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# NUTRIENT CONTENT OF ON-FARM FORMULATED NILE TILAPIA (*Oreochromis niloticus*) FEEDS: IMPLICATIONS FOR THE AQUACULTURE INDUSTRY IN KENYA

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## ABSTRACT

Due to the high costs and the unavailability of good quality fish feeds in Kenya, farmers have opted to use cheaper, locally available on-farm formulated feeds. In spite of this, farmers continue to incur losses probably due to poor nutritive quality of these on-farm feeds. Furthermore, literature on the proximate composition and appropriateness of on-farm formulated feeds for raising farmed fish in Kenya is scanty. Motivated by these reasons, this study sought to investigate the proximate composition of on-farm formulated Nile tilapia feeds and selected commercial fish feeds used in Bomet, Kericho and Nakuru Counties of the Rift Valley Region of Kenya and compared the proximate composition with the official nutrient composition of fish feeds. The method of feed formulation used was also investigated using semi-structured questionnaires. The study also estimated the weight of fish harvested at the end of a production cycle. The results revealed a significant difference between the sampled feeds' moisture, crude protein and mineral contents and the legislated nutrient levels of the commercial feeds commonly used in the counties. There was also a significant difference between the crude protein content of feeds in the three counties ($P < 0.05$). More than 50% of respondent farmers in the three counties used Pearson Square Method for fish feed formulation, while the rest used the trial and error method. The mean weight of fish during harvest was 311.5±155.8 g with fish from Kericho County weighing significantly lower than those from Nakuru and Bomet Counties ($P < 0.05$). Most of the on-farm formulated feeds from the three counties do not meet the recommended nutrient requirements for raising Nile Tilapia. This may be contributing to the observed low weights of the fish harvested, the low fish production and the apparent stagnation of the aquaculture sub-sector in Kenya. The study recommends the formulation of good quality fish feeds through the use of proper methods and appropriate ingredients. This could be achieved through monthly farmers' trainings on best aquaculture practices.


**Key words:** On- farm formulated feeds, fish feed quality, Nutrients, Nile tilapia, Kenya

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## INTRODUCTION

The increasing world population has forced the global focus to shift to food security and sustainable strategies of food production. Aquaculture tops the list of strategies most governments are currently giving attention to, for food security. According to the Food and Agriculture Organization (FAO), the aquaculture sector has over the decades showed high potential to ensure food security, employment creation and growth of national economies, especially in developing countries [1]. The sector has also been recognised as one of the fastest-growing food production sectors in the world [1]. This is attributed to the increase in fish consumption and production. In 2013, fish contributed 16% of all animal protein consumed by humans globally [2].

The fisheries sector in Kenya contributes approximately 0.54% to the country's Gross Domestic Product. The total fishery and aquaculture production in 2016 amounted to 147,916 and 14,952 metric tons, respectively. The latter figure was, however, a decrease from 18,656 metric tons in 2015 for aquaculture [3]. Various initiatives have been undertaken to encourage fish farming and consumption as well as attracting investment in the sector. These ideas gained momentum in 2009-2010 through a government initiative dubbed as the Economic Stimulus Program (ESP) whose overall aim was economic development and poverty alleviation [4].

Despite the success stories, aquaculture in Kenya still faces challenges which have resulted in stagnation of the industry [4]. Some of the challenges are: lack of readily available and quality fish seed, inadequate good quality and affordable fish feeds, poor adoption of recommended fish husbandry techniques by some farmers and inadequate market information [5]. Poor quality and costly fish feed top the list of these challenges as widely reported by researchers and experienced by most fish farmers in the country. It has been reported that fish feed accounts for more than 40% of total fish production costs [6].

The small number of certified commercial fish feed producers in the country coupled with the increased fish feed demand result in inadequate feeds in the market. Additionally, feed producers are scattered all over the country and for this reason, farmers travel long distances to obtain the feeds, which eventually results in high costs of production [7].

To counter this problem, a majority of fish farmers have opted to use locally available ingredients to formulate feeds on-farm, in order to lower fish production costs. In spite of this effort, they are faced with the challenge of limited information on the quality of feeds they formulate. This challenge, therefore, necessitates the proximate analysis of on-farm formulated feeds to ensure that they meet the Kenyan commercial fish feed nutrient standards for Catfish and Nile tilapia fry, fingerlings, growers and brooders. This study, therefore, aimed at evaluating the proximate composition of the on-farm formulated feeds that are currently being used by small-scale farmers for raising tilapia, and compared the results with the Kenyan commercial fish feed nutrient contents for growing tilapia.

## MATERIALS AND METHODS

### Study Area

The study was carried out on purposively selected fish farms in Nakuru, Kericho and Bomet Counties of the Rift Valley region in Kenya (Fig. 1).

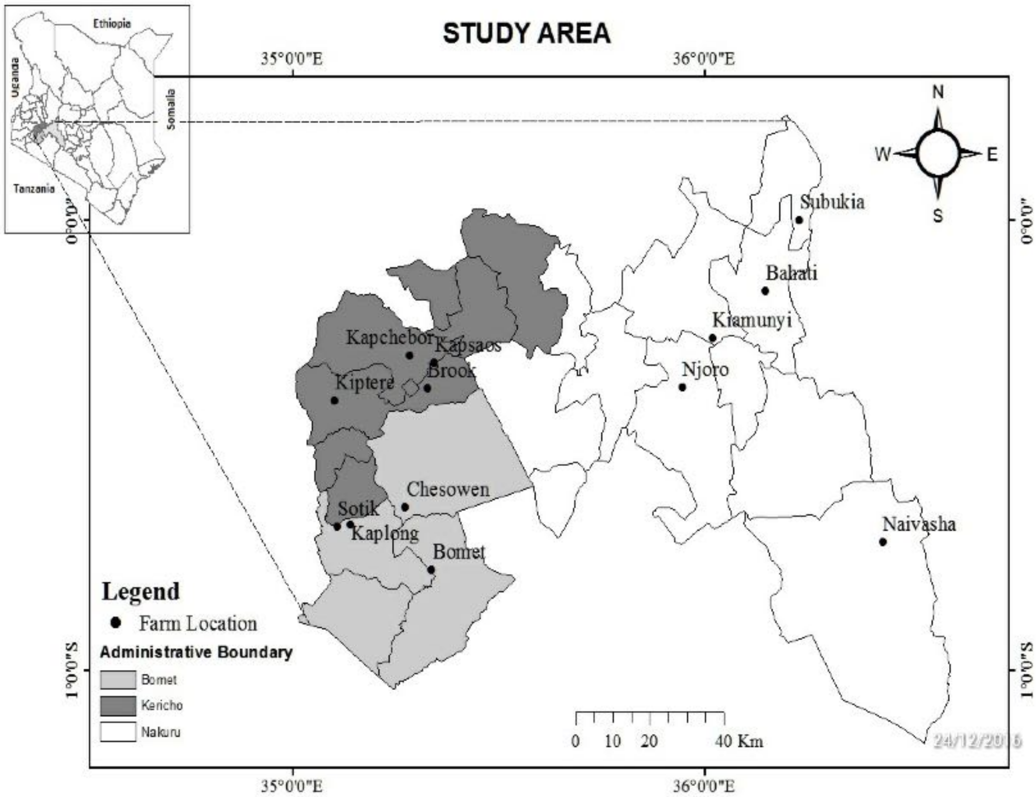


**Figure 1: Counties in the Rift Valley region of Kenya where the study was undertaken**

This region is of interest because originally it was known to produce cash crops on a large- scale basis, but in recent years, fish farming has become a point of attention [3]. This trend has been attributed to the need for farmers to increase farm production per unit area as land area for food production continues to decline [8]. The main crops cultivated in these counties include: maize, wheat, tea, vegetables and fruits [9]. These crops are important as far as local fish feed ingredients are concerned, making the region potentially suitable for sustainable and cost-effective aquaculture. Moreover, the temperature ranges of 10–28 $^{o}$C in this region is favourable for Nile Tilapia culture [10]. Fish production in the Rift Valley largely uses semi-intensive systems, with more than 3,000,000 m$^2$ of culture area established [4].

### Criteria of Farm Selection

Small-scale farms that raise Nile tilapia using semi-intensive pond culture systems were purposively selected from the three counties, based on: scale, where small-scale semi-intensive farms with at least one pond to the maximum of 4 ponds were selected. Secondly, location of the farm in relation to a major cosmopolitan town. The distance to major urban centres affects the availability and price of feed ingredients, as well as the potential for marketing the fish and the potential prices they can fetch. Most of the farms in the sample were less than 100 km from the capital town of each county. Finally, the type of fish feed used was identified. 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. Thirty-eight farms were selected randomly on the basis that they met the above criteria. Forty percent of these farms were sampled, giving a total of fifteen farms. One farm using commercial fish feed was picked from each county for comparison, making a total of eighteen, farms rearing Nile tilapia by the semi-intensive system of farming.

During the study, other aspects of the farms were recorded, including; source of feed ingredients and types of feeds used, weight of fish during harvest, method of feed formulation and knowledge of farmers on feed formulation methods. These were obtained using a semi-structured questionnaire, and personal visits to the farms.

**Proximate Analysis**
In the laboratory, formulated and commercial feed samples were sundried for a day at the prevailing mean air temperature (25±3 °C), finely ground then subjected to proximate analysis, according to the Association of Analytical Chemists (AOAC) Standard Methods [11].

The samples were stored at a constant room temperature of 20° C, to avoid nutrient losses. Moisture content was determined by drying 5 g of sample in an oven at 105 °C for 12 hours to constant weight. Ash content was determined by incineration of dried samples in a muffle furnace at 550 ºC for 12 hours until a constant weight was attained. Crude protein was analysed by the Kjeldahl method, using a Behroset (Labor-Technik GmbH, Germany) digestion apparatus and a Buchi K-355 distillation unit. The distillate was trapped in 4 % boric acid solution prior to titration with 0.1N HCl. Crude protein was estimated by multiplying the nitrogen content with a factor of 6.25. Crude lipid was analysed using 3 g of sample which was heated in a Soxhlet extractor with petroleum ether. Crude fibre was determined by boiling 1 g of sample in a standard solution of 3.13 % $H_2SO_4$ for 10 minutes. The boiled sample mixture was rinsed with hot water (20 mL) and boiled in 20 mL of 1.25 % NaOH for 10 minutes. Thereafter, the sample was rinsed with hot water followed by 10 mL of acetone. The residue was oven-dried at 60 °C for 4 hours, cooled in a desiccator and weighed. The dried residue was ashed at 550 °C in a muffle furnace overnight. Crude fibre was quantified by expressing the loss in weight after ashing as a percentage of the original dry weight of the sample. Sodium (Na), magnesium (Mg), phosphorous (P), iron (Fe) and calcium (Ca), were determined on digests of all collected samples using a Flame Atomic Absorption Spectrophotometer [12].

**Data Analysis**
One-way ANOVA test was performed to compare means in nutrient content of on-farm formulated feeds and commercial feeds against the official standards. Turkey Post-hoc test was performed to separate means that were significantly different. The tests were

conducted using R statistics, X 64 3.3.0 2016 version. Descriptive statistics were generated for feed management practices of the sampled farms, with confidence levels set at 0.05 where applicable.

## RESULTS AND DISCUSSION

Achieving optimal levels of all nutrients in a feed as required by fish is critical as the requirements vary from one fish species to another and for different life stages of the fish [13, 14]. Various locally available ingredients of plant and animal origin available for fish feed formulations were identified in the three counties during the study (Table 1).

### Moisture and ash contents

The lowest moisture content in all the feeds was 4% and the highest was 15% (Figure 2). There were significant differences in moisture and ash contents (Table 3) between the feeds and Official Standard Values. There was also a significant difference in moisture content between the feeds in the counties, where a post hoc test revealed a difference between feeds in Bomet County and the Standard ($P < 0.05$). (Table 2).

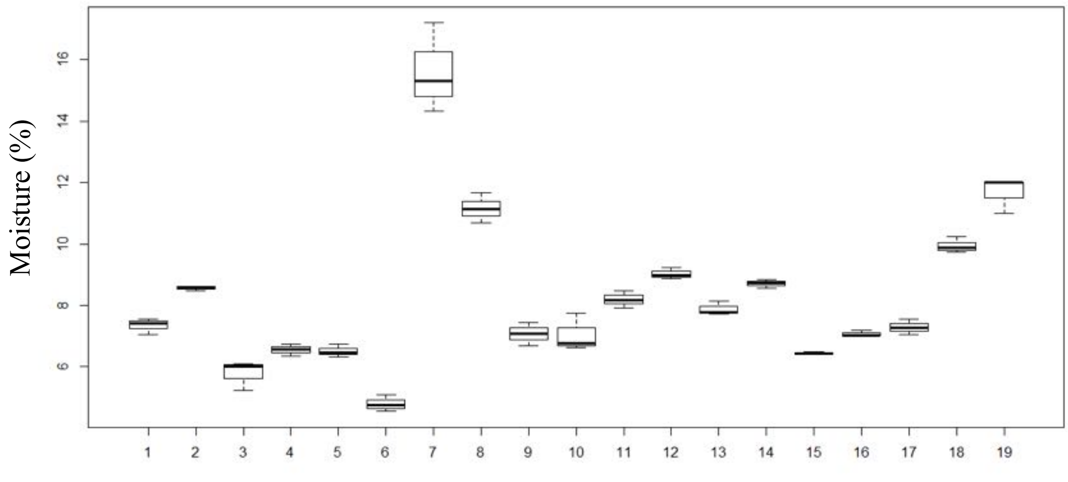


**Figure 2: Variations in moisture content of the 18 feeds and the standard value (Feed 19), commercial feeds (2, 7 and 14)**

Moisture content of more than 10 % tends to encourage microbial activities and activates spoilage of the feed [15]. The shelf life of such feed, therefore, is shortened and the fish are put at a risk of consuming spoilage toxins, such as aflatoxin that is likely to develop in the feed ingredients [16].

Moisture content of fish feed less than 10% on the other hand reduces the binding effect of the ingredients, leading to high wastage during feeding. The high levels of moisture content-(15 %) analysed in feed sample 7 from Bomet County could be due to the fact that fish farmers did not adequately dry their ingredients and stored on earthen floors, which encouraged dampening. Previous works have shown that moisture content in fish feed should be 10 ± 2 % [17]. This range helps in maintaining appropriate levels of other soluble nutrients like minerals and vitamins. This is achieved through proper drying of ingredients during formulation and later storing the feeds away from wet environments [17].

**Crude lipid and Crude protein contents**

Values of crude lipid varied from 1 % to 24 % (Fig.3). All these values varied significantly different among the on-farm formulations, commercial feeds and the Official Standards. There was, however, no significant difference in crude lipid contents among the major commercial feeds in the Counties and the Official Standards (Table 3). Adherence to quality standards of fish feeds by producers ensures acceptability of products by fish farmers and, thus, a high market base.

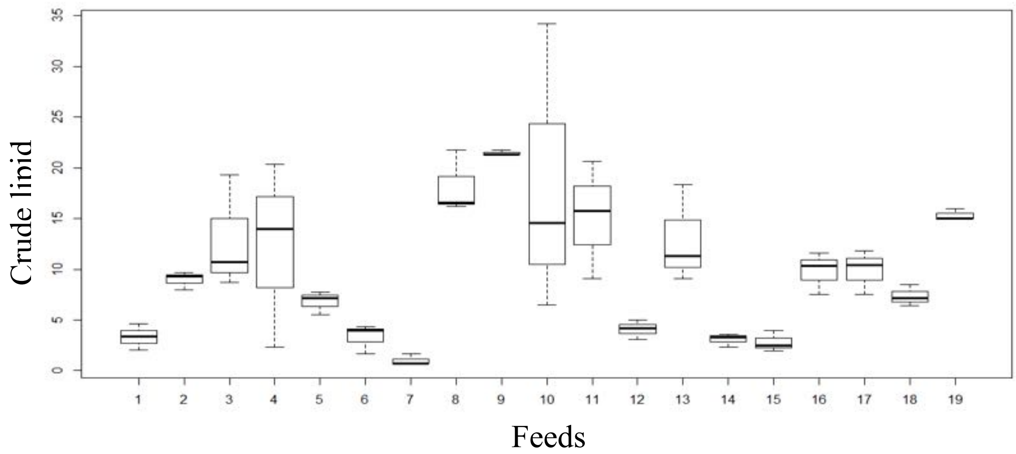


**Figure 3: Variations in Crude lipid contents of the feeds in the counties versus the standard value (Feed 19), commercial feeds (2, 7, and 14)**

Crude protein values on the other hand ranged from 8 % to 53 % in the on-farm made feeds. There were significant differences between the protein levels in the on-farm formulated feeds, commercial feeds and the standards ($p < 0.05$) (Table 3). Similarly, there were significant differences ($p < 0.05$) in crude protein levels among the sampled feeds and also between the official standard levels and feeds sampled (Figure. 4). Crude protein content in the fish feeds available in the three counties was generally lower than the Official Standard Value. There were significant differences between feeds made on-farm in Nakuru County and the other two counties of Bomet and Kericho. This could be associated with, among other reasons, high knowledge and farmer training observed in the County as compared to the other two. No significant differences were observed between crude protein levels of on-farm feeds in Bomet and Kericho Counties ($P > 0.05$) as farmers in both counties used similar ingredients in their formulations. On the contrary, on-farm fish feeds in Kericho and Bomet Counties showed a significant difference in crude protein levels with the Official Standard Value. There was, however, no significant difference between crude protein levels in feeds used in Nakuru County and the Standard Value. For this reason, fish grown in Nakuru County attained market weight in a shorter time compared to the Nile tilapia fish grown in the other two counties.

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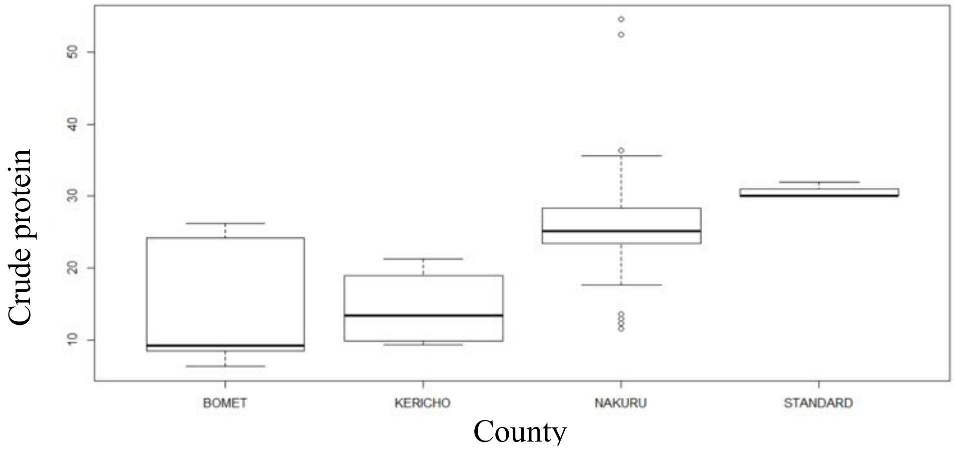


**Figure 4: Variations in crude protein content in the on-farm formulated feeds from the counties and the official standard values of crude protein**

The study revealed that values of crude protein and lipids for some of the analysed fish feeds could not cater for Nile tilapia at grow-out stage. Nile tilapia requires crude protein in the range of 30 %-45 % and crude lipids in the range of 5 % -18 % [15]. This range, however, is specific to the fish developmental stage [13]. This study focused on the grow-out stage.

Inconsistent values were also recorded for commercial feeds whose guaranteed values of the crude lipids and protein as on the packaging label were not consistent with the analysed value. Researchers have associated these differences with marketing strategies, where manufacturers cheat by using labels that attract farmers to buy their products [7]. This can also be as a result of nutrient distortion by heat over a long time in storage, in situations where feeds take more than one month to reach the farmer [18].

In the on-farm feed formulations, however, low values of crude protein were associated with the use of single ingredients containing low levels of proteins. For example, a feed with a mixture of wheat bran and kitchen waste contained 7.4 % crude protein compared to feed containing 53 % crude protein, as the latter consisted of a mixture of shrimp meal and fish meal. It is known that mixing ingredients containing all the required nutrients in the right proportions results in quality feeds in terms of balanced nutritional requirements [15].

Similar observations were made for fish feed lipid content. A fairly high value of 21.4 % crude lipid was achieved when avocado was mixed non-gravimetrically with shrimp meal and wheat bran. Such an undertaking involving lipids has been shown to be of no value as research has established that high levels of fats in fish feeds result in fat deposition in fish muscle. The deposition of lipid in fish muscle compromises fish growth, eventually resulting in low quality fish fillet with reduced shelf life [18, 19]. Feeds comprising shrimp and fish meal exclusively, would also be expensive as these are singularly expensive with shrimp being a premium food. However, the potential in the use of fruit meals like avocado in fish feeds, has been demonstrated [20]. The


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formulated fish feed that contained avocado meal had higher lipids than the commercial feeds. The avocado meal containing feed proved to be cost-effective and enhanced weight gain in fish more than the commercial feed [20]. In the context of this current work, however, avocado was used to feed fish as a single feed without physical formulation with other ingredients, thus compromising nutrient balance in the feed and resulting in the low fish weights.

The use of forage feeds could also have the potential in the fish feed industry. In this study, leaves of *Leucaena trichandra* which were used in on-farm fish feed formulations, were found to contain 24.5 % crude protein, 2.5 % crude lipid, and 11.3 % crude fibre. This showed that *L. trichandra* has a potential to be used as a protein source ingredient, although it has to be gravimetrically mixed with other ingredients to supply lipids and carbohydrates. This tree has proved successful as a livestock feed in Kenya and Uganda [21].

Earlier research has established that 80 % of fish meal could be replaced with *Amaranthus hybridus* leaves without causing negative effects on fish growth performance. The cost per gram of protein in these leaves (0.05 USD) is also low, implying that it is a potential cost-effective source of proteins for on-farm formulated feed [22].

Poultry wastes on the other hand have continued to gain popularity as fish feed ingredients 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 more than 80 % of farmers who participated in the study reared poultry. The use of poultry manure in fish farming provides a sustainable way of its disposal and, thus, also helps in keeping the environment clean. Investment returns increased by an average of 10 % for fish produced using collected chicken waste compared to 5 % for fish produced with inorganic fertilizer [23]. The wastes act as both fertilizer for primary production and are also directly consumed by Nile tilapia. In this study, crude protein content in poultry waste was found to be 18.8 %, and crude lipid 12.3 %.

As a single ingredient, poultry waste does not supply all the required nutrients, and, therefore, should be ground and mixed with other ingredients in the right ratios before use. This was, however, not the case with the farmers in the study, as all of them used poultry waste as single feed without mixing with other ingredients, which is a challenge for most Kenyan farmers. Studies have also recommended precaution be taken when using poultry waste as it spreads disease-causing organisms such as *Escherichia coli* and *Salmonella spp.* [24]. Further, unregulated use of poultry waste as fertilizer in aquatic systems could result in eutrophication of pond water [25]. This phenomenon was observed in all farms using poultry waste in this study. Therefore, this ingredient should be thoroughly dried and weighed accordingly before being used in feed formulation [24].

**Crude Fibre and Minerals**

Variations in crude fibre content, though not significant (Table 3) were observed in the sampled feeds in all the counties and also between the feeds and the required Standard Level. More than 80 % of the sampled feeds were found to contain significantly higher values than the Standard Value. Similar results were apparent in the feeds across the three counties and between the values in the feeds from the three counties and the Official Standard. The highest level of crude fibre was recorded 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 shrimp. Incidentally, the study established that fish from these farms had the lowest weights after production periods of over 12 months.

Results of the feed analysis also showed that all the minerals analysed in the feeds did not meet the legislated and desirable levels required in the feeds for raising Nile tilapia. Levels of sodium, phosphorus and calcium were considerably lower than the Official Standard Level (Table 4). However, the levels of iron and magnesium were higher than the Official Standard Values (Table 4).

The three commercial feeds did not also meet the standard levels of specific minerals. Significant differences in all mineral levels between the different analysed feeds were observed, as well as differences between mineral levels in the feeds and the Standard recommended levels ($P < 0.05$). Feeds from Nakuru County differed significantly in the mineral content with feeds from Bomet and Kericho Counties ($P < 0.05$).

The on-farm formulated feeds analysed in this study did not contain required standards of all minerals, probably due to the fact that mineral and vitamin premixes were not included in most of the formulations as for commercial feeds which did not also attain the required specific mineral levels. Magnesium and calcium, are required by fish in skeletal development, in ion exchange processes and in the functioning of enzymes as they act as precursors [26]. These elements were notably low in the on-farm feeds. On the other hand, higher values of iron, magnesium and phosphorus (in all the on-farm formulated feeds studied) were found to be above the levels required to grow Nile Tilapia. The analyses showed high levels of phosphorus in all the feeds. High content of phosphorus encourages excessive algal growth (eutrophication in pond water, which results in adverse negative effects on dissolved oxygen content at night [25]. Furthermore, it has been demonstrated that excessive phosphorus in feeds does not necessarily enhance further growth in fish [17].

**Implications of the On-farm Feeds Compositions on Kenya's Aquaculture Industry**

Being the most important nutrient content in the fish feed that highly affects growth of fish, crude protein levels have been used to estimate the quality of feed [26]. In the questionnaires, farmers provided the average weights of fish they harvested. Fig. 5 shows that the mean weight of fish during harvest was in the range of 150 - 550 g according to the farmers' records.

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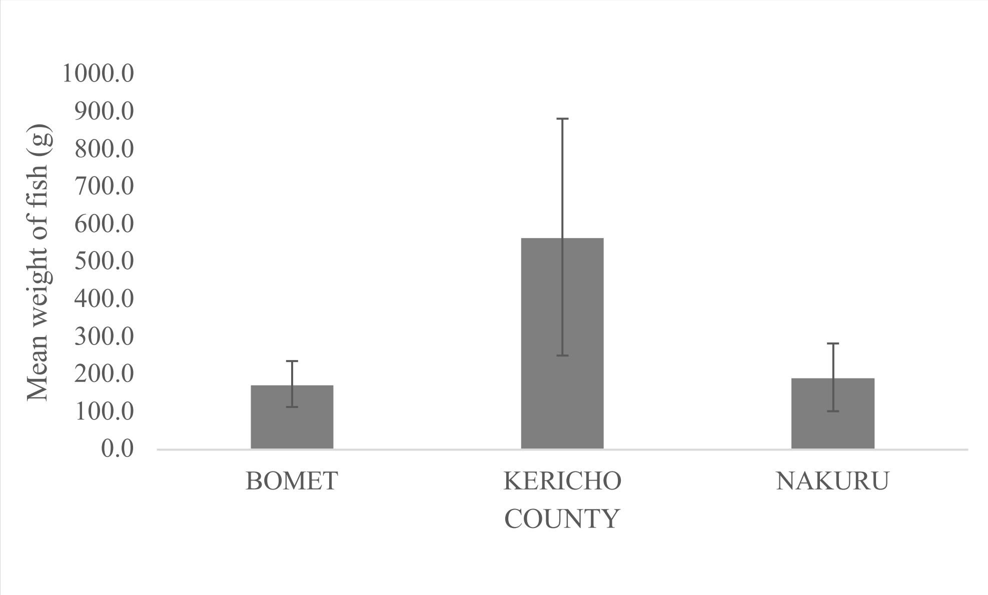


**Figure 5: Average weight (g) of fish harvested in the three counties**

The weight of fish at harvest was highly variable especially in Kericho County, with some farms recording fish weighing over 1 kg. From the survey, it was interesting to note that one farm in Nakuru County which recorded the highest crude protein levels of 53.15 % in the on-farm formulated feed, produced fish weighing only 100 g at harvest within a production cycle of 1 year. This is unlike the use of commercial feed in the same county with 27.47 % crude protein that resulted in heavier fish with a mean harvest weight of 250 g in the same period of one year. Previous studies have demonstrated that providing properly balanced ratios of protein to non-protein energy in diets could spare dietary protein from energy metabolism and increase its utilization for fish growth [13]. This may explain the low fish weights recorded from using feeds with high crude protein contents although other management practises such as feeding regime may also have contributed to the result. Nutritionally balanced feeds are a prerequisite to cost-effective fish production [27]. Availability of species-specific feeds that address the nutritional requirements of the different growth stages of fish is still a challenge for both commercial and farm-made feed production sectors [28].

The insufficient nutrient content in the on-farm formulated feeds as established in this study, has direct implications on fish growth. Despite the low prices of on-farm formulated feeds, they have been found to have fairly high (more than 3) figures of Feed Conversion Ratios [24]. In such a situation, it is not cost-effective as more feeds are used for a longer period. In the long run, the expenditure on feeds increases as opposed to the revenue from fish produced, making fish farming unprofitable to farmers.

More than half (55 %) of the farms visited used the Pearson's Square Method of fish feed formulation. The rest used trial and error methods in which the various ingredients were mixed without measuring their proportions unlike in the Pearson's Square Method. Pearson's Square Method was used across the three counties, at rates of 35, 10 and 5 % in Nakuru County, Bomet and Kericho counties, respectively. In addition, it was

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recorded from the study that farmers do not use feed charts to ascertain amounts of feed to be administered during feeding, resulting in excess unused feed which tends to settle at the pond bottoms. This compromises water quality parameters such as reducing dissolved oxygen concentration. Such situations may result in depressed fish growth, sometimes mass fish kills and eventually financial losses to the farmer.

These findings together with some other factors, render the aquaculture practice in Kenya expensive, unsustainable and, therefore, the observed stagnation in the growth of the sector. It, therefore, follows that quality of fish feed has a direct impact on the fish farming sector and hence the need to invest resources and establish policies so as to improve the sector and ensure its sustainability [27].

## CONCLUSION

The majority of fish farmers in the study used on-farm formulated fish feeds for raising Nile Tilapia. The proximate composition of these feeds varied significantly from the Official Standard nutrient values resulting in low fish production and long production cycles.

Low fish weights were associated with the unbalanced nutrient ratios in the formulated feeds and in some cases, insufficient feeding. Improper fish feed formulation methods and feed storage appear to contribute to the poor quality of on-farm formulated feeds. These findings may partly explain the reported stagnation in the growth of Kenya's aquaculture sector.

The study recommends that both national and local governments put more efforts in ensuring farmers formulate quality feeds. The National level of Government should shoulder the responsibility for quality assurance and standardization of fish feeds coupled with regular farmers training on feed formulation and handling. On the other hand, farmers should be advised to avoid the use of single ingredients as fish feeds. Gravimetric mixing of feed ingredients should be taken into consideration by farmers during feed formulation. For a wider and deeper view of the status of the sector, similar studies should be conducted in other areas of Kenya.

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**Table 1: Major ingredients and finished feeds used as farm-made fish feeds**

| INGREDIENTS | BOMET | KERICHO | NAKURU |
|---|---|---|---|
| **MIXED** | | | |
| Kitchen wastes | ++ | + | + |
| **PLANT-BASED INGREDIENTS** | | | |
| 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 leaves | - | - | ++ |
| Grass | + | + | - |
| Molasses | + | - | - |
| **ANIMAL-BASED INGREDIENTS** | | | |
| 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)

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**Table 2: 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 '*'

**Table 3: One way ANOVA output for variances between the 18 samples feeds and the Standard values of the proximate compositions and minerals**

| | F | d.f | P |
|---|---|---|---|
| Moisture | 54.431 | 18 | 1.572e-05*** |
| Ash | 30.11 | 18 | 0.0003** |
| Crude lipid | 45.694 | 18 | 0.0003** |
| Crude Protein | 54.972 | 18 | 1.293e-05*** |
| Crude fibre | 30.544 | 18 | 0.03* |
| Magnesium | 36.855 | 18 | 0.005** |
| Calcium | 47.497 | 18 | 0.0002*** |
| Sodium | 53.565 | 18 | 2.144e-05*** |
| Iron | 48.386 | 18 | 0.0001** |
| Phosphorous | 42.372 | 18 | 0.001** |

Notes: *Signif. codes: 0 '***' 0.001 '**' 0.01 '*'

**Table 4: Tukey's post hoc output for differences between mineral contents 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 | 0.001*** |
| Nakuru-Kericho | 0.775 | 0.481 | 0.351 | 0.570 | 0.000*** |
| Standard-Bomet | 0.000*** | 0.000*** | 0.000*** | 0.258 | 0.000*** |
| Standard-Kericho | 0.000*** | 0.000*** | 0.000*** | 0.279 | 0.000*** |
| Standard-Nakuru | 0.000*** | 0.000*** | 0.000*** | 0.071 | 0.071 |

Notes: *Signif. codes: 0 '***' 0.001 '**' 0.01 '*'

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