers on fish feed formulation and appropriate feeding regimes through the various research centres spread round the country together with extension officers from the Kenyan Fisheries and Aquaculture Department (Munguti *et al*. 2014). This has come with notable success. As shown by Munguti *et al*. (2014), the proximate composition of some commercial feed processors and a number of established cottage feed industries. Only 15 of them met the standards. Limited information is currently available on the quality of feeds formulated by small scale farmers in most parts of the country, especially for pond and tank culture. Research has however been done on on - farm formulated feeds used in fish cage culture in Kenya (Gutmann, 2013). Munguti *et al.* (2014) echoed the need to evaluate these feeds and compare them to the recently developed Kenyan commercial fish feed standards for tilapia fry, fingerlings, growers and brooders (GoK, 2013) to uphold good farming practises. The effects of these feeds on water quality cannot be overemphasized. Turbidity, conductivity, and total dissolved substances are some of the water quality parameters that are highly influenced by the remains of fish feed depending on the ingredients used and amounts fed to fish. In their work, Ghosh *et al*. (2010) proved that the extent of fish feed effect on pond water quality depends on the nutritional profiles of the ingredients used. Different ingredients, however, are more available in some areas than in others, due to differences in climatic, soil and other conditions.

Fish meal for example, is more readily available in the Lake Victoria region than in other areas, whereas wheat bran is more readily available in some parts of the Rift Valley, than in other regions (Ngugi and Manyala, 2009). High transportation costs place many feed ingredients and feeds beyond the affordability of the majority of fish farmers in Kenya. This makes it necessary to utilize the locally available ingredients, depending on the location of the farm, to produce affordable feeds, for the nutrition requirements of target fish. This study therefore aimed at analysing the proximate composition of the on-farm formulated feeds currently being used by small scale farmers, and compare them to the Kenyan commercial fish feed standards for tilapia fry, fingerlings, growers and brooders (GoK, 2013). The work also focused on assessing the prevailing water quality in the farms, feed management practises and pond characteristics currently used by farmers. Estimates of costs incurred in formulation of the on-farm made feeds, was also assessed, with the aim of suggesting an affordable nutritious formulation based on locally available ingredients in the areas of study.

### 1.2. Statement of the Problem

The high cost of commercial fish feeds has slowed down the growth of aquaculture in many parts of Kenya. To counter this problem, farmers have opted to use locally available ingredients to formulate feeds at lower costs. The low level of productivity being experienced in small scale aquaculture, results from the lack of appropriate knowledge on the right ingredients to be used in feed formulation, inconsistent feeding regimes for the cultured fish species. In addition, poor storage facilities for feeds, coupled with poor water quality management and poor pond designs contribute to the low fish production. Limited information is currently available on the quality of feeds formulated by small scale farmers in most parts of the country, especially for pond and tank culture. Therefore, there is need for the analysis of on-farm formulated feeds to ensure that they meet the Kenyan commercial fish feed standards for Catfish and Nile tilapia fry, fingerlings, growers and brooders. The application of the recommendations of the study by farmers, is likely to increase pond fish production and eventually, national fish production and contribute to national food security.

### 1.3. Objectives

#### 1.3.1. General objective

To analyse on-farm formulated fish feeds for nutrient content and cost at the prevailing pond characteristics and management practises, for improved pond productivity of Nile tilapia (*Oreochromis niloticus*) in Nakuru, Kericho and Bomet counties of the Rift Valley region of Kenya.

#### 1.3.2. Specific Objectives

i. To determine the crude protein, crude lipids, crude fibre, ash and moisture, and minerals (P, Ca, Fe, Na, Mg and K) contents of the on-farm formulated feeds in selected farms in the three counties, and compare them to the Kenyan fish feed standards.

ii. To determine the cost of on- farm formulated Nile tilapia feeds in the selected farms in the three counties.

iii. To characterise selected semi-intensive fish farms based on fish feed management practises, pond water physico - chemical parameters, feeding regime, and pond dimensions.

### 1.4. Hypotheses

1. The crude protein, crude lipids, crude fibre, ash, moisture, and minerals (P, Ca, Fe, Na, Mg and K) contents of on-farm formulated feeds are not significantly different from farm to farm and from KEBS feed quality standards.
2. The costs of on-farm formulated feeds are not significantly different from those of commercial feeds in the market.
3. Feed management practises, pond water quality and farm characteristics of the sampled semi – intensive farms are not significantly different.

### 1.5. Justification

Aquaculture contributes about 0.54 percent of Kenya GDP, and provides a cheap source of protein for human needs. The high costs of fish feeds, however, have negatively affected the production levels, especially after the end of the Economic Stimulus Programme, since farmers are no longer provided with quality fish feeds. In spite of the extensive research that has been done on various aspects of local aquaculture, this decreasing trend in fish production persists, indicating a missing link.

A high percentage of small scale farmers have opted to use locally available ingredients in fish feed formulations. This may be the missing link. This supposition made it necessary to analyse current on-farm formulated feeds for nutrient contents and costs. Furthermore, farmers who were provided with feed pelletizers after the Economic Stimulus Programme, should be followed to ensure feed formulations are carried out correctly. This study was therefore aimed at identifying strengths and weaknesses of the on-farm formulated feeds and feed management practices, with a view to recommending appropriate formulations and management strategies, for a sustainable and profitable Nile tilapia farming. The research findings will also serve as reference materials for further research and may help in identifying the main gaps in extension services offered to fish farmers in the country.

# CHAPTER TWO

# LITERATURE REVIEW

## 2.1. Aquaculture in Kenya

Fish farming in Kenya began in the early 1920s (FAO, 2010). However, commercial fish farming started in 1940s when farmers in parts of Central, Western and Rift Valley constructed fish ponds to culture Nile tilapia (FAO, 2000). In spite of several decades of fish culture, Kenya's aquaculture remains a small industry that is practiced mainly on small scale with the main culture species being *Oreochromis niloticus* (Nile tilapia) and *Clarias gariepinus* (African catfish).The industry produces approximately 12,000 metric tonnes of fish annually (FAO, 2010). In 2013, however FAO reported fisheries contribution of approximately 0.54 percent to the country's GDP. There have been remarkable attempts by the Kenyan Government to encourage development of this sector. In a nationwide fish farming mass campaign launched by government in 2009, the total area of fish ponds increased from 220 ha to 468 ha after building of 7,760 new fish ponds throughout the country (FAO, 2016). Moreover, the supply of quality fish seed, human and capital investments in the sector and extension services saw the fish production increase from 12, 000 metric tonnes in 2010 to about 25,000 metric tonnes in 2014 (Fig. 1), according to FAO (2016).

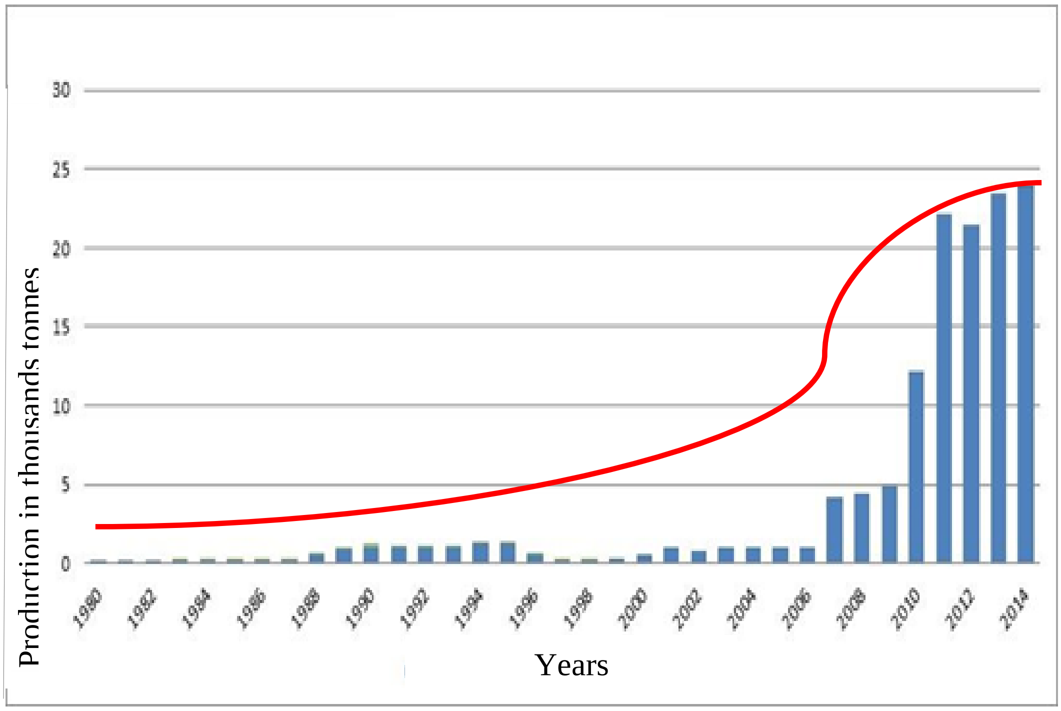



Figure 1: Graph showing changes in aquaculture production in Kenya from 1980-2014 (FAO 2016)

On the other hand, there has been a reduction in the harvest of fish in both inland and marine capture fisheries as a result of overfishing and negative environmental impacts from pollution in water bodies (Ruwa, 2006). This explains the considerable attention the aquaculture sector is receiving from government.

In terms of employment provision, out of the 20,000 employment opportunities in the fisheries sector, 6,000 are from aquaculture. This includes fish farmers, fish and feed processors and seed producers, among others (FAO, 2015). Aquaculture production in Kenya is organized into; extensive, semi-intensive and intensive production systems. With the adoption of new technologies, production is shifting from extensive to semi-intensive and a good number of farmers are expanding into semi-intensive systems (Ngugi and Manyala, 2009).

Surveys by Bowman (2007) have shown that 50 percent of fish farmers are growing fish in small scale extensive production systems. A total of 1.4 million hectares of land, were found to be suitable for aquaculture but only 0.014 percent of it is utilised. This shows that there is still room to make improvements and explore this type of farming. Fish farming practice has proved successful in most parts of the country but is highly practised in central, Nyanza, Western, Rift Valley and some Coastal areas (Munguti *et al.*, 2014). This is attributed to the favourable climatic conditions, in particular, temperatures that favour growth and survival of most farmed fish species.

### 2.2. Nile tilapia (*Oreochromis niloticus*) production in Kenya

Nile tilapia, a freshwater fish which is native to Africa and the Middle East, belongs to the family *Cichlidae,* genus *Oreochromis* and species *Oreochromis niloticus* (Shelton, 2002*)*. It is one of the most productive and internationally traded food fish in the world (Gupta and Acosta, 2004). Tilapiine species form about 74 % of farmed fish in Kenya (FAO, 2016) (Fig. 2).

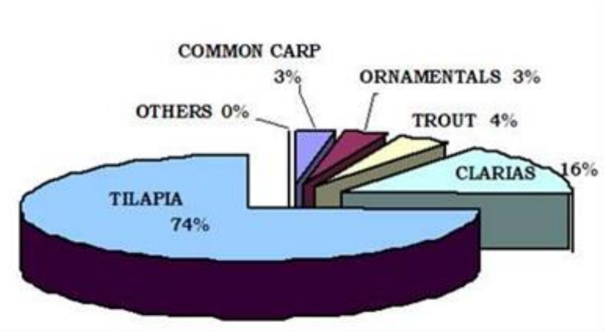



Figure 2: The relative proportions of cultured fish species in Kenya (FAO, 2016).

This is attributed to the species' ability to live in poor water quality and disease resistance, the fast growth on low protein feeds, ability to reproduce in captivity and ability to utilize feeds from a wide range of materials. Although Nile Tilapia thrives well in saline water if properly acclimated, they are all unable to reproduce effectively below 20°C and their activity and feeding response is considerably compromised at low temperatures below 16°C.

### 2.3. Quality of fish feed and Nile tilapia *(O. niloticus*) nutritional requirements

Good nutrition in animal production systems is essential to economically produce healthy, high quality products while at the same time ensuring metabolic processes for growth and survival (Craig and Helfrich, 2009). In spite of its importance, fish nutrition is critical because fish feed represents 40-50 percent of the production costs (Munguti *et al.*, 2004; Liti *et al*., 2005; Gutmann, 2013; FAO, 2014).At the same time, it is also important that during culture, fish gets all the required nutrients. When reared in high densities, *O. niloticus* require a high-quality, nutritionally complete, balanced diet to grow rapidly and remain healthy (Craig and Helfrich, 2009). However, Boyd *et al.* (2008) pointed out that the requirement is species specific and depends on environmental conditions, especially water quality and the life stage of the fish. Apart from the nutrient composition of the fish feeds, their physical aspects also affect their utilization by the fish. These include; digestibility, water stability, smell, colour and granule or pellet size. Tilapia being a surface feeder, obtain feed from the surface, for this matter a quality feed ought to float for at least ten minutes to allow for feeding by fish (Cho *et al.,* 2003). The size must also be of correct dimension depending on the life stage of the fish, as tilapia feeds on material less than a third of its mouth size (Njiru *et al.,* 2006). Despite availability of this information, local farmers in Kenya have not been able to incorporate these requirements in feed formulation (Charo-

Karisa and Gichuri, 2010). The main groups of nutrients that are important to fish growth and survival are proteins, lipids, vitamins and minerals (Shiau, 2002).

### 2.3.1. Protein

Proteins are large, complex molecules composed of carbon, hydrogen, oxygen and nitrogen, as well as some amounts of sulphur and phosphorus. The main building blocks of proteins are amino acids of which 20 have been identified (El-Sayed, 2006). Proteins are important in repair of cells and for organismal growth and development. In fish however, with insufficient levels of lipids and carbohydrates, proteins may be used for energy (Ng and Romano, 2013). According to FAO (2016) and El-Sayed (2006), as high as 45-50 percent protein is required for feeding larvae, 35 - 40 % for fry and fingerlings (0.02-10 g), 30-35 percent for juveniles (10.0-25.0 g) and 28 - 30 % for grow-out fish ( > 25.0 g). This is similar to the range set for Kenya fish feed requirement standards set by Kenya Bureau of Standards (KEBS). (Table 1).

Table 1: The Kenyan Standards for commercial fish feed standards for catfish and Nile tilapia fry, fingerlings, growers and brooders.

| **Feed Parameters** | **Fry** | **Fingerlings** | **Growers** | **Brooders** |
|---|---|---|---|---|
| Feeding rate | 5% b.w | 6-8% b.w | 3%bw | 3%b.w |
| Crude protein % | 40-45 % | 35-40% | 30-34% | 40% |
| Energy (MJ/Kg) | ≥ 10 | ≥ 10.5-11 | ≥11.5- 12.5 | |
| Crude fibre | ≥ 4% | ≥ 4% | ≥ 6% | ≥ 6% |
| Moisture content | ≤12% | ≤ 12% | ≤ 12% | ≤ 12% |
| Enzymes | Needed to improve FCR | | | |
| Pellet size (mm) | Mash | 2 | 2 - 5 | 2 – 5 |
| Packaging labels | Company address, Manufacturing and expiry date | | | |
| Packaging size | 5 Kg, 10 Kg, 20 Kg, 50 Kg | | | |
| Packaging Material | Must be air tight | | | |
| Acidifier | Preferred | | | |

(Source: KEBS, 2015).

Various studies have been carried out in Kenya and in the African region, on the potential of ingredients, both plants and animals, to be used in fish feeds, for example, Gustavsson (2016), Obe *et al.* (2015), Ogello *et al. (*2014), Munguti *et al*. (2014), Gutmann (2013), and Benson (2010). This comes in handy due to the fact that protein sources are the most expensive portions of fish feed (Craig and Helfrich, 2009) and therefore the need to establish locally available sources that are also nutritious.

Trials are also being done to establish efficacy of non-conventional animal sources of protein. Sogbesan and Ugwumba (2008), established that clupeid fishmeal had high crude protein, of 71.64 percent. Bauer *et al.* (2012) focused on the potential of microbes for example bacteria as possible sources of fish feed proteins. It is clear that understudied animal proteins can supplement fishmeal in fish feed since they all have complete essential amino acids profiles (Munguti *et al.,* 2014). Furthermore, fish are capable of using only a portion of protein in diets, but as much as 65 percent of the protein may be lost to the environment (Craig and Helfrich, 2009). Most nitrogen is excreted as ammonia ($NH_3$) through fish gills, and only 10% is lost as solid wastes. This suggests the need to have all proteins contained in the feed being ingested by the fish. If not, ammonium is produced from proteolysis which transforms into ammonia at high pH (White, 2013). This therefore calls for wise choice of ingredients, feeding regimes and waste management practices to minimise environmental impacts of aquaculture, minimise feed wastage and eventually increasing the profitability of small scale fish farming.

### 2.3.2. Lipids

Crude lipids are the predominant source of energy for fish. They can also partially substitute for protein in aquaculture feeds. Compared to proteins and carbohydrates, lipids supply about twice the energy by proteins and carbohydrates (Craig and Helfrich, 2009). Lipids also supply essential fatty acids (EFA) and serve as transporters for fat-soluble vitamins (Ng and Romano, 2013). Research has shown that *O. niloticus*, like other warm water fish species, require greater amounts of n-6 fatty acids compared to n-3 fatty acids for maximal growth (Ng and Romano, 2013). However, high levels of Poly Unsaturated Fatty Acids (PUFA) have been reported to depress the growth of Nile tilapia. Huang *et al.* (1998) and other researchers have shown that no enhancement in growth was obtained when highly unsaturated fatty acids (HUFA) was supplemented in *O. niloticus* diets.

These contradicting results have been attributed to nutritional history of the experimental fish, size of fish, source of dietary lipids and water temperatures (Shiau, 2002). This shows there is need to do more research on the effects of the different fatty acids on fish growth, most importantly the *O. niloticus*. Studies by El-Sayed (2006), reported that levels of dietary oil up to 15 percent improved protein utilization efficiency. Technological advances have recently permitted use of lipid levels of up to 40 percent (Shivaraj, 2010). This have however been proven to help reduce the high costs of diets by partially sparing protein in the feed, but problems such as excessive fat deposition in the liver, decrease the health and market quality of fish (Craig and Helfrich, 2009). Various studies have also proved the possibility of successful replacements of fish oils with plant oils in fish feeds (Benson, 2010; Shivaraj, 2010 and Ogello *et al*., 2014), which has been shown to register significant growth, and proved to be a cheaper source. This therefore calls for determination of the exact lipid requirements of *O. niloticus*, and matching this in feed formulations.

### 2.3.3. Carbohydrates

Carbohydrates have been termed inessential (Shiau, 1997), although they are included in aquaculture diets to reduce feed costs and for their binding ability during feed processing. These are the starches and sugars that are stored in fish as glycogen and that can be mobilized to satisfy energy demands by fish. Craig and Helfrich (2009) established that they are not efficiently utilised by fish and therefore have to be cooked to be made more available to fish. El-Sayed (2006), however, found out that Nile tilapia can effectively use between 35-40 percent of digestible carbohydrates, because they are herbivorous, as opposed to carnivorous fish. Shiau (1997), also established that the amount of fibre affects the utilization of carbohydrates in Nile tilapia. High fibre levels reduce feed palatability. Meal frequency also affects some carbohydrate metabolic enzymes which are altered due to changes in meal frequency (Kaya, 2015). The ability of fish to utilize certain carbohydrates changes with the size or age of the fish, as small fish utilize glucose better than larger fish but starch is utilized equally well in all the sizes (El-Sayed, 2006).

Wheat bran, maize and rice bran have been used as the major dietary carbohydrate sources for tilapia in Africa (El-Sayed, 2006) and this also includes Kenya. In their work, Liti *et al*. (2005) established wheat bran and maize bran to be cost effective as compared to rice bran, however maize bran treatments produced the highest growth, but the highest profitability was obtained in the wheat bran treatments. According to El-Sayed (2006), cocoa husks have been found to successfully replace wheat bran, wheat flour or rice bran in tilapia feeds up to 20 percent inclusion level. Barley seeds replace up to 30 percent of dietary maize in *O.*

*niloticus* diets without adverse effects on fish performance. This therefore shows that price consideration and availability of the ingredients is important as far as carbohydrate inclusion is concerned. However, 20 percent of dietary carbohydrates have been found to be effective in Nile Tilapia growth (Craig and Helfrich, 2009).

### 2.3.4 Minerals

Mineral supplementation in form of premixes may be beneficial in intensive systems, although most of these nutrients are usually met naturally in extensive and intensive pond cultures. However, specific *O. niloticus* requirements are not exactly known for all the minerals. Tacon and De Silva (1997) noted that though not specific to Nile tilapia, excessive supply of certain minerals can cause deficiency of other minerals and in extreme cases, toxicity to fish. High dietary calcium for example, can cause deficiencies in phosphorus, zinc, iron and manganese. According to Dato-Cajegas (1996), high concentrations of zinc, calcium and selenium can be toxic to fin fish species. He showed that addition of phosphorus was found to significantly affect Nile tilapia's weight gain, conversion ratio and protein efficiency ratio. There is also need to supplement so as to ensure sufficient levels are available to protect against mineral deficiencies (Bhujel, 2001). These are caused by reduced bioavailability such as when plant phosphorous is used in tilapia feed (FAO, 2016). Many of the plant based feed ingredients have high phytic acid content which binds metal ions such as calcium, phosphorous, magnesium, manganese and zinc, thus rendering them unavailable. In addition, phosphorous levels in fresh water have been recorded to be 0.005-0.05 ppm which is much lower than the established requirement by Nile tilapia, as demonstrated by Bhujel (2001).

### 2.3.5. Gross Energy

The gross energy (GE) of a feed is the total energy that it holds (Tacon and De Silva, 1997). This, however, comprises of the digestible energy together with what is lost during metabolism and what remains to be used in growth and body maintenance. The feed's GE depends on its composition and can be calculated by adding up the GE brought by each ingredient. According to Craig and Helfrich (2009) the nutritional value of a dietary ingredient is in part dependant on its ability to supply energy. Physiological fuel values, developed by Atwater in 1981 (FAO, 2016b) can be used as conversion factors to estimate energy in mixed feeds. Average gross energy value can be worked out based on composition of carbohydrate, fat and protein using appropriate value. The conversion factors used to calculate the gross energy values are 5.65, 4.15 and 9.40 kcal per gram of protein, carbohydrate and lipid, respectively (FAO, 2016b).

In fish, energy needs are supplied by fats, carbohydrates, and proteins (Tacon and De Silva, 1997). Determination of energy values in fish feeds is important as they help in assigning the correct Protein: Energy ratio. Shiau (2002) noted that high protein: energy ratios, results to high fat deposition as protein will be utilized for energy and not body building while lipids are accumulated. On the other hand, low ratios lead to slow growth. However, Li *et al.* (2013) demonstrated that tilapia can tolerate a wide range of energy to protein levels without adversely affecting performance. They further concluded that tilapia can utilize low-protein diet as long as intake is adequate to meet daily requirements. In their work, they suggested 30/2800, protein/Kcal energy ratio for *O. niloticus*.

## 2.4. Status of fish feeds in Kenya

Like in most parts of Africa, aquaculture in Kenya is one of the youngest and fastest growing sectors. Despite of this, fish feed technology remains one of the least developed segments of the sector (Gabriel *et al.*, 2007). In spite of their low development, fish feeds still account for over 60 percent of cost of production in both small and large scale production systems (Ngugi and Manyala, 2009). Many authors concur with the narrative that lack of sufficient quantity and quality fish feeds is the main challenge facing fish farmers (Bowman, 2007) and may be contributing to the stagnation currently faced by the aquaculture production sector in Kenya (Fig. 1). Fish feed in Kenya is produced both on commercial and on-farm scales. According to a survey by Munguti *et al.* (2014), only a few have been approved, to produce quality feeds, which meet fish feed quality standards set by the KEBS. However, further survey efforts are needed to identify more firms and to help eliminate unscrupulous feed producers who according to Liti *et al.* (2005), have been found to add sand in feeds, fix high costs and supply low quality feeds which do not meet the nutrition requirements of *O. niloticus*.

Due to the high costs associated with quality feeds, farmers in Kenya have opted for more affordable sources, as highlighted by Awuor and Karugu (2014). At the inception era of aquaculture, farmers used manure only without supplemental feeds but this has changed over time from the use of single ingredients to properly formulated feed compounds (Ngugi and Manyala, 2009). This has been supported by the wide range of research on potential ingredients for fish feeds, and the need to cater for the high fish feed demand, which has gone up to 50,000 MT from 14,000 MT per year in 2010 as a result of the Economic Stimulus Program which was established in 2009 (Munguti *et al.,* 2014). The high fish feed demands also lead to unscrupulous dealers sometimes selling feeds of compromised quality as reported by Liti *et al.* (2005). This is a problem experienced in Africa (Moehl and Halwart`, 2005). With time, the venture becomes a liability rather than a profit source. Farmers end up feeling demotivated potentially, lowering farmers' income, as production stagnates. This may explain the sudden stagnation in the sector as shown in Figure 3, with the abrupt flattening of the curve. This has also been reported by the FAO (2016). The situation is made worse by farmers' lack of knowledge on nutritional requirements of target fish, poor water quality in ponds, incorrect feeding regimes among other factors (Munguti *et al.,* 2014). The most commonly used feed ingredients in Kenya, according to surveys done include fresh water shrimps locally known as "Ochonga" (C*aridina nilotica*), "Dagaa" (*Rastrineobola argentea*), wheat, maize or rice bran, sunflower or cotton seed cake and cassava (Munguti *et al.,* 2004). The situation has however changed and farmers are currently using non-conventional sources like plant leaves, such as yams, sweet potatoes, cassava, tea leaves remains, brewer wastes, molasses, blood meal, feather meal, kitchen wastes and most recently insects and worms (Munguti *et al.,* 2004 ; Liti *et al.,* 2005; Awuor and Karugu, 2014).

This was also shown by Omasaki (2013), where more than 50 percent of farmers interviewed, used mixed ingredients. The farmers still lack the knowledge of proper formulation and nutritional requirement of fish according to their developmental stages, thus making fish production stagnate. This is reiterated by Aquaculture Association of Kenya (2016), and the State department of fisheries and aquaculture (2016), who have constantly expressed the need to educate farmers on proper feed production, and evaluation of nutritive relevance of these on-farm formulated feeds. As echoed by most aquaculture nutrition researchers, success of aquaculture is reflected by the quality of fish feeds used. Compounded feeds have been shown to promote better fish growth than single ingredients (Obe *et al.,* 2015). The economic comparisons have also shown that formulated diets are better than single ingredients (Omasaki *et al.,* 2013). This therefore shows that there is need for low-cost compounded diets formulated from locally available ingredients, to promote and sustain aquaculture development in Kenya.

## 2.5. Feeding and water quality

The quality of the fish feed and the feeding management adopted by Nile tilapia farmers can significantly affect growth, survival and feed conversion of the fish. This is also true for water quality variables like oxygen and pH (Caldini *et al.,* 2011). According to Tacon and De Silva (1997) feeds should be delivered to fish equally throughout the day. Mjoun *et al.* (2010) on the other hand reported that feed utilization in *O. niloticus* being a cold blooded animal, is a function of temperature, as it increases with increasing temperatures. This means that water temperatures affect fish growth rate and therefore production cycle and fish weight at harvest in aquaculture enterprises. It also influences solubility of dissolved oxygen and aerobic decomposition of organic matter. Therefore there is need to monitor these factors for better feeding practices. Distributing the feeds equally throughout the day may lead to feed wastage. White (2013) showed that excess feeds sink to the bottom of ponds and adds to the organic matter which results to anoxic conditions in this section of the pond which eventually leads to release of more nutrients, pond eutrophication and negatively affects other parameters like pond-water pH. This situation is made worse in cases of ponds of more than 1 meter depth, as less oxygen reaches the pond bottom. In their work, El-Sayed *et al.* (1996) showed the influence of pond depth and temperature on growth performance and feed utilization in Nile Tilapia. The study revealed that the lowest growth was recorded at temperatures below $21^0$ C and growth stopped when temperatures reduced to $10^0$ C. The researchers also showed little feed utilization by fish for ponds with more than one meter depth and those with less than 0.5m depth. This therefore implies that adjusting fish feeding rates and designing ponds appropriately, have practical importance in improving fish production and also in saving the cost of feeds.

## 2.6. The criteria for determining suitable feeds for Nile Tilapia.

Fish feed formulations must be cost effective, and should produce palatable and nutritious feeds to meet the basic nutritional needs of the fishes (El-Sayed, 2013). Below are some important aspects of fish feeds to be considered in fish feed formulations.

### 2.6.0. Cost

Because fish feeds account for the highest percentage of production costs, the main focus of farmers in on-farm feed formulations is to cut cost by making use of locally produced ingredients without compromising the quality (El-Sayed, 2013). Bhosale *et al.* (2010), emphasized the need for the formulation of low-cost balanced diet using locally available agro-industry by- products for commercial culture of Nile tilapia, thus cutting costs on feeds, and enabling Nile tilapia farmers to break even in their enterprises. Alternative sources of proteins for example, should be selected based on the market price. Some ingredients in Kenya contain high levels of nutrients, but tend to be more costly than others.

Liti *et al.* (2005) for example, found out that using wheat bran and maize bran was more cost effective than using rice bran. Their study also found out that maize bran treatments produced the highest growth, although the highest profits were obtained in the wheat bran treatments. The cost of these ingredients however, varies from place to place depending on the availability.

### 2.6.1. Availability

Availability of plant sources of fish feed ingredients depends mainly on the climatic and soil conditions of the fish farm location. Locally available ingredients are cheap, and can be obtained in desired quantity and in unaltered quality. Low cost of transportation, for example, should help farmers to maximize profits in their enterprise when they use locally available ingredients in feed formulation. Ingredients obtained from distant locations are vulnerable to quality and quantity alterations due to rancidity in lipids and addition of unwanted elements like ashes or sand by unscrupulous traders (Liti *et al.,* 2005). Munguti (2007) stated that in case important ingredients in Nile tilapia feed are not available, farmers can still formulate their feed to meet the nutritional needs of their fishes with little adjustment when using the available local ingredients.

### 2.6.2. Nutrient composition

The purpose of fish feed formulation is to ensure a feed meets the nutritional requirements of the target fish species at a reduced cost without reducing the quality. Therefore, nutritional composition of the available ingredient must be given due consideration. For this reason, Shiau and Lin (2006) point out that individual nutritive profile of the ingredients should be known so as to establish a mixing ratio that will ensure the nutrient, is as required by the target species. Nutrient composition also shows the deficiencies of the ingredient and thus helps in deciding additional ingredients ( Gutmann, 2013). Feather meal, for example, is a good source of protein and can replace fish meal by 66 percent, but it is poor in amino acids profile and digestibility. Blood meal on the other hand, is rich in lysine but deficient in methionine (Ogello *et al.*, 2014). All these considerations are important during feed formulation, in achieving quality fish feed for *O.niloticus.*

## CHAPTER THREE

## MATERIALS AND METHODS

### 3.1. Study area

The study was carried out on selected fish farms in Nakuru, Kericho and Bomet Counties of the Rift Valley region in Kenya (Fig. 3). Global positions of these farms together with other farm details are given in APPENDIX 3.

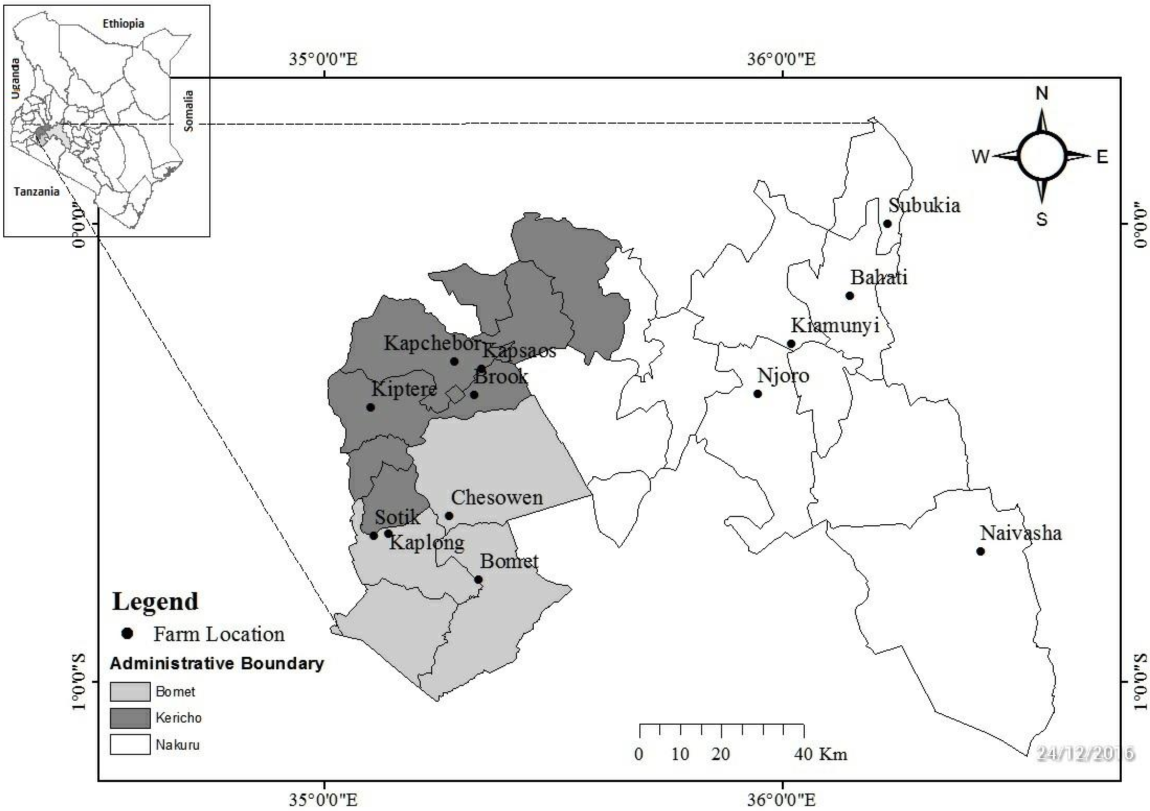



Figure 3: A map of Kenya showing the counties where the study was undertaken.

This region is of interest because originally it was known to produce cash crops on large scale but in the recent years, fish farming has become a point of attention (Ngugi and Manyala, 2009). This has been attributed to the need for farmers to increase farm production per unit area, as land area for food production continues to decline. Introduction of, 'eat more fish campaign' and recently the Economic Stimulus Program by the Government of Kenya, have also diverted the attention of more farmers into fish farming (State department of Fisheries and Aquaculture, 2016). The former Rift Valley region is currently administratively subdivided into 14 counties, following enactment of the 2012 Kenyan constitution. The main crops cultivated in these counties include; maize, wheat, tea, vegetables and fruits (Lukuyu *et al.*, 2011).

These crops are advantageous to fish farmers as far as local fish feed ingredients are concerned, making the region suitable for sustainable and cost effective culture of Nile Tilapia. A temperature range of 10–28$^0$C in this region is fairly favourable for Nile Tilapia culture (Bowman *et al.,* 2007). Fish production in the selected counties in Rift Valley region is largely by semi-intensive systems, with over 3,000 fish farmers and more than 3,000,000 m$^2$ of culture units established (Ngugi and Manyala, 2009).

## 3.2. Study design and field sampling

### 3.2.1. Criteria of farm selection

Small- scale farms growing Nile tilapia by semi-intensive pond culture systems were selected from the three counties, based on the selection criteria given below:

i. Small scale semi-intensive farms with at least one pond to maximum of 4 ponds were selected.
ii. Location of the farm in relation to a major cosmopolitan town. The distance to major urban centres affects the availability and price of local ingredients as well as, the potential for marketing the fish and the potential prices they can fetch.
iii. The type of fish feed used. In this study only farms that used on-farm formulated feeds, with single or mixed ingredients were targeted.

A pilot survey was conducted at the start of the study to select farms to be sampled. 35 farms were selected randomly from the total number that satisfied this criteria. 40 percent of these farms were sampled, giving a total of 15 farms. In addition, the selection considered concentration of farms in the counties, where more farms were picked from Nakuru, followed by Kericho and Bomet in that declining order. This translated to 8 farms in Nakuru, 5 in Kericho and 2 in Bomet. One commercial farm was picked from each county for comparisons. This made a total of 18 semi-intensive farms that were finally selected.

### 3.2.2. Collection of feed samples

Fish feed samples were collected from the 18 fish farms in the three counties of Bomet, Kericho and Nakuru. The feed samples were ground to fine particles in preparation for proximate analysis and stored in polythene bags for transportation to the laboratory at Egerton university Biological Sciences department. For comparison purposes, one commercial feed was sampled from dealers in each of the three counties. This was done as a confirmatory test necessitated by the fact that in some cases, package labelling of commercial feeds do not match the proximate composition of the feeds.

Information about the type of ingredients used, their availability and seasonality, feeding frequency, the formulation method applied during preparation and amounts of ingredients used were also recorded during farm visits.

### 3.2.3. Characterisation of farms

During the study, descriptive aspects of the farms were recorded. These aspects included location of the farm, ownership, size of the farm, number of ponds, depth of pond, stocking density, type of system, source of feed ingredients and types of feeds used among others. These were obtained by use of a semi-structured questionnaire, and personal visits to the farm to obtain accurate and reliable information. Physico-chemical characteristics of pond-water, including dissolved oxygen, pH, conductivity and temperature, which also affect performance of fish, were measured *in-situ* using DO meter between 12 pm - 2 pm, when the parameters were at optimal levels, between December 2016 and February 2017. All these and other aspects, determine the time taken by fish to grow to market size and also the final weight attained by Nile tilapia (Mjoun *et al.*, 2010).

### 3.2.4. Feed cost analysis

First, the unit market prices of individual ingredients used were obtained, then the best- buy technique used to compare the ingredients with one another on the basis of cost per unit of protein or lipids, depending on what nutrient the ingredients are supposed to provide. The cost per gram of on-farm formulated feed was determined through interviews and market price surveys, which was then divided by the protein content in a gram of the feed. Protein was used here because of its importance in growth of fish and because it is usually the most expensive ingredient in fish feeds

Best-buy will be calculated using the formula of Bhosale *et al.* (2010).

$$\text{Cost per unit of protein} = \frac{\text{cost per gram}}{\text{protein per gram}} \qquad [1]$$

### 3.3. Proximate analysis

In the laboratory, feed samples from the selected farms were subjected to proximate analyses. Each Analysis was done in triplicate. Analysis was according to Association of Official Analytical Chemists, AOAC (2012) standard methods of analysis.

The feed samples were stored in a cool dry store to avoid nutrient losses where the analyses took longer than 2 weeks to conclude. Fat soluble vitamins were however not analysed.

***Moisture Content***

This method was used to determine the percentage of water in fish feed sample by drying the sample to a constant weight. 5 g of thoroughly ground samples contained in crucibles were placed in an oven at $105^0$ C for 12 hours and weights taken until a constant weight was achieved. Percentage moisture was then calculated according to the formula by AOAC (2012).

$$\text{Percent moisture} = \frac{\text{p-a}}{\text{P}} * 100 \qquad [2]$$

Where; P=Weight in g of fresh feed sample
a =Weight in g of dried sample

***Ash content***

This is the solid residue that remains after incineration of organic matter. It measures the mineral and micronutrient fraction of a sample. In some instances, it provides an estimate of contamination, that is, it can indicate levels of non-food particles like soil or salt that may have been added to the feed. Incineration of samples was done in a muffle furnace at 550 $^0$C for 12 hours until a constant weight was attained. Weights of crucibles with samples were taken before and after incineration, and percentage ash content based on wet weight calculated as in AOAC (2012).

$$\text{Percentage ash content} = \frac{\text{wt.crucible and ash} - \text{wt.crucible}}{\text{wt.crucible and sample} - \text{wt.crucible}} * 100 \qquad [3]$$

***Crude lipids***

Soxhlet method was used to extract crude lipids into ether (AOAC, 2012). 3 g of well ground sample was weighed into a thimble and placed into a thimble holder. Petroleum ether was heated to $90^0$ C, ascended toward the condenser and trickled in the thimble to extract the fat.

The thimble was then dried to constant weight in the drying oven and the residue weighed. Calculation of percent crude fat was done according to AOAC (2012) equation 4.

$$\text{Crude Lipid} = \text{Wres} - \text{Wta}/\text{Weight of sample(g)} * 100 \qquad [4]$$

Where,

Wta = tare weight of beaker in grams

Wres = weight of beaker and fat residue in grams

***Crude protein***

Nitrogen compounds were estimated through the Kjeldahl method, which assumes that in all protein molecules, nitrogen forms an average of 16 percent of feed. Therefore, nitrogen multiplied by 6.25 gives crude protein. 0.5 g of well ground sample was first, digested with concentrated sulphuric acid and a Kjeldahl catalyst tablet, for four hours. The digest was cooled down and distilled in sodium hydroxide solution. The distillate was mixed with 50 ml of boric acid and methyl red-methylene blue indicator solution and titrated against 0.1 M hydrochloric acid. The volume of titre was then used to get crude protein content in equation 5. Percent nitrogen was calculated according to AOAC (2012).

$$\text{Percent Nitrogen} = \frac{(A-B)*0.1*14.007}{\text{weight of sample(g)}} \text{x}100 \qquad [5]$$

Where: A = Initial volume of HCl

B = Final volume of HCL

0.1 Molarity of HCL used

14.007 being molecular weight of nitrogen

Percent protein calculated as: % Protein= % nitrogen x 6.25

Where; 6.25 is the protein-nitrogen conversion factor for fish and fish by- products (AOAC 2012).

***Crude Fibre***

This is the indigestible portion of feed composed of polysaccharides such as cellulose, hemicellulose and lignin. Crude fibre has little or no nutritional value and can therefore lead to weight loss in fish if not appropriately considered. 3 g of the sample was digested in 3.15% sulphuric acid and 1.25% sodium hydroxide solutions and the residue calcined (AOAC, 2012). The difference in weight after calcination, indicates the quantity of fibre present, worked out as:

$$\text{Crude fibre content (\%)} = \frac{A-B}{C} * 100 \qquad [6]$$

Where: A= Weight of crucible with dry residue (g)

B= Weight of crucible with ash (g)

C= Weight of sample (g)

***Nitrogen - Free Extract***

This proportion consists of digestible carbohydrates such as starch and sugar, vitamins and other non-nitrogen soluble organic compounds. This is obtained by difference method (AOAC, 2012), following the formula;

$$\text{Nitrogen-free extract (\%)} = 100 - (A - B - C - D - E) \qquad [7]$$

Where: A is moisture content (%), B is crude protein content (%), C is crude lipid content (%), D is crude fibre content (%) E is ash content (%)

***Minerals***

In the study, five minerals namely, Sodium (Na), Magnesium (Mg), Phosphorous (P), Iron (Fe) and calcium (Ca), were measured in the feed samples. Flame Atomic Absorption Spectrophotometer (FAAS) was used to measure the elements. The principle is based on the attenuation of light to the properties of the material through which the light is traveling (AOAC 2012). The samples digested in sulphuric acid were liquefied with dilute hydrochloric acid, diluted with distilled water to 50 ml, and then injected into the instrument where it was atomized by flames, in order to be analysed for its atomic constituents. The atoms were then irradiated by optical radiation, and radiation passed through a monochromatic flame in order to separate the element-specific radiation from any other radiation emitted by the radiation source. These waves were finally measured by a detector. The analysis was done in triplicate under the same conditions as standards and blanks, according to Dawodu *et al.* (2012), and the standard calibration curves used to determine the concentration of the mineral.

***Gross Energy calculation***

The average gross energy value was worked out based on composition of carbohydrate, fat and protein using appropriate value (Le Gouessant, 2006).

Specific energy conversion factors for the ingredients, (5.65, 4.15 and 9.40 kcal per gram of protein, carbohydrate and lipid, respectively), were used to calculate the gross energy, using the formula;

GE of a feed = Sum of the GE of each nutrient (proteins, lipids, carbohydrates)

Where GE for each nutrient = % composition × specific conversion factor.

### 3.4. Data collection using questionnaire

Data of feed management strategies, year of farm operation, farm ownership, method of fish feed formulation, geographical location of the farm, cost of feed ingredients among others, were collected by use of a semi structured questionnaire which was filled by the interviewer, accordingly, depending on the farmers ‘responses. Sample questionnaire in APPENDIX 4.

### 3.5. Data analysis

Data obtained was entered and organised in Ms-Excel. Using R statistics, normality of data was tested using Kolmogorov–Smirnov test. For hypotheses 1 and 2, One way ANOVA test was performed, to compare variations in nutrient content means of commercial and on-farm formulated feeds and the set standards, and the difference between mean costs of on-farm formulations and commercial feeds. A Tukey’s post-hoc test was then employed to separate the significantly different means. In hypothesis 3, pivot charts were used to show proportions of, duration of farm operation observed, feed formulation methods used, levels of farmers training, fish feeding frequencies used by farmers and methods of fish feed storage. Descriptive statistics, box plots, pivot tables were generated for the farm characteristics and feed management practises of the sampled farms, with confidence intervals set at 0.05.

# CHAPTER FOUR

# RESULTS

## 4.1. Proximate analysis of on-farm formulated feeds and comparison to Kenya standards.

### 4.1.1. Ingredients commonly used by farmers in on-farm fish feed formulation.

Various locally available ingredients of plant and animal origin used in fish feed formulations were identified in the three counties during the study. Table 2 summarizes the common ingredients and their availability from the three counties.

Table 2: Major ingredients used in farm-made fish feed formulation in the counties of Nakuru, Kericho and Bomet.

| INGREDIENTS | BOMET | KERICHO | NAKURU |
|---|---|---|---|
| **MIXED** | | | |
| Kitchen wastes | ++ | + | + |
| **PLANT SOURCE** | | | |
| Wheat bran | ++ | ++ | ++ |
| Maize bran | + | + | + |
| Wheat flour | - | - | + |
| Maize flour | + | + | - |
| Kales | + | + | - |
| Cassava | + | - | - |
| Sweet potato vines | - | - | ++ |
| Avocado | - | ++ | - |
| Banana peelings | - | + | - |
| Sunflower oil | + | - | - |
| Sunflower cake | - | - | + |
| Cotton seed cake | - | - | + |
| *L.Trichandra* | - | - | ++ |
| Grass | + | + | - |
| Molasses | + | - | - |
| **ANIMAL SOURCES** | | | |
| Shrimp meal | ++ | ++ | ++ |
| Poultry droppings | + | + | - |
| Fish meal | + | + | + |
| Blood meal | - | + | ++ |
| **FINISHED FEEDS** | | | |
| Chick mash | - | + | + |
| Pig finisher | - | - | + |
| Mineral mix | + | - | - |
| Vitamin mix | + | - | - |

Notes: + (Moderately available and used, not sourced locally), ++ (Highly available and used, sourced locally), − (Not easily available and rarely used).

## 4.1.2. Proximate constituents of on-farm formulated feeds and selected commercial feeds

Specific biochemical composition of the 18 sampled feeds were analysed each in triplicate (n = 54). In this chapter the results of the proximate analyses of the on- farm formulated feeds and the commercial feed mixtures are presented in terms of moisture, ash, crude lipids, crude protein, crude fibre, gross energy, nitrogen free extracts and the selected minerals. The proximate analysis results are shown in figures 5, 6, 7, 8, 9, 10 and 11. The numbers in plots represent the 18 feeds that were analysed, whereas the number 19 represents the country standard value set for the specific nutrient.

### *a. Moisture and ash contents*

The lowest moisture content in all the feeds was 4% for feed 6 and highest in feed 7 with 15% from Kericho County (Fig. 4). Differences in moisture and ash contents were compared between the feeds, as well as with the set standard levels. There were significant differences in moisture (*ANOVA*, $F$ = 54.431, n = 19, *d.f* = 18 P < 0.05), and ash contents (*ANOVA*, $F$ *=30.11,* n =19, *d.f* = 18 P<0.05) between the feeds and with the standards. There was also a significant difference observed for moisture content between the counties, where a post hoc test revealed a difference between moisture content in Bomet County feeds and the standard, P < 0.05. (Table 3).

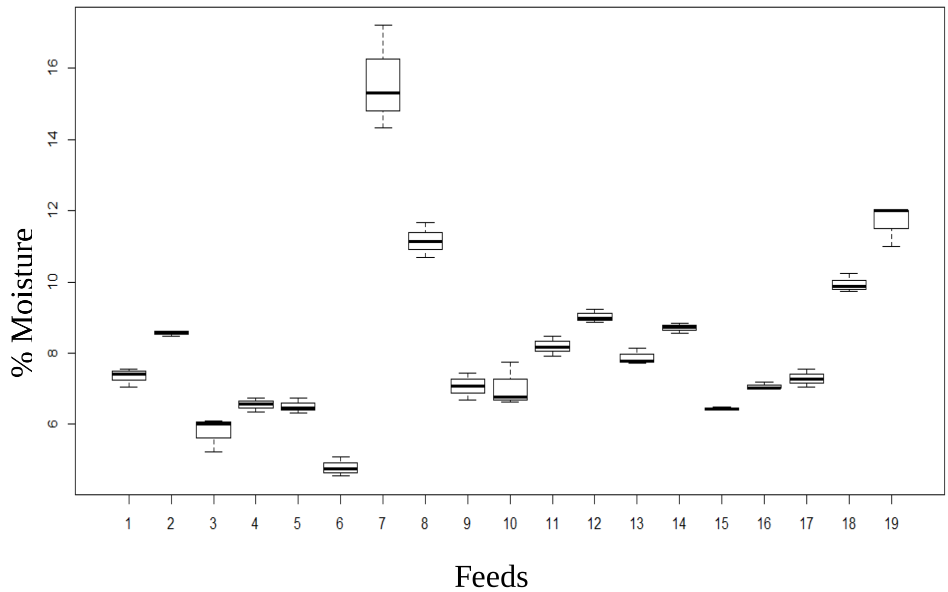



Figure 4: Box plots showing variations in moisture contents of the 18 feeds and the standard value.

Table 3: Tukey's post hoc output for differences between proximate constituents of fish feeds from the three counties with the standard values.

| | **POST HOC P Values** | | | | |
|---|---|---|---|---|---|
| | Moisture | Ash | Crude lipid | Crude protein | Fibre |
| Kericho-Bomet | 0.478 | 0.159 | 0.889 | 0.999 | 0.510 |
| Nakuru-Bomet | 0.853 | 0.922 | 0.988 | < 0.05** | 0.182 |
| Nakuru-Kericho | 0.794 | 0.118 | 0.944 | < 0.05*** | 0.881 |
| Standard-Bomet | 0.032 | | 0.468 | < 0.05* | 0.991 |
| Standard-Kericho | 0.174 | | 0.697 | < 0.05* | 0.615 |
| Standard-Nakuru | 0.058 | | 0.507 | 0.933 | 0.375 |

Notes: *Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

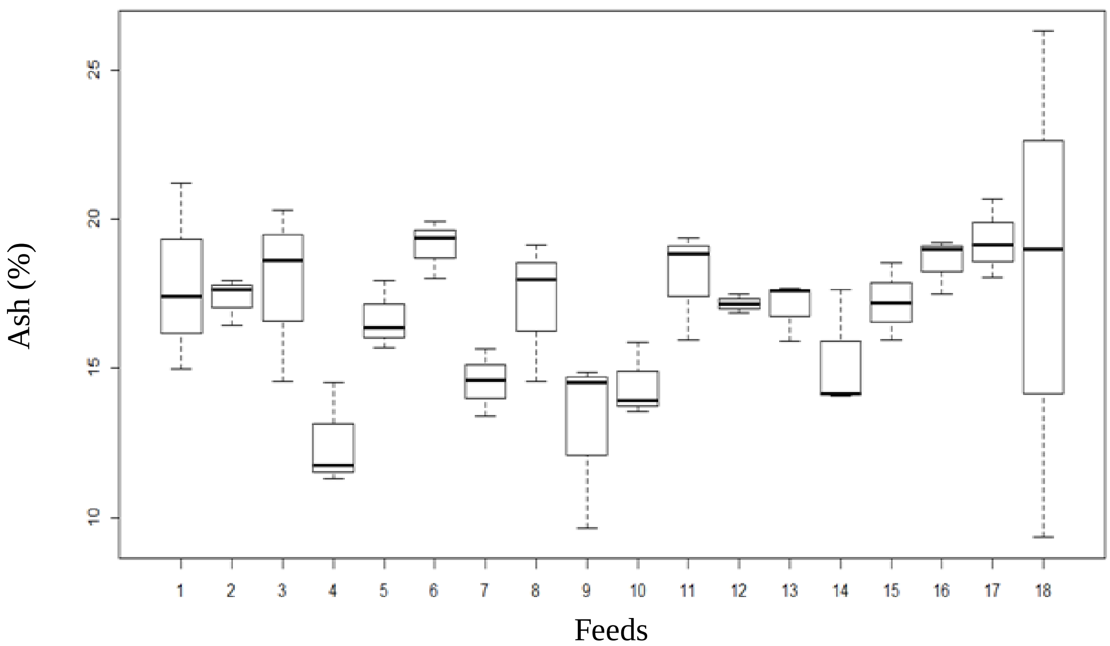



Figure 5: Box plots showing variations in ash contents of the 18 feeds and the standard value.

***b. Crude lipid and Crude protein contents***

Results for crude lipid and protein are shown in Fig. 6 and 7.

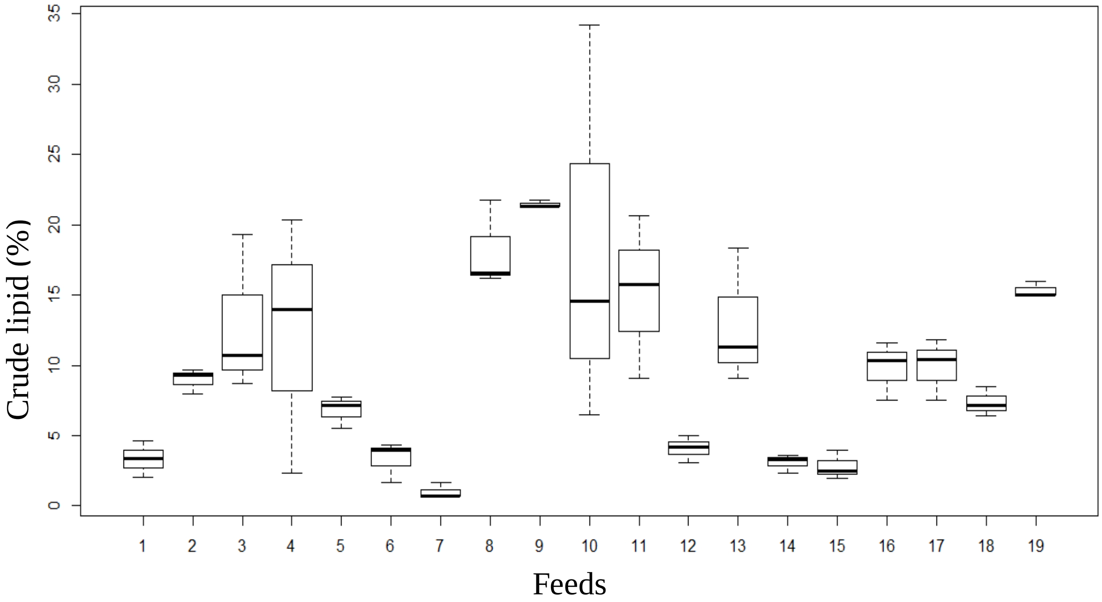



Figure 6: Box plots showing variations in Crude lipid contents of the feeds in the studied counties and the standard values.

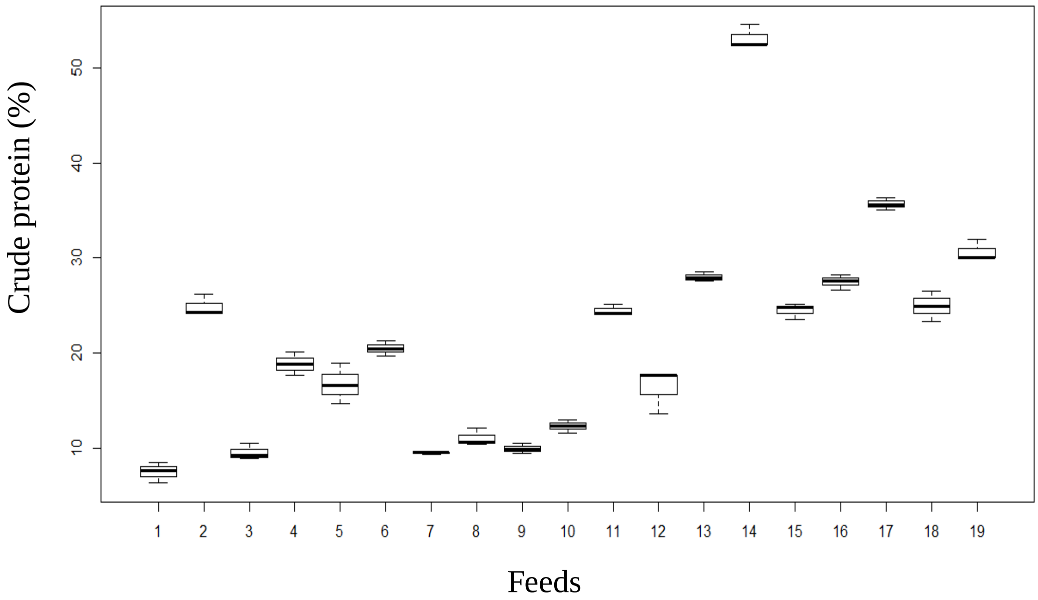



Figure 7: Box plots showing variations in protein contents of the feeds in the studied counties and the standard value.

Values of crude lipid varied from 1% in farm 7 to 24% in farm 9 in Kericho County (Fig. 6). All these values varied significantly between the on- farm formulations, commercial feeds and the standards (*ANOVA*, $F = 45.694$, $n = 19$, $d.f = 18$ $P < 0.05$). There was no significant difference in crude lipid contents between the counties and between the counties and the set standards (*ANOVA*, $F = 2.794$, $n = 19$, $d.f = 3$, $P < 0.05$). Crude protein values on the other hand ranged from 8% to 53% in the on-farm made feeds (Fig. 7). There were significant differences between the on-farm feeds, commercial feeds and the set standards (*ANOVA*, $F = 54.972$, $n = 19$, $d.f = 18$ $P < 0.05$). Similarly, a one way ANOVA test revealed significant differences ($P < 0.05$) in crude protein levels between the counties and between the set standards and the counties (Fig. 8). The values of crude protein in all the three counties were below the standard value. A Tukeys' post hoc test further revealed significant differences between protein levels in Nakuru County and the other two counties; Bomet and Kericho. There was no significant differences between protein levels in Bomet and Kericho counties ($P > 0.05$) (Table 3). In addition, Kericho and Bomet counties showed a significant difference with the set standards. There was no significant difference between Nakuru county protein content values of feeds and the set standard values.

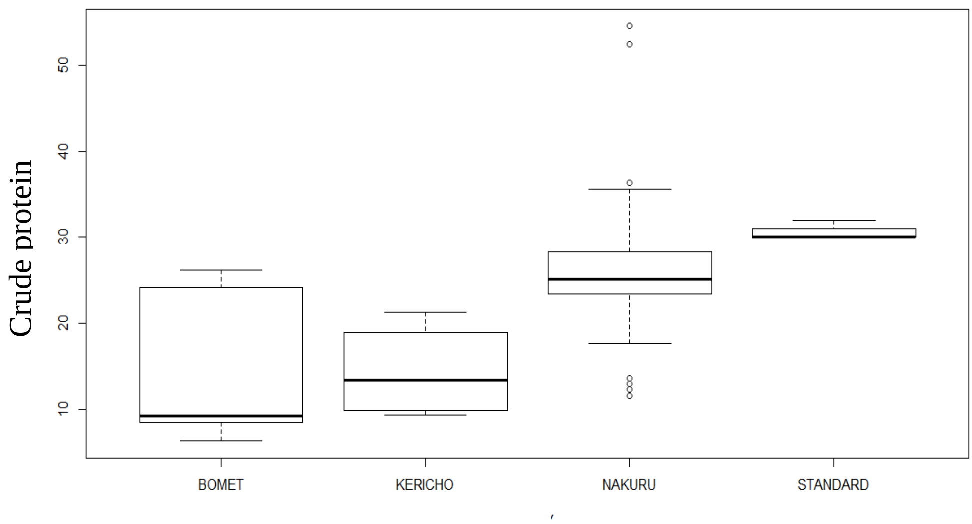



Figure 8: Box plots showing variations in crude protein contents of the feeds for the studied counties and the standard values of crude protein.

### *c. Crude fibre*

As shown in the Fig. 9, variations in crude fibre content existed between the sampled feeds in all the counties and also between the feeds and the set standards. More than 80% of the sampled feeds recorded values significantly higher than the standard value. These values however, did not vary significantly across the various feeds owing to the fact that similar ingredients were used on the farms for feed formulation (*ANOVA*, *F* = 9.665, n = 19, *d.f* = 18 P > 0.05). Similar results were observed between the three counties and between the counties and the set standard (Table 4). The highest level of crude fibre was registered in an on-farm formulated feed from Kericho County, which contained high proportions of maize cobs and wheat bran, and two in Nakuru County which contained high amounts of fresh water shrimps with exoskeleton.

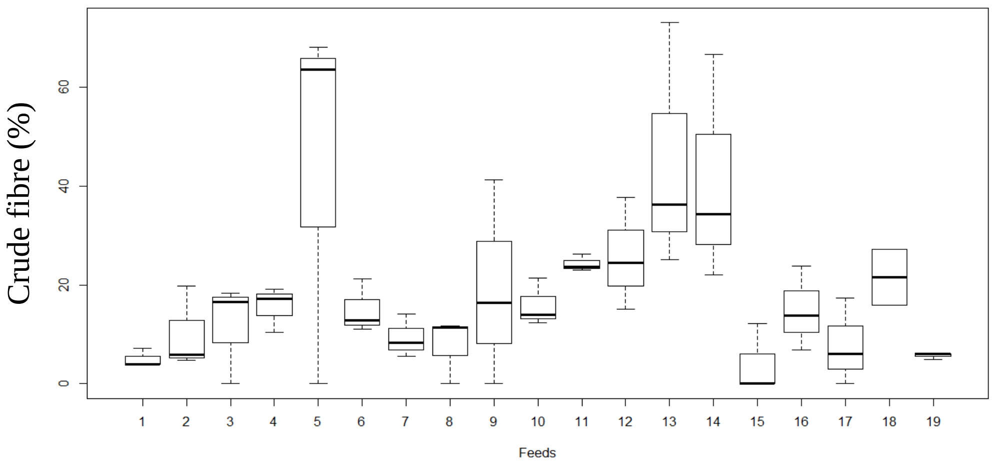



Figure 9: Box plots showing variations in crude fibre contents of the 18 feeds for the studied counties and the standard values.

Table 4: One way ANOVA output for the differences between proximate constituents of fish feeds from the three counties with the standard values. n = 4

| | F | d.f (n -1) | P |
|---|---|---|---|
| Moisture | 2.957 | 3 | 0.041 * |
| Ash | 2.622 | 3 | 0.083 |
| Crude lipid | 0.824 | 3 | 0.487 |
| Crude Protein | 10.79 | 3 | < 0.05 *** |
| Crude fibre | 1.982 | 3 | 0.128 |

Notes: *Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

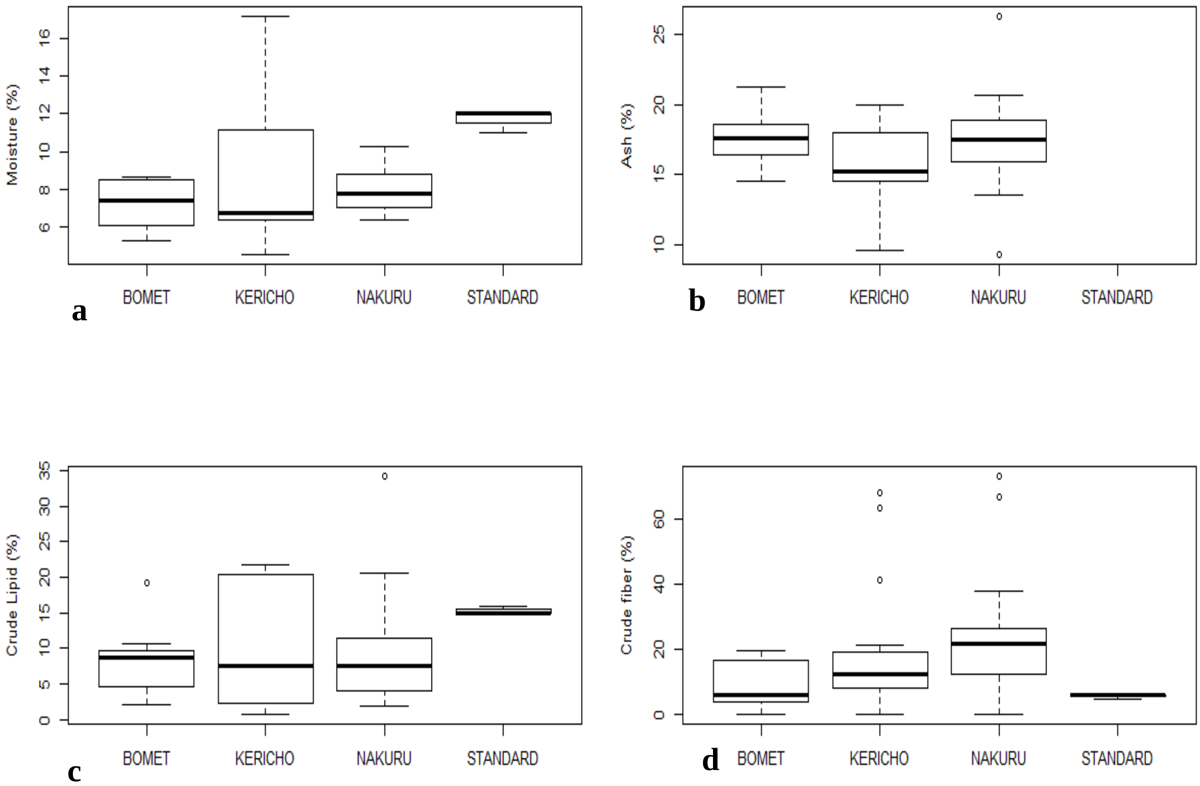



Figure 10: Box plots showing variations in proximate contents of (a) moisture, (b) ash, (c) crude lipid and (d) Crude fibre of the feeds for the three counties and the standard values.

### *d. Minerals*

Selected minerals were analysed in the sampled feeds to determine their composition and to compare these to specific mineral requirements by Nile Tilapia. Results showed that all the minerals analysed for could not attain the standard levels in most of the feeds. Levels of sodium, phosphorus and calcium were way too low in relation to the standard level. However, the levels of iron and magnesium, in the feeds were higher than the set standards. All the three commercial feeds (2, 6 and 17) did not also attain the standard levels (Fig. 11). One way ANOVA showed significant differences in all mineral levels between the different feeds and between these feeds and the standards $P < 0.05$. There was, a significant difference observed between the counties and the standards $P < 0.05$ (Table 6). There was no significant difference between the three counties, except for iron. Minerals levels in feeds from Nakuru County differed significantly with those from both Bomet and Nakuru counties (*ANOVA*, $F = 32.41$, $n = 4$, $d.f = 3$ $P < 0.05$). Summaries of the results from One way ANOVA and post hoc tests are shown in table 4 and table 6.

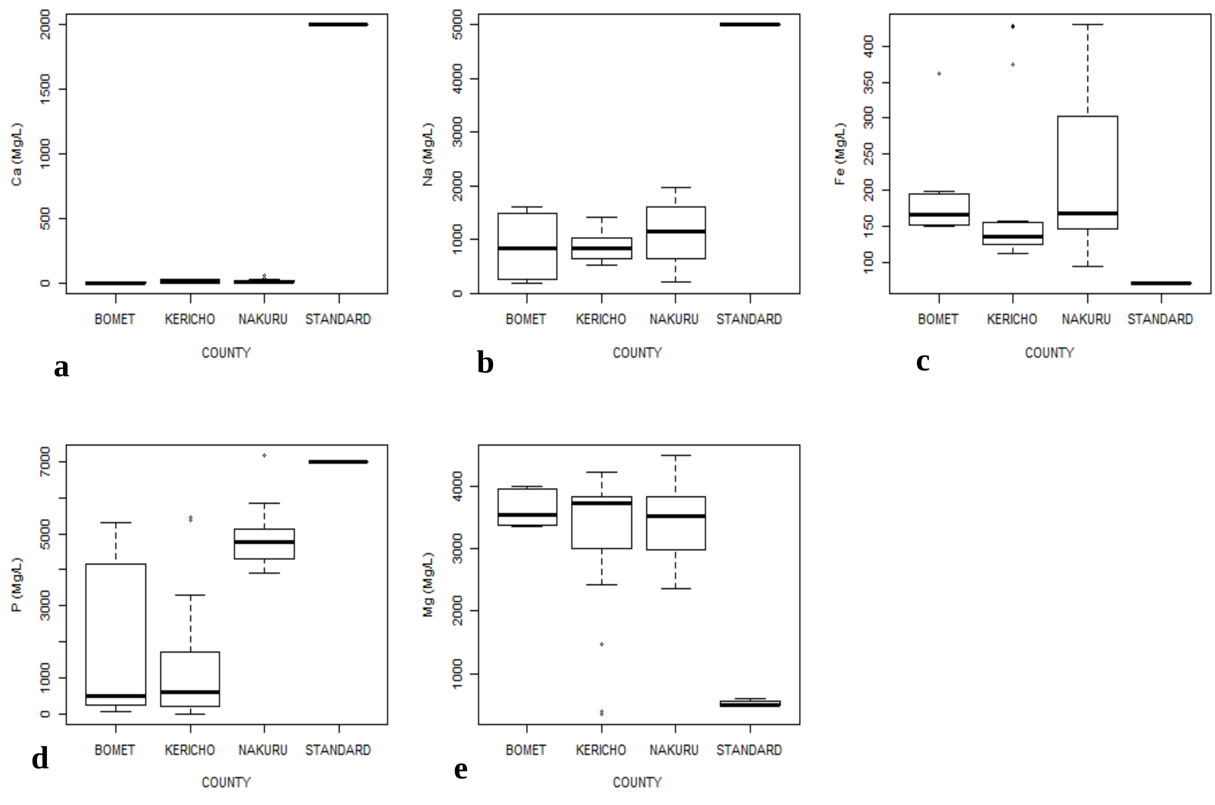



Figure 11: Box plots showing variations in minerals contents of the feeds for the three counties and the standard values, where (a) Calcium, (b) Sodium, (c) Iron, (d) Phosphorus and (e) Magnesium.

Table 5: One way ANOVA output for differences between mineral contents of fish feeds from the three counties with the standard values. n = 4

| | F | d.f (n -1) | p |
|---|---|---|---|
| Magnesium | 12.6 | 3 | < 0.05 *** |
| Calcium | 25149 | 3 | < 0.05 *** |
| Sodium | 67.23 | 3 | < 0.05 *** |
| Iron | 2.314 | 3 | 0.086 |
| Phosphorus | 32.41 | 3 | < 0.05 *** |

Notes: *Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 6: Tukey's post hoc output for differences between proximate constituents of fish feeds from the three counties with the standard values.

| | POST HOC P Values | | | | |
|---|---|---|---|---|---|
| | Magnesium | Calcium | Sodium | Iron | Phosphorus |
| Kericho-Bomet | 0.505 | 0.766 | 0.999 | 0.993 | 0.833 |
| Nakuru-Bomet | 0.885 | 0.145 | 0.506 | 0.881 | < 0.05 *** |
| Nakuru-Kericho | 0.775 | 0.481 | 0.351 | 0.570 | < 0.05 *** |
| Standard-Bomet | < 0.05 *** | < 0.05*** | < 0.05 *** | 0.258 | < 0.05 *** |
| Standard-Kericho | < 0.05 *** | < 0.05*** | < 0.05 *** | 0.279 | < 0.05 *** |
| Standard-Nakuru | < 0.05 *** | < 0.05*** | < 0.05 *** | 0.071 | 0.071 |

Notes: *Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

## 4.2. Fish Feed costs

NAFA 1 and 3 recorded highest value in terms of the cost per gram of protein. On the other hand, KEFA farm 3, 4 and Nakuru farm 5 and 6 recorded the lowest values (Fig. 12).

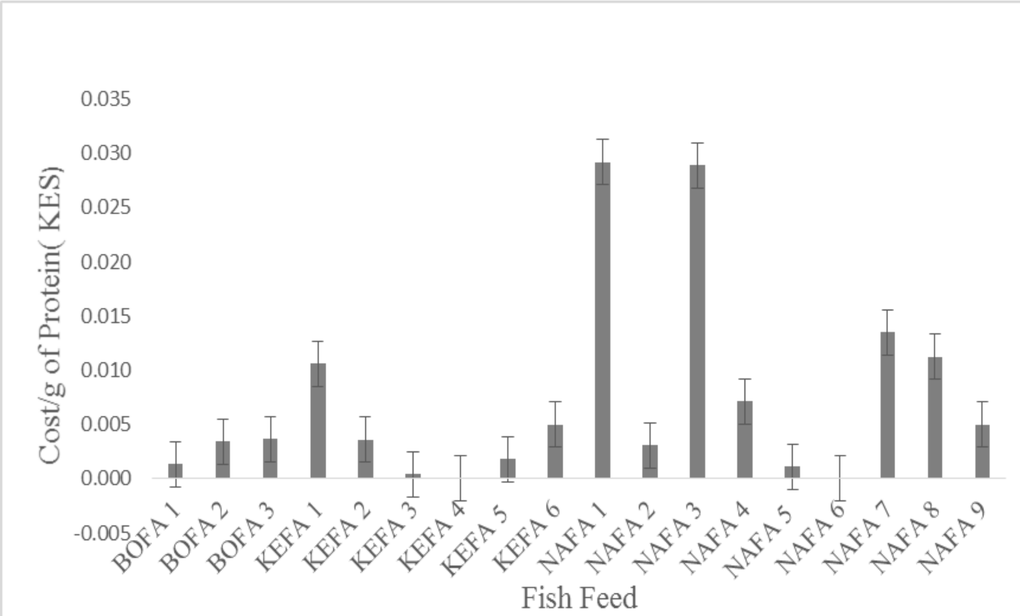



Figure 12: A bar graph showing cost per gram of proteins in the 18 feeds analysed from Bomet, Kericho and Nakuru counties.BOFA, KEFA, and NAFA are farm codes.

In terms of counties, Nakuru county recorded highest cost per gram of feed, which varied significantly with Kericho and Bomet which recorded the lowest values ($P < 0.05$) (Fig. 13).

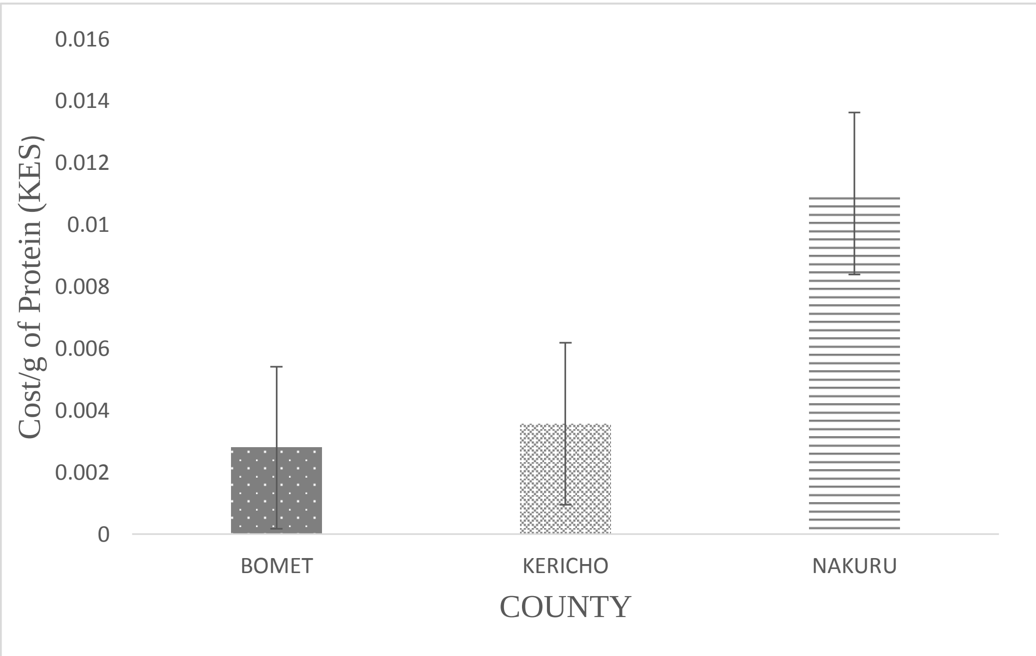



Figure 13: A bar graph showing mean cost per gram of protein in feeds in the counties of Nakuru, Kericho and Bomet.

### 4.3. Fish Farm management

Out of the farms visited, more than 70% were owned by individuals as family farms. In these types of farms most of the daily management activities were carried out by family members. The remaining 30% of the farms were shared between cooperative societies and institutions, (Fig. 14). Interestingly, all the cooperative owned farms were found in Nakuru county and none in Bomet and Kericho counties (Fig. 14b). This however does not justify the absence of cooperatives in the said counties because sampling in the present study was purposively aimed at farms that formulate fish feeds on-farm.

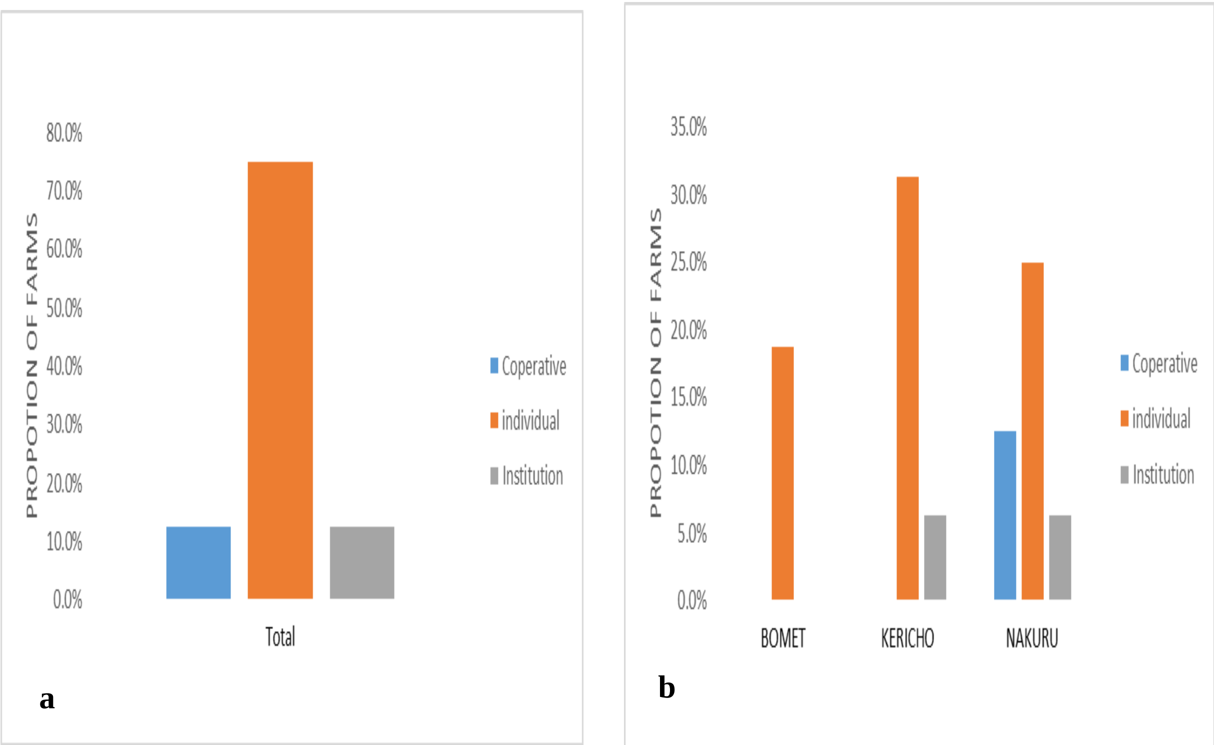
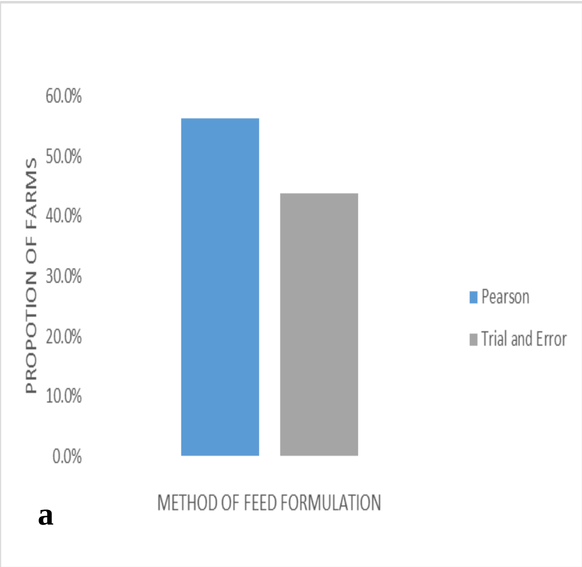



Figure 14: Graphs showing types of farm ownership (a) in combined region of study and (b) in Bomet, Kericho and Nakuru counties.

### 4.6. Method of feed formulation

Guided by the main objective of this study, it was of important to assess the methods used by the fish farmers to formulate the specific fish feeds on-farm. This was done through the use of interviews and observations. The results of this aspect are shown in Fig. 15 (a) and (b). More than half of the farms interviewed used Pearson's square method of fish feed formulation (Fig. 15a). The rest used trial and error methods, in which the various ingredients were mixed without precisely measuring their proportions unlike in the Pearson's square method. It was evident that Pearson's method was used across the three counties but widely applied in Nakuru County, where 35% of the farms used the method (Fig. 15b).



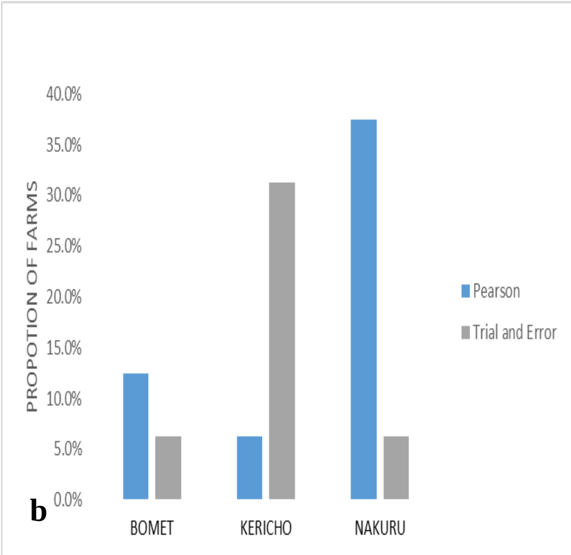




Figure 15: Graphs method of feed formulation used by farmers in the whole region of study (a) and in each of the three counties studied (b).

### 4.4. Knowledge of the farmer on nutrient requirements of Nile tilapia and level of farmers' training.

Fig. (16a) shows 35% of the farmers had been trained as opposed to 5% who did not have knowledge on nutrient requirements of Nile tilapia. This proportion of untrained farmers was only recorded in Bomet County. In addition, this group of farmers admitted to have had no training on fish farming and therefore used trial and error method in fish feed formulation. Those who had the moderate to high knowledge on nutrient requirements of Nile tilapia had attended training at least twice and therefore applied Pearson's method of fish feed formulation. This proportion accounts for more than 50% of all the farmers interviewed. Three quarters of these were farmers from Nakuru County (Fig. 16b).

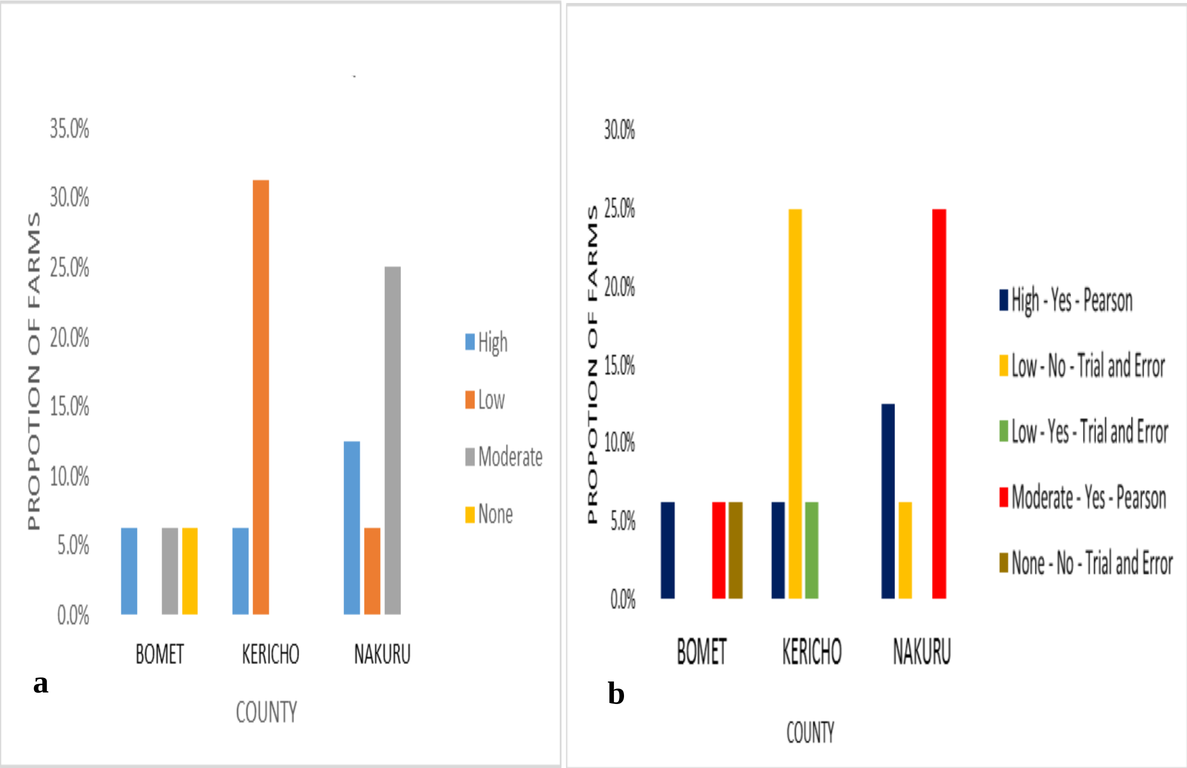



Figure 16: The response of farmers on knowledge on (a) fish nutrient requirements in relation to level of knowledge on fish farming practises and (b) shows farmers' knowledge on fish farming practises, in relation to training attendance and the feed formulation methods they use, in the three counties.

It was established that training of farmers on fish farming and farm management strategies is mainly conducted by the Department of Fisheries and aquaculture in the various counties. This is observed throughout the region covered by the study, which accounted for 60% of total farms visited (Fig. 17) who admitted to have been trained by government extension officers. Managers of farms owned by institutions however, were trained by the institutional staff. This was observed in the Egerton University fish farm.

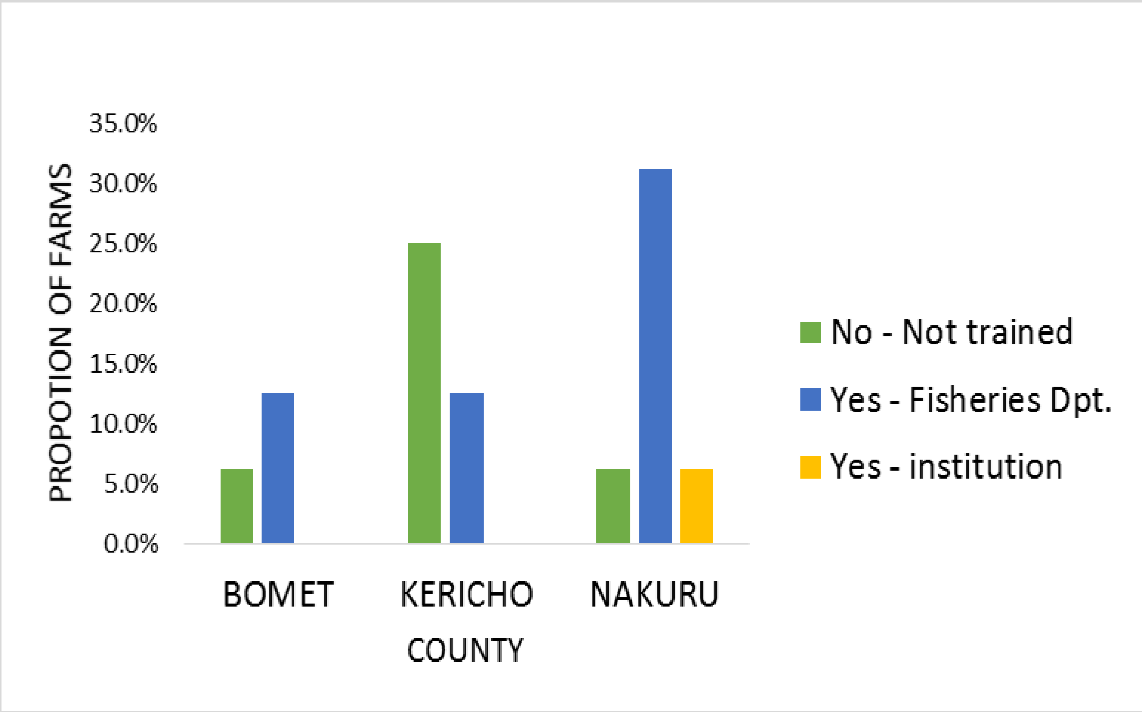
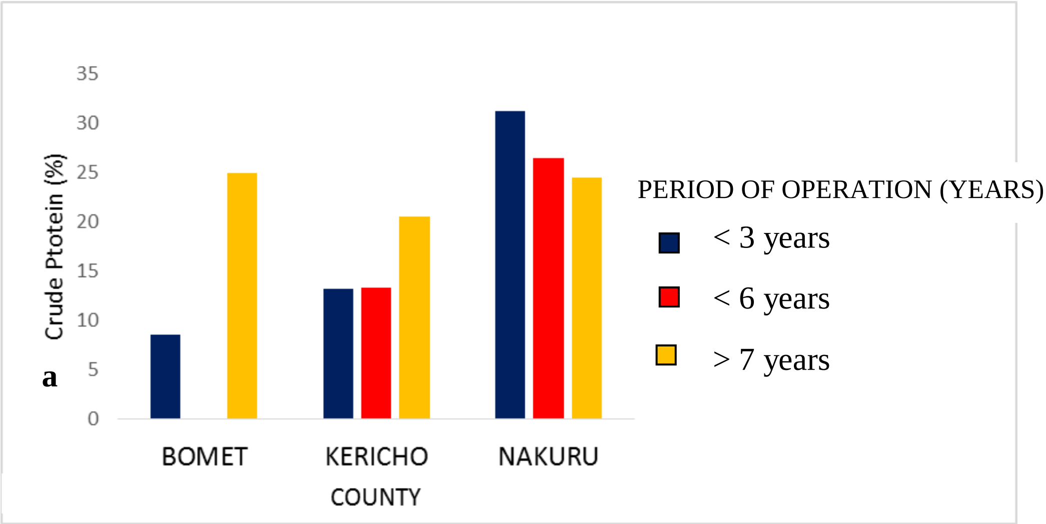



Figure 17: Graph showing attendance of training by the farmers and the responsible training providers in Bomet, Kericho and Nakuru Counties.

**4.5. Experience of farmer in the industry and training**

The period of experience of farmers was categorised into, less than 3 years, not exceeding 6 years, and more than 7 years. It emerged that 50% of the interviewed farmers had operated for less than 3 years and only 19% had experience of more than 7 years. In terms of feed quality, crude protein levels were considered and it was clear that 20% of farmers in Nakuru County who had operated for less than 3 years could attain a feed with 30% crude protein. Those with more than 7 years' experience in all the three counties could not formulate feeds with at least 30% crude protein, the required level for Nile tilapia (Fig. 18a).

Training of the farmers on the other hand had a lot of influence on the quality of fish feeds made by farmers. Fig. 18b shows that trained farmers had high knowledge levels in farm management practises and fish feed formulation and in turn, produced feeds with at least 25% crude protein .This is however less than the set standard level of 30% crude protein in Nile tilapia feed.



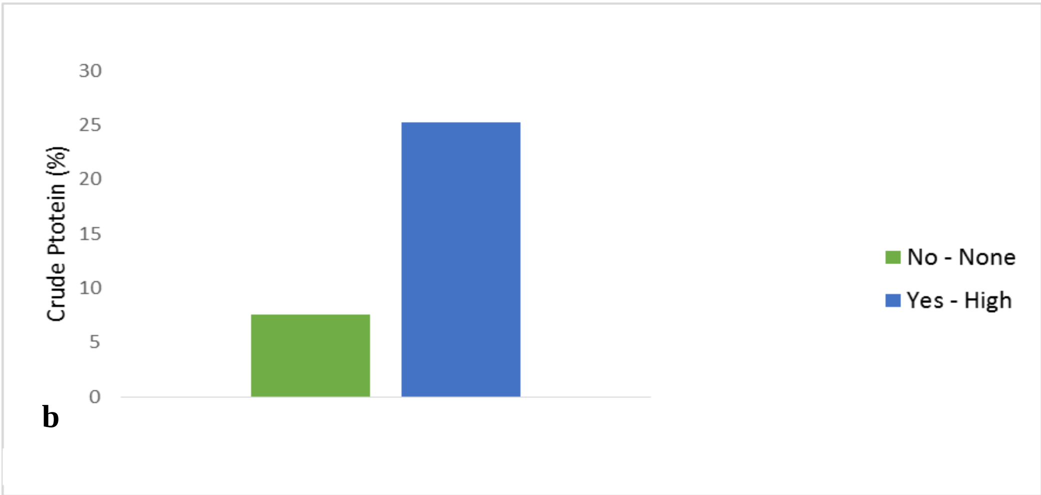




Figure 18: Bar graphs showing effects of (a) training and year of operation of the farmer on levels of crude protein in three counties, and (b) effects of farmers training and level of knowledge on crude protein levels in on-farm formulated fish feeds.

### 4.6. Feed management practises.

The two main feed storage containers were, gunny bags and plastic bags. Storage in plastic bags was observed in equal proportion 5% (Fig. 19) in the three counties. It also emerged that those farmers who stored their fish feeds in plastic bags did not have well-structured storage rooms, as the farmers placed the feeds directly on cement and earth floors. A large proportion of farmers however, stored the feeds in gunny bags and had raised wooden platforms in the storage rooms. This latter category accounted for 70% of farmers of which 10% were in Bomet, 25% in Kericho, and 35% in Nakuru County (Fig. 19).

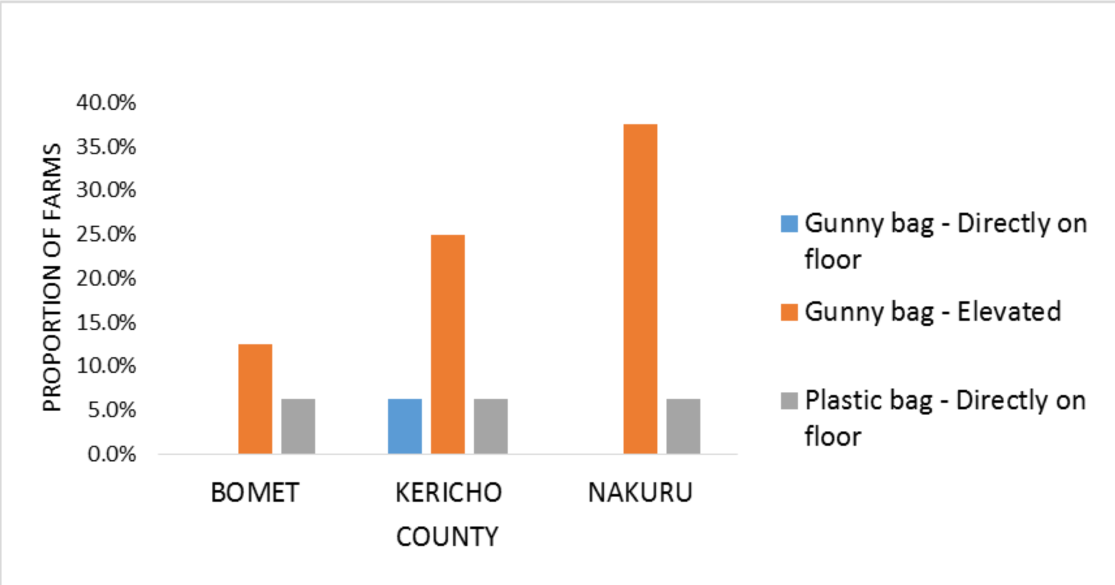



Figure 19: The response of farmers to fish feed storage in Bomet, Kericho and Nakuru counties.

### 4.7. Frequency of fish feeding.

On the number of times food was supplied to the fish, a high percentage of farmers fed their fish twice a day (65%) (Fig. 20). In Nakuru County however, all farmers fed their fish twice a day. However, in Kericho and Bomet 10% of farmers fed their fish twice a day, and 30% fed the fish only once in a day.

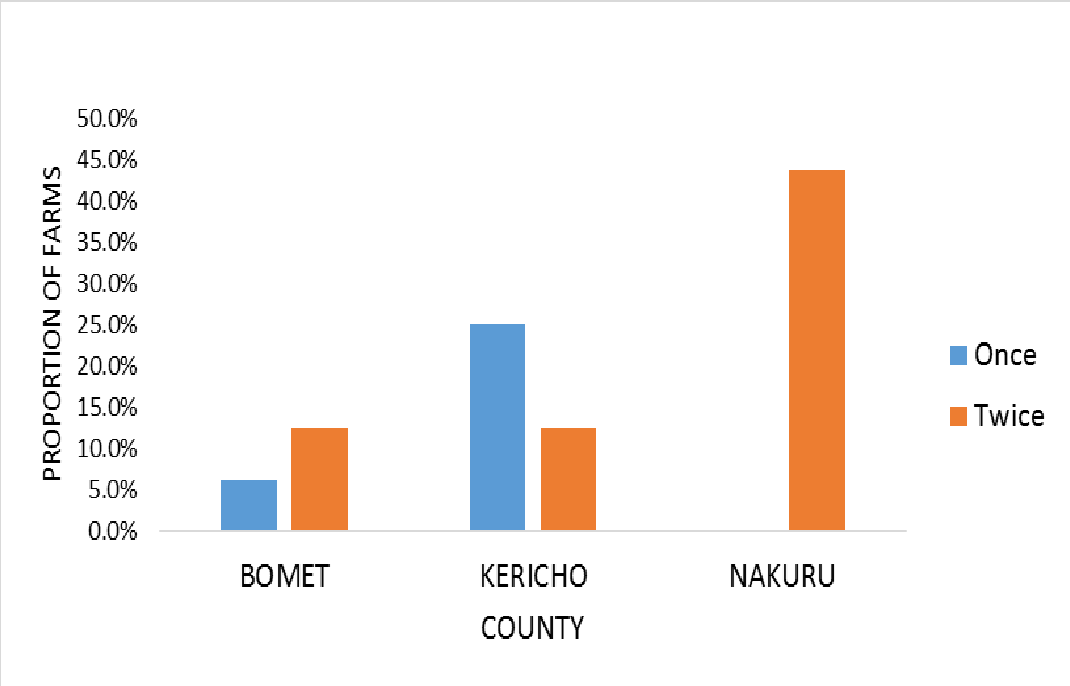



Figure 20: Fish feeding frequency in the counties of Nakuru, Kericho and Bomet.

**4.8. Physico-chemical parameters and pond characteristics.**

Selected pond water quality parameters were measured *in-situ* twice during the study period. Means of these parameters in the ponds from the three counties are summarised in table 8. The parameters were measured from three points of the pond, at an interval of 20 cm in the water column. Temperature, dissolved oxygen, and pH did not vary significantly widely across the three counties due to similar climatic conditions. Conductivity however showed a wide dispersion among the three counties. The mean conductivity levels in Nakuru County of 402.555 ± 377.23 (µs/cm) were significantly higher than the levels of 26.472 ± 25.15 (µs/cm) in Kericho County and 62.346 ± 37.20 (µs/cm) in Bomet County.

Table 7: The mean values of selected water physico-chemical parameters in the studies fish ponds.

| COUNTY | Temp. ($^0$C) | DO (Mg/l) | Cond. (µs/cm) | pH range |
|---|---|---|---|---|
| BOMET | 22.561± 4.08 | 5.518 ± 3.09 | 62.346 ± 37.20 | 6.232 - 8.47 |
| KERICHO | 22.143 ± 1.40 | 6.953 ± 2.72 | 26.472 ± 25.15 | 7.657- 7.96 |
| NAKURU | 23.102 ± 2.67 | 10.830 ± 4.13 | 402.555 ± 377.23 | 8.670- 10.09 |

The pond depths were measured at three points in each pond at shallow and deep ends and mean depth was then calculated. Length and width were measured and the area calculated based on the shape of the ponds which ranged from trapezium, rectangle, square or some triangle. The product of depth and area were used to estimate pond volume. Results showed that pond depth in the 18 ponds sampled ranged from 0.131 to 0.673 m. In terms of counties however, the mean depths ranged between 0.331 to 0.410 m with Nakuru County having the lowest (Fig. 21). This was explained in terms of sources of water. Nakuru County which relied on harvesting storm water and municipal tap water, had mean pond volume, which ranged from 100 to150 $m^3$. However, in Bomet county, mean pond volume was between 20 and 300 $m^3$ (Plate 1).

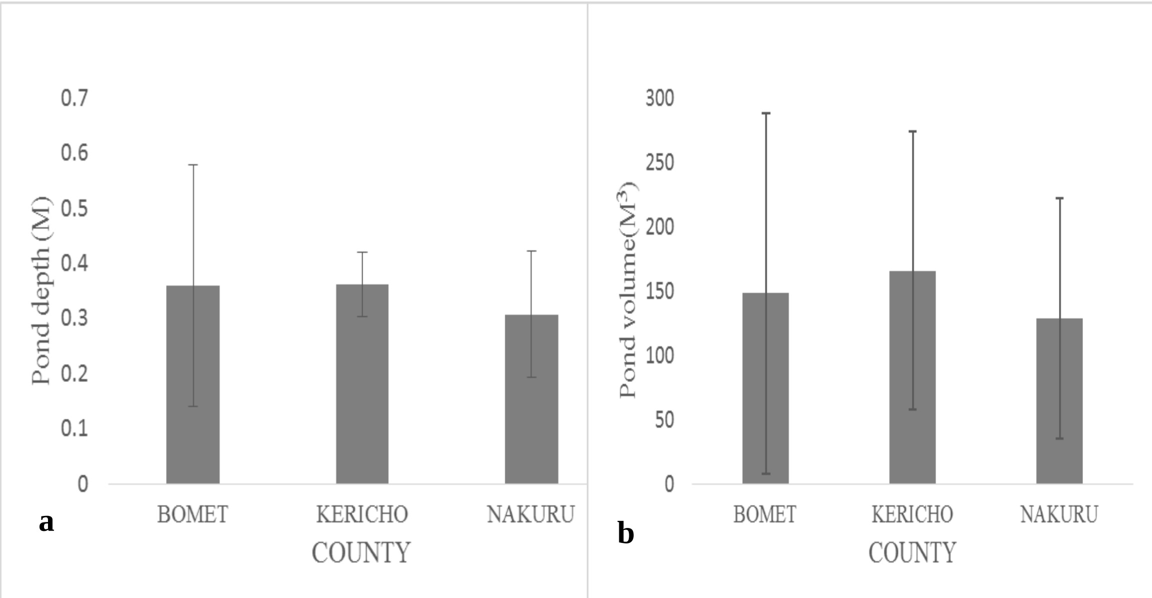



Figure 21: Bar graphs showing (a) mean depth (m) and (b) mean pond volume (m3) of sampled ponds taken during the study.

# CHAPTER FIVE

# DISCUSSION

## 5.1. Ingredients availability and use in on-farm feed formulations

Being a region where farmers practise cash crop farming, the three counties have high availability of maize and wheat bran, although their utilization in fish feeds faces competition from the need in production of livestock feeds (Lukuyu *et al.,* 2011). Furthermore, the quality of these brans and other ingredients are adulterated along the value chain (Liti *et al.,* 2005). This compromises the quality of the on-farm formulated feeds. Shrimp meal, fish meal, cotton seed cake and sunflower oil, are not locally available in this region. They are however widely used in the three counties studied because of their popularity in fish feed formulations, despite their high prices and dwindling availability (Gatlin *et al.,* 2007, Tacon and Metian, 2008). They are sourced from the neighbouring county of Kisumu.

It is notable from the survey that most of the commonly used ingredients like cassava, wheat and maize flour and fish meal are also consumed by humans and thus reduces availability and raises their costs. While vitamin and mineral premixes designed especially for fish feeds have been made, they are not used in any of the three counties. There is a tendency to utilize vitamin and mineral premixes and feeds designed for other species, like poultry and pig, for on-farm formulated fish feeds (Kassahun *et al.,* 2012). On the other hand it is evident that the use of ingredients from plants have gained popularity among on- farm formulated fish feeds in all the three counties. The farmers are shifting from animal sources like shrimps and fish meal, which are becoming less available. Instead, animal wastes such as abattoir wastes and chicken droppings are now being used more. Tacon and Metian (2008) emphasized that finding alternative protein sources to replace fishmeal in fish feed is important if the growth of the aquaculture industry is to be sustained.

It also emerged from the study that a majority of on-farm formulated fish feeds were in the form of mash, which led to high wastage of fish feed during feeding (Plate 2). Some commercial feeds for grow-out fish were also in this form, especially from Bomet County. However, the farmers who benefited from the pelletizing machines from county governments, produced pelleted feeds. Other farmers have resorted to use of meat mincer machines to produce fish pellets of different sizes. Use of correct size of feed pellets is essential for the utilization of the feed by the fish. In his research work, Jahan (2006) showed that wastage of feed was reduced by 90% when pellets were used for grow out Nile tilapia. It was noted that, production was also low when mash feeds were used instead of crumble or pelleted feeds. In addition, pelletizing fish feeds ensures all nutrients contained in a feed are available to fish wholesomely (Bhujel, 2013). Tacon and Metian (2008) also noted that fish uses most energy in feeding on mash as it spreads over a wide surface on the water. This could explain the low weights in fish and long periods of production cycles observed among farmers in this study.

## 5.2. Proximate composition of on-farm fish feeds and their effects on fish production and pond water quality

According to Craig and Helfrich (2009) all proximate compositions of fish feed are important and they affect growth and survival of the target fish species in specific ways. In the present study, the proximate compositions analysed included moisture, ash, crude protein, crude lipid, crude fibre, gross energy, Nitrogen Free Extract, and minerals (Magnesium (Mg), Calcium (Ca), Sodium (N), Iron (Fe), and Phosphorus (P)). Achieving optimal levels of these compositions required by fish is very critical as these requirements vary from species to species and for life stages of the fish (Boyd *et al.,* 2008). In this study, it was evident that the on-farm formulated feeds were not within the set standard levels of the various nutrients. Moisture content of more than 10% easily encourages microbial activities and activates spoilage process of the feed (El-Sayed, 2006). The shelf life of such feed therefore is shortened and the fish are put at a risk of consuming spoilage toxins especially in maize and wheat bran. Less than 10% moisture on the other hand, reduces binding effect of the feed leading to high wastage during feeding. The high levels of moisture (24%) analysed in some fish feeds was attributed to the fact that fish farmers did not adequately dry their ingredients thus stored them wet on earthen floors which encouraged dampening in them.

The study also revealed that values of crude protein and lipids for some of the analysed fish feeds, could not cater for Nile tilapia requirements. This included commercial cottage feeds, whose labels could not tally with the analysed value. In previous studies, Liti *et al.* (2005) associated the differences to marketing strategies, where manufacturers put labels that attract farmers to buy their products. This can also be as a result of nutrient distortion from heat and storage time, as these feeds take a long time to reach the farmer. Thus chemical alterations in proteins and lipids could occur during transportation (Lokuruka, 2016). In the on-farm formulations however, low values were associated with the use of similar single ingredients with low levels of proteins. For example a feed with a mixture of wheat bran and kitchen waste contained 7.4% crude protein while a feed with 53% crude protein contained, a mixture of shrimp meal and fish meal only. It is known that mixing ingredients containing all the required nutrients in the right amounts results in quality feeds (El-Sayed, 2006). Similar observations were made for lipid content in this study. A fairly high value of 21.4% crude lipid was achieved when avocado was mixed non-gravimetrically with shrimp meal and wheat bran. Huang *et al.* (1998) showed that high levels of fats in fish feeds results in fat deposition in fish muscle and thus compromises fish growth and eventually low quality of fish fillet and reduced shelf life. This was supported by the low fish weight observed (100g), when fish was fed with feed containing 24% lipids. This is also expensive as fish meal and shrimp meal attract high market prices and are not easily available throughout the year. However, the work by Chaves *et al.* (2014) demonstrated potential in the use of fruit meals like avocado in fish feeds. In their work, the formulated fish feed that contained avocado meal had higher lipids than the commercial feeds. The avocado meal feed proved to be cost effective and enhanced weight gain in fish more than the commercial feed.

The use of plant feeds could also have potential in fish feed industry. In this study, *Leucaena trichandra* contained 24.5% crude protein, 2.5% crude lipid, and 11.3% crude fibre. This showed that *L. trichandra* has potential to be used as a protein source ingredient, although, it has to be gravimetrically mixed with other ingredients to supply lipids and carbohydrates. The leaves can be treated by boiling, drying, grinding before mixing with other ingredients. This tree has proven successful as a livestock feed in Kenya and Uganda (Franzel *et al.*, 2014). Ngugi *et al.* (2017) established that 80% of fish meal could be replaced with amaranth leaf without causing negative effects on fish growth performance. The cost per gram of protein in these leaves is also low meaning it is a potential cost effective source of proteins for on-farm formulated fish feeds.

Poultry wastes on the other hand, have continued to gain popularity as fish feed among fish farmers. In this study, it emerged that poultry waste was a cheap fish feed ingredient which can be obtained easily from the farm, as most farmers keep poultry. Their use in fish farming as feeds and fertilizer, provides a sustainable way of disposal and thus helps in keeping the environment clean. Engel (1992) showed that investment returns increased by an average of

10% for fish produced using collected chicken waste compared to 5 % for fish produced with inorganic fertilizer. The wastes act as both fertilizer for primary production and are also directly consumed by fish. Crude protein content in poultry waste was found to be 18.8% and crude lipid was 12.3%. As a single ingredient poultry waste does not supply all the required nutrients therefore should be ground and mixed with other ingredients in the right ratios before use. Hasan (2013) however warned that extra precaution should be taken when using poultry waste as it spreads disease causing organisms like *Escherichia coli* and *salmonella* spp. Therefore, this ingredient should be thoroughly dried before being used in feed formulation.

On-farm formulations analysed in this study, did not contain required standards of all minerals analysed. This is due to the fact that mineral and vitamin premixes were not included in most of the formulations except for commercial feeds which did not also attain the required levels. Magnesium and calcium, which were notably low in the on-farm feeds are required by fish in skeletal development, in ionic exchange processes and in the functioning of enzymes as they act as precursors (Tacon and De Silva, 1997). On the other hand, iron, magnesium and phosphorus recorded higher values than the required standards in all the fish feeds formulated as these were contained in the ingredients used in high amounts. High levels of phosphorus in feeds lead to eutrophication of fish pond water. White (2013) showed that the feeds act as sources of nutrients which encourage excessive algal growth. However, Bhujel (2001) also demonstrated that excessive phosphorous in feeds does not enhance further growth in fish.

**5.3. Fish feed costs**

In this study, it was found that fish feeds containing locally available ingredients were cheaper than those containing ingredients not sourced locally. This agrees with Musiba *et al.* (2014) who established that locally sourced fish feed ingredients can be used cost effectively to produce fish feeds. This difference is due to the high transportation costs incurred in sourcing the ingredients from distant places. It can also be attributed to the fact that ingredients such as fish meal and shrimps have continually reduced in supply due to dwindling stocks in inland fisheries and the high competition faced as a result of the use of these ingredients in poultry and other animal feeds. Seasonality of ingredients such as *Rastrineobola argentea* or “Omena” also contributes to the high prices especially during low seasons. Kwikiriza *et al.* (2016) showed that some farmers spent a lot of resources on ingredients that only provide low levels of protein in fish feeds. This situation can be countered by using locally available ingredients which are of little or no costs, and which provide same or higher levels of proteins in fish feeds. *L. trichandra* leaves for example, which can be obtained at no cost are more cost effective to use than shrimp meal, although in terms of protein content, shrimps contain twice as much as *L. trichandra* leaves. The high costs incurred in fish feed formulations have been reported to contribute highly in the stagnation of aquaculture (FAO, 2015).

### 5.4. Fish farm management strategies in aquaculture

Proper management practises of fish farming, are of importance to aquaculture as they determine the level of production (Pillay, 1990). Management practises range from daily, weekly and yearly activities that enhance operations of a fish farm. Ngwili (2014) noted that the right experience, proper information and sufficient knowledge are the key pillars to proper management of fish farming. Inadequate outreach programmes and inefficiency in dissemination of technology transfer to farmers, has been shown to be the major reason for the slow development of the aquaculture sector (Kiptot, 2012; Shitote, 2012; Ngwili, 2014). In this study, more than 40 % of the farmers had no training on fish farming management. Similar results were reported by Shitote (2012), who recorded 95% of farmers in Western Kenya who faced challenges in managing their fish farms lacked training. These high percentages of untrained fish farmers have been attributed to challenges facing the organizations responsible for providing trainings in the aquaculture sector. From the results of this study, fish farming extension services are mainly provided by the government through the State department of Fisheries and Aquaculture, through collaboration with affiliate organizations. Apart from the State department of Fisheries and Aquaculture, Ngwili (2014) suggested that Non-Governmental Organizations, Radio stations and social media could be used to sufficiently disseminate practical information to farmers. These suggestions arose as a result of the major challenges facing extension services by the government. These challenges include low funding of the sub- sector, understaffing and lack of expertise by the extension service providers. These challenges were also echoed by Shitote (2012). On the other hand, lack of entrepreneurial skills among farmers, further amplifies this problem. The formation of farmers' cooperative societies in Bangladesh proved to be effective in developing entrepreneurial skills among farmers who share vital management information among themselves during meetings (Saha, 1985) and thus enhanced dissemination of information. The results of this study agree with the findings of Saha (1985).

In this study, there were more cooperative societies in Nakuru County, with more than 40% of trained farmers who used Pearson method in fish feed formulation, attaining at least 25% crude protein in their feeds. Halver (2002) emphasised that proper feed formulation is based on sufficient knowledge on specific nutritive requirements of the fish and knowledge on specific nutritive constituents of feed ingredients. Since fish farming is a scientific practise, the experience of the farmer alone cannot achieve proper skills, as shown in this study. Thus, proper aquaculture management can only be achieved through proper training of farmers coupled with on-farm demonstrations and formation of farmer cooperatives societies to enhance entrepreneurial skills.

### 5.5. Fish feed management strategies and their impacts on fish feed quality in aquaculture production

Fish feed represent the major production cost for fish farmers, and therefore great care is paramount in its handling and management. It was shown in this study that 15 % of the fish farmers stored fish feeds in plastic bags and buckets directly on the floors of their stores. Once the feed or feed ingredients are delivered to the farms they were either stored in feed storage areas in houses or near the ponds. Prior to use, the farmers often stored their feed for a week or even months, in large buckets at the pond or cage sites. Although these buckets are usually covered by lids, excessive heat can in some cases negatively affect the nutrient composition of the feeds (Bhujel, 2013). In this study, it was established that farmers using on-farm formulations, produced feeds just enough to be used for a day to two weeks while those using commercial feeds, bought them  in bulk during low price season to last for more than a month to keep costs down. Russo (2010) showed that storage of feed for more than two weeks leads to chemical deterioration of the feed. The deterioration is more when storage temperatures are above 27 $^{o}$C. Oxidation of lipids occurs in feeds under storage leading to rancidity of the feed therefore temperatures more than 20 $^{o}$C coupled with poor room ventilation should be avoided (Watabane, 1982). Some farmers applied fermentation of the on-farm feed so as to increase shelf-life of the feed, however, when feeds are not completely dry, high moisture content promotes rotting of the ingredients during storage. Fermentation has been found to increase the shelf- life of feeds but thorough drying of the feed after fermentation and grinding is highly recommended (Samaddar *et al.,* 2015).

## 5.6. Fish Feeding Frequency

The feeding frequency and amount of feed are important basic principles that must be known in fish rearing and should be performed regularly (Kaya, 2015). It was established in this study that although farmers lacked training in feed management practises, they often attempted to minimize costs. The study showed that 25% of the farmers fed the fish in the morning and only once a day. 75% of farmers on the other hand fed the fish twice a day in the morning and evening. These findings agree with those of Kiptot (2012) who found out that the shifting of farmers from feeding fish thrice a day to twice a day proved to be cost-effective.

Furthermore, recent work by Nguyen (2013) has shown that break feeding, (feeding fish after every two days) in fish farming is cost-effective, has less effects on water quality and enhances fish growth. However, Kaya (2015) argued that many factors can affect the feed utilization by fish including the amount of feed, feeding frequency, size of fish, water temperature, and feed quality. Therefore the low amount of feeds administered to fish by some farmers, feeding only once in a day by some farmers or low quality feeds prepared by some farmers, may explain the low mean weights of fish harvested and the long production cycle of one year being experienced by farmers in the three counties of Rift Valley region, studied.

It should be noted that excessive feeding leaves a lot of uneaten feed in the culture media, which on dissociation affects water quality negatively (White, 2013). Feed losses and poor water quality decrease the fish feed efficiency. In this study, feed ratio was not used by farmers during feeding. The fish feeds were not measured according to fish size and stocking density and therefore excess feeds were observed floating on the water surface (Plate 2) and some uneaten feed remains were observed on the pond bottom. It is suspected that the decomposition of the excess feeds lead to the low levels of dissolved oxygen (0.9 mg/l) measured and the high conductivity recorded.

# CHAPTER SIX

# CONCLUSIONS AND RECOMMENDATIONS

## 6.0. CONCLUSIONS

From the results of the study, it can be concluded that;

i. Majority of fish farmers use on-farm formulated fish feeds. However, proximate composition of these feed varied significantly with the required standards for Nile tilapia. Some of the commercial feeds used, although more costly than on-farm formulated feeds, do not meet nutrient requirements of Nile Tilapia, resulting to the long production cycles being experienced by farmers in the studied region.

ii. From the findings, it is concluded that on-farm feeds are more cost effective than commercial feeds or feeds made from ingredients not locally sourced. By using the on-farm formulated fish feeds, farmers are able to minimise costs of production. However, the majority of these feeds do not meet nutritional requirements of Nile tilapia as it was noted. This led farmers harvesting fish with low weights due to improper feed formulation and insufficient and excessive feeding.

iii. Fish farm management practises vary from farm to farm with a majority of farms being owned by individual farmers with only a few being owned by cooperatives. This has an effect on the ease of dissemination of information through training. It was found that training of farmers is mainly carried out by the State Department of Fisheries and Aquaculture and due to various challenges being faced by the department, a fair number of farmers in the region have not been trained sufficiently on fish farm management strategies.

## 6.1. RECOMMENDATIONS

The study therefore recommends;

i. Despite the on-farm feeds being cheaper than commercial feeds, it is recommended that the local ingredients are mixed gravimetrically, stored in gunny bags and correct feeding frequencies applied by farmers, so as to reduce feed wastage and thus achieve maximum production.

ii. The study recommends establishment of local fish feed manufacturing plants with qualified fish nutritionists to manufacture high quality feeds by county governments, at low costs to reduce the distance of transporting the feeds. This is expected to reduce cost of commercially made feeds and could supplement on-farm formulated feeds.

iii. Training of farmers on formation of farmers' cooperatives and SACCOS will help in enhancing their entrepreneurial skills. Other modes of information dissemination like radio, social media should be explored so as to expose farmers to vital information on fish farming, which currently is wanting. This has been applied in parts of Uganda with notable success. More research is recommended on the potential of more forage ingredients that prove cost -effective in Nile tilapia feeds, and at the same time, research is recommended for anti-nutritional aspects of most of these local ingredients that have now gained popularity as fish feeds. The national government on the other hand should consider increasing facilitation of extension work through more staffing and budget allocation for transportation and communication to farmers. Organizing and facilitating farmers to attend exhibitions, symposiums and trainings will help in disseminating new research findings to farmers especially on feed formulation methods and potential local ingredients that can be used in fish feed formulation.

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# PLATES

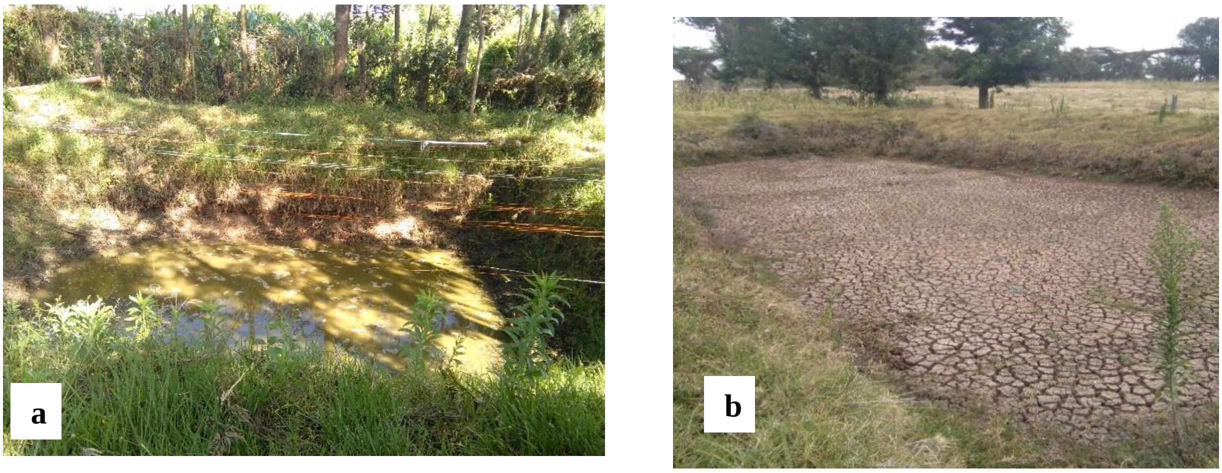



Plate 1: A photograph (a) showing water levels and pond design as observed in Bomet County, and (b) Nakuru County.

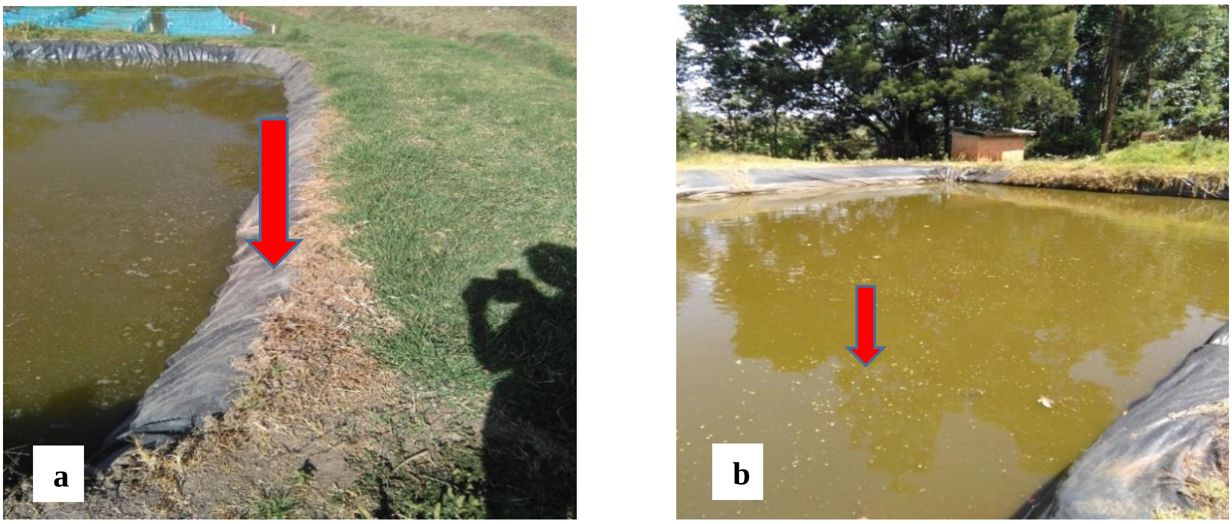
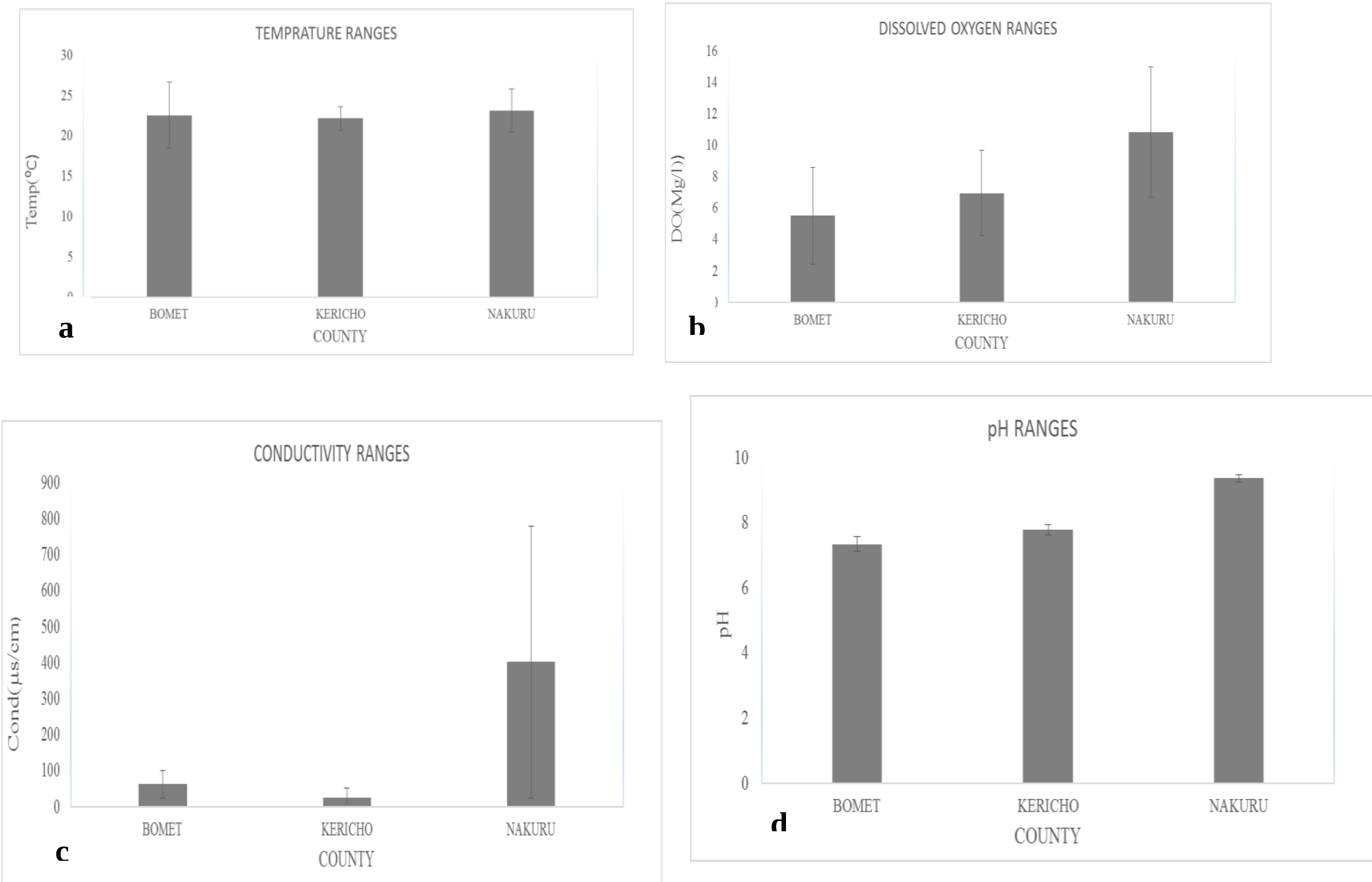



Plate 2: Photograph showing (a) spreading of mash fish feed, being wasted on the pond dykes and (b) shows excess uneaten feed floating on pond water.

# APPENDICES




APPENDIX 1: Bar graphs showing ranges of physico-chemical parameters taken *in-situ* during the study in Bomet, Kericho and Bomet counties. n=19

| | F | d.f( n-1) | P |
|---|---|---|---|
| Moisture | 54.431 | 18 | 1.572e-05*** |
| Ash | 30.11 | 18 | 0.0003287** |
| Crude lipid | 45.694 | 18 | 0.0003287** |
| Crude Protein | 54.972 | 18 | 1.293e-05*** |
| Crude fibre | 30.544 | 18 | 0.03248* |
| Magnesium | 36.855 | 18 | 0.005473** |
| Calcium | 47.497 | 18 | 0.0001788*** |
| Sodium | 53.565 | 18 | 2.144e-05*** |
| Iron | 48.386 | 18 | 0.0001319** |
| Phosphorous | 42.372 | 18 | 0.0009809** |

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

APPENDIX 2: One way ANOVA output for variances between the 18 samples feeds with the standard values of the proximate compositions and minerals.

| **FARM CODE** | **SUBLOCATION** | **CO-ORDINATES** | **COUNTY** |
|---|---|---|---|
| BOFA 1 | Kaplong | $0^{0}$ 47'7.01"S,$35^{0}$19'38.81"E | BOMET |
| BOFA 2 | Chesowen | $0^{0}$ 41'9.77"S,$35^{0}$18'52.75"E | BOMET |
| BOFA 3 | Chesowen | $0^{0}$ 41'12.32"S,$35^{0}$18'45.89"E | BOMET |
| KEFA 1 | Kipsaos | $0^{0}$ 17'31.98"S,$35^{0}$20'19.2"N | KERICHO |
| KEFA 2 | Kipsaos | $0^{0}$ 17'33.25"S,$35^{0}$23'18.2"N | KERICHO |
| KEFA 3 | Kapsoas | $0^{0}$ 17'12.8"S,$35^{0}$16'49.2"N | KERICHO |
| KEFA 4 | Kipsaos | $0^{0}$ 22'59.91"S $35^{0}$14' 44.84"E | KERICHO |
| KEFA 5 | Kipchebor | $0^{0}$ 18'14.20"S,$35^{0}$40'13.7"N | KERICHO |
| KEFA 6 | Kiptere | $0^{0}$ 22'19.82"S,$35^{0}$16'57.21"N | KERICHO |
| NAFA 1 | Bahati | $0^{0}$ 09'5.6"S,$36^{0}$08'15.7"E | NAKURU |
| NAFA 2 | Subukia | $0^{0}$ 0'8.08"S,$36^{0}$14'47.1"E | NAKURU |
| NAFA 3 | Njoro | $0^{0}$ 20'0.57"S,$35^{0}$56'36.97"E | NAKURU |
| NAFA 4 | Njoro | $0^{0}$ 22'14.9"S,$35^{0}$56'19.3"E | NAKURU |
| NAFA 5 | Piave Njoro | $0^{0}$ 26'0.02"S,$35^{0}$58'38.89"E | NAKURU |
| NAFA 6 | Njokerio | $0^{0}$ 24'0.9"S,$35^{0}$56'32.63"E | NAKURU |
| NAFA 7 | Karagita | $0^{0}$ 47'19.25"S,$36^{0}$25'49.7"E | NAKURU |
| NAFA 8 | Karagita | $0^{0}$ 46'0.76"S,$36^{0}$15'36.4"E | NAKURU |
| NAFA 9 | Njoro | $0^{0}$ 23'2.7"S,$35^{0}$55'23.7"E | NAKURU |

APPENDIX 3: A table showing fish farmer database and co-ordinate locations of the farms sampled in the study.