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# FEED FORMULATION AND FEED QUALITY ASSESSMENT FOR TILAPIA FARMING IN SAINT LUCIA

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## ABSTRACT

Feed costs contribute the most to operational costs in aquaculture production. The nutrient input and utilization need to be balanced, especially proteins, because it contributes the highest cost in aquafeeds. Key constraints to aquaculture development in Saint Lucia are the poor quality and limited availability of supplementary feeds. Where commercial feeds are available, they are often prohibitively expensive. The alternative for farmers is to make their own feeds. However, the limited availability of ingredients, lack of information on fish nutrition and on how to make and deliver feeds often results in poor quality feed and reduced production and profitability. This study was conducted to assess the current feed being used by aquaculture farmers and to formulate a fish feed that could be used as a possible alternative. Samples of the current pellet feed being used by aquaculture farmers were analysed for level of crude protein, crude lipid, ash, and dry matter. The results indicated that feed was below protein and lipid requirements for optimal tilapia growth. An experimental diet for tilapia (*Oreochromis niloticus)* was then formulated using an online diet formulator. The diet prepared contained 33.57% crude protein. Tilapia (450 g) were fed between 7-10 days using experimental feed. Faeces were then collected from the fishes. Digestibility of protein, lipid, ash and dry matter was estimated at the end of the feeding period using an inert marker. The results of the digestibility studies show the protein digestibility rather low and probably affected by relatively high level of plant protein in the feed. The results of the digestibility studies show the protein digestibility is not very high and probably affected by relatively high levels of plant protein in the feed.

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# 1 INTRODUCTION

## 1.1 Background

Saint Lucia is a Caribbean island bordered by the Caribbean Sea on the West and the Atlantic Ocean on the East, as seen in Figure 1, with land area of 638 km² and a population of 182,000 (FAO, 2016). Saint Lucia lies in the path of the north-eastern trade winds and has a tropical maritime climate suitable for freshwater aquaculture. The temperature varies very little throughout the year with the annual mean monthly temperature ranging between 26°C and 28°C.


Figure 1. Location of Saint Lucia in the Caribbean

Traditionally the main economy of the island has been agriculture. It was known for its thriving agriculture sector and banana industry. However, in recent times the focus has shifted to tourism, placing an increased demand for seafood. This has now raised the need for tilapia production, which is currently being cultured by aquaculture farmers around the island. Aquaculture is now seen as a valuable component of a thrust to diversify agriculture in the country. The fishery in Saint Lucia is still quite artisanal in nature. The main species being caught include dolphin fish, wahoo, king fish, tuna and various reef fishes. As a supplement to marine caught species, tilapia culture is currently actively promoted by the Department of Fisheries Saint Lucia.

## 1.2 Rationale

The Silver tilapia (*Oreochromis niloticus),* Red tilapia (*Oreochromis mossambicus*) and freshwater prawn (*Macrobrachium rosenbergi*) are the primary aquaculture species produced in Saint Lucia. They are mainly cultured in earthen ponds and concrete or plastic tanks. Fish farming in Saint Lucia is semi-intensive and practiced in mono-sex culture (all male species) for tilapia. The main water sources are rivers, natural springs and rainwater harvesting. With support from the government of Saint Lucia, the Fisheries Department is actively seeking to facilitate improved communication and interaction among aquaculture producers and the aquaculture community. To support that effort, an Aquaculture unit was established under the

Fisheries Department of the Ministry of Agriculture. The government also operates hatcheries which produce seed to stock aquaculture facilities in Saint Lucia.

One mission of the Department of Fisheries is to foster in-land aquaculture that creates employment and business opportunities in communities across the island. Another objective is to provide a safe and sustainable way of acquiring seafood and improving family diets. Fisheries officers have been trained to provide technical assistance to aquaculture farmers throughout the duration of the production cycle, from stocking to harvesting. Technical assistance also includes consultation on feed formulation and regular sampling of ponds and tanks using nets to monitor stocking density and growth.

In Saint Lucia there is need to improve the sustainability and profitability of the aquaculture sector. One way to help improve the sector is to work towards overcoming the challenges associated with poor quality fish feed. There is currently no collaboration between feed producers and the contribution from the government of Saint Lucia, which is needed in order to work together to formulate more viable feeds that farmers can use to potentially increase their production.

Currently there are 80 aquaculture facilities registered by the Department of Fisheries with pond sizes ranging from 500 $m^2$ to 9000 $m^2$ (DOF, 2016). These facilities include five schools, eight aquaponics facilities and two government hatcheries which are operated by the Ministry of Agriculture. In a bid to help improve the aquaculture sector in Saint Lucia, the Taiwanese government donated an aquaculture hatchery facility in 2010, where they lent their expertise and technical support, working alongside fisheries extension officers until 2016 (Edmund, 2011). Hatchery production of tilapia fingerlings (Table 1) distributed to farmers is recorded by the fisheries data unit.

Table 1. Fingerling production from tilapia hatchery in Saint Lucia (Fisheries Department 2012 - 2015)

| **Year** | **No. of Tilapia fingerlings** | **Area Under production ($m^2$)** | **Production (kg)** |
|---|---|---|---|
| 2012 | 60,000 | 48462 | 7,000 |
| 2013 | 85,820 | 56656 | 11,000 |
| 2014 | 80,000 | 61917 | 8,401 |
| 2015 | 84,000 | 72682 | 15,273 |

Most aquaculture facilities in Saint Lucia are not specific to the production of any one species and ponds are generally stocked with either tilapia or shrimp or in some cases may be stocked with both in polyculture. Aquaculture facilities are usually stocked with juvenile fish according to the capacity of their facility. The average stocking density in a pond is one to two fish per square meter. The expected survival rate in a pond is 90% of the total number of fish stocked, under normal conditions (Ajiboye *et al.* 2015). At the beginning of a production cycle, farmers are given seed providing that all necessary requirements are met. These include emptying ponds of previous stock, desilting ponds if necessary, removing foreign objects such as debris or weeds and having adequate water to start up a new production cycle.

The aquaculture sector in Saint Lucia is faced with many challenges despite support from the Department of Fisheries Extension Unit and members of the Taiwanese Technical Mission. Some of the problems faced by farmers include:

- Poor quality or inadequate feed
- Access to finance for equipment and maintenance of facilities.
- Pond management
- Marketing of product
- Limited access to education and training
- Predation
- Effects from climatic conditions e.g. hurricanes, droughts
- Theft of aquaculture produce and equipment

The average aquaculture farmer in Saint Lucia is subjected to at least one, if not all the challenges highlighted. However, this research will focus on the most common challenge which is poor feed quality. This challenge includes not only to the poor quality of local fish feed, but access to commercial feed which is costly for the average aquaculture farmer.

### 1.3 Research objectives

The main goal of this project is to formulate a fish feed that feed manufactures can consider and could serve as an alternative for aquaculture farmers in Saint. Lucia.

Specific objectives are:

- To test and analyse the current pelleted fish feed used by aquaculture producers and determine its nutritional quality.
- To explore the possible local ingredients, try to recognize their chemical composition and to formulate nutritionally balanced fish feed that could be used by aquaculture farmers in Saint Lucia.

## 2 LITERATURE REVIEW

### 2.1 Growth of tilapia in pond culture

Several factors affect the growth rate of tilapia and it is important to take all these factors into consideration. The growth rate will for instance be affected by water quality, temperature, oxygen levels and the general health of the fish. The type of food provided to them with and in which quantities will naturally also be of imperative importance. Optimal stocking density is also important for growth rate of cultured fish. The recommended stocking density for tilapia is three fish per square meter, however, in Saint Lucia the tilapia stocking rate is one tilapia fingerling per square meter (Sung, 2014). This is because most ponds are not equipped with aerators to increase oxygen in the water.

Fish are sensitive to water quality. Feeding should be reduced or stopped if water quality falls below certain levels. Dissolved oxygen levels should be maintained above 5.0 ppm for best growth. Shortly after feeding, dissolved oxygen levels decline rapidly. At dissolved oxygen levels between 3.0–5.0 ppm feeding should be reduced, and feeding should be stopped at dissolved oxygen levels below 3.0 ppm (Riche, 2003).

Tilapia do not feed or grow at water temperatures below 15°C and do not spawn at temperatures below 20°C. The normal water temperature should be 20-30°C, preferably about 28°C, which is considered the ideal temperature for good health and growth. At higher temperatures their metabolic rate rises, leading, in extreme cases, to death.

In Saint Lucia, tilapia take 6-7 months to grow from time of stocking fingerling size fish of 5-10g to reach 450g which is the demand or required marketable size (Sung, 2014). Tilapia will only grow and reach marketable sizes when they are kept in optimal conditions and fed a nutritionally complete diet. Their success depends on good feed quality, accuracy and maintenance of good farm management practices.

Feed Conversion Ratio (FCR) is a major indicator of feed efficiency in tilapia production. The feed conversion ratio is informative on the feed utilization by the fish. It can provide a good indication of the efficiency of a feed or a feeding strategy. In other words, the FCR is the mathematical relationship between the input of the feed that has been fed and the weight gain of a population. The lower the FCR, the higher the weight gain obtained from the feed (Aqua Techna, 2004). In the context of aquaculture, the FCR is calculated as follows:

$$FCR = Feed\ given\ (g)\ /\ weight\ gain\ (g)$$

The information required for calculation of FCR include:

**Population or sample:** should a farmer weigh his entire animal population or just a sample of it? If it is the whole population, the problem is solved. That might be practical in fry and fingerling production. Otherwise, the farmer needs to know the exact number of individuals making up that population. The number (and weight) of mortalities must be registered during the period. Estimation of the biomass increase is needed for calculating the FCR and therefore a reliable average weight of the initial and final fish weight is needed. The farmer must ensure that the chosen sample is representative of that population.

**Mortality rate:** all mortalities occurring between the date of initial weighing and the date of final weighing are to be deducted from the final biomass. Therefore, their effect on the FCR is negative. Their impact is significant if death occurs late. Accurate inspection and registration of mortalities can be difficult in ponds.

**Amount of feed distributed:** provided that a daily register of feed weight given is held at the farm, this information is usually easy to obtain.

**Actual consumption of feed**: from the initial amount of distributed feed, the actual consumption of feed is calculated. This information can be difficult to obtain but is common in feed experiments. Specific feed traps are modified to the experimental tanks and effluent feed weight estimated by counting and/or weighing pellets. This gives a quality estimate for the feed and a guideline for the practical feeding in bigger culture systems, like in ponds for instance.

In addition to the feed consumption and utilization, the FCR is affected by the energy content of the feed. One can expect lower FCR in high energy feed and feed with high dry matter content, presuming the nutritional requirement of the species is fulfilled.

### 2.2 Feeding of tilapia

To avoid over or under feeding the fish, the right amount of feed must be given each time. The amount of feed provided to the fish per day, the feeding rate (ration), is dependent on the weight of the fish and the water temperature, both influencing the growth rate. Fish adjust their food consumption rates to meet their metabolic energy requirements. Therefore, the required ration varies with time during the production cycle depending on the fish size (i.e. average weight of the fish), the pond water quality notably in terms of water temperature, dissolved oxygen and pH levels (Isyagi & Daniels, 2009).

The feed intake affects the efficiency of feed utilisation by the fish, so it is important to establish the optimal frequency of feeding to attain the best possible weight and uniform sizes of fish. The feeding frequency is the number of times fishes are fed in a day. For optimum growth and feed conversion, each feeding should be about 1% of body weight or feeding to satiation. Therefore, visual inspection or feeding by hand may give best feed utilization. In tilapia grow-out ponds, feeding 2 or 3 times a day is adequate but smaller fish should be fed more frequently. Proper feeding frequencies reduce starvation, stress and hierarchy and will result into more uniform sizes of fish (Isyagi & Daniels, 2009). It is best to always feed the fish around the same time and in the same part of the pond preferably in the early morning before sun rise and in the evening, when oxygen level is higher. Most oxygen depletions occur in warm weather, usually June-September. Warm water holds less oxygen than cool water. In addition, fish experience a faster metabolic rate as water temperature increases, therefore their requirement for oxygen increases. As a result, more oxygen is needed by the fish during a season when less is available. The fish are therefore more likely to become stressed during the warmer months (Higginbotham, 1997).

Tilapia diet differ depending on their life stage (Keong & Romano, 2012). Feeding rations should be adjusted either weekly or fortnightly depending on the fish's size. Smaller fish have a much higher metabolic rate and grow at a much faster rates, so their rations need to be adjusted more frequently (preferably weekly). Feeding rations can be adjusted with the aid of feeding charts and occasional sampling (at least monthly) to ascertain actual fish sizes and growth rates. The specific growth rates (%SGR) is an estimate of average weight increase during a period. It is calculated as follows:

$$\%SGR = 100^* (\ln w_2 - \ln w_1) / (t_2 - t_1)$$

where $w_2$ is the final weight, $w_1$ is the initial weight, $t_2$-$t_1$ is the period of time between final and initial sampling weight. At sampling, adjust the ration based on the growth rate of the fish obtained.

Best performance results from fish feed is not dependent on pellet quality alone. Better results are obtained when fish are fed correctly ensuring all fishes have access to the feed. To avoid overfeeding, one must follow the feed intake of fish and learn to know when they are satisfied. Feeding in excess will be a waste of feed and will spoil the water quality. Feeding fish correctly means:

- giving feed of the correct nutritional composition and quality for the specified age of fish,
- feeding the right feed size for easy consumption,
- feeding the correct amounts,
- feeding by response and at the right time(s) each day.

When fish are fed correctly, growth rates are good and uniform across the population, feed conversion ratios (FCRs) are low and pond water quality is better managed.

### 2.3 Nutritional Requirements of Tilapia

One of the most important aspects in aquaculture is the nutritional requirement of the species. When fish is cultured in a system where natural food is absent such as in a fish tank, or where natural foods make only a small contribution to the nutrition of the fish, as an in intensively stocked tilapia pond, the feed supplied should be nutritionally complete. This means that low-cost tilapia feed that is formulated using locally available ingredients should be nutritionally comparable with good quality commercial tilapia feed to maintain productivity (World Fish Center, 2009). For optimum development and growth of organisms, it is essential to provide them with all the necessary nutrients, in terms of both quantity and quality. Nutrition plays a key role in aquaculture by influencing the growth and health of fish and the quality of the aquatic animal produced. Uneaten feed and animal waste can add nutrients to water sources and impact the environment and fish growth conditions (Hardy, 2011). Nutritional principles are similar for all animals but, the required level of nutrients can vary between species. Fish in production systems need a properly balanced diet for specific requirements. It must also be considered that nutritional requirements are affected by the growth rate linked to the size of the fish. To stimulate feed intake, the water quality parameters must be within acceptable range.

Tilapia is an omnivorous grazer that feed on phytoplankton, periphyton, aquatic plants, small invertebrates, benthic fauna, detritus and bacterial films associated with detritus. Their nutritional requirements include protein, lipids, vitamins, minerals and carbohydrates. Tilapia need energy and essential nutrients for maintenance, movement, normal metabolic functions, growth and reproduction.

Feed is the most expensive component in aquaculture, particularly intensive culture, where it accounts for over 50% of operating costs (El-Sayed, 1999). In pond culture, fish can obtain their energy and nutrients from natural food in ponds, from feed supplied by the farmer or from a combination of both sources. The major nutrient requirements of cultured tilapia are summarized in Table 2 (Halver, 2011).

Table 2. Tilapia Nutrient Requirements (Halver, 2011)

| **Amino Acid (AA) Requirements of Tilapia** | | **Mineral Requirements of Tilapia** | |
|---|---|---|---|
| ***Essential Amino Acid*** | ***% of protein*** | ***Macro Minerals*** | ***% of diet*** |
| Arginine | 1.20 | Calcium | 0.70 |
| Histidine | 1.00 | Chlorine | 0.15 |
| Isoleucine | 1.00 | Magnesium | 0.06 |
| Leucine | 1.90 | Phosphorus | 0.40 |
| Lysine | 1.60 | Potassium | 0.02-0.03 |

| | | | |
|---|---|---|---|
| Methionine | 0.70 | Sodium | 0.15 |
| Methionine, cystine | 1.00 | ***Micro mineral (mg/kg diet)*** | ***(mg/kg diet)*** |
| Phenylalanine | 1.10 | | |
| Phenylalanine, tyrosine | 1.60 | Copper | 57 |
| Threonine | 1.10 | Zinc | 20 |
| Tryptophan | 0.30 | Iron | 85 |
| Valine | 1.50 | Manganese | 7 |

*2.3.1. Protein Requirements*

Protein is the most expensive major ingredient of fish feed. Therefore, it is important to determine the protein requirements accurately for each species and size of cultured fish. Proteins are formed by linkages of amino acids (Craig & Helfrich, 2009). Tilapia requires the same ten essential amino acids (Table 2) as other finfishes. Protein requirements for optimum growth are dependent on fish size and the energy contents of the diets and have been reported to vary from as high as 45-50 percent for first feeding larvae, 35-40 percent for fry and fingerlings (0.02-10 g), 30-35 percent for juveniles (10.0-25.0 g) to 28-30 percent for on-growing (>25.0 g) (Table 3). Tilapia broodfish require about 40-45 percent protein for optimum reproduction, spawning efficiency and for larval growth and survival (Hasan, 2017).

Table 3. Protein Requirement in Tilapia production (FAO, 2017)

| **Life Stage** | **Weight (g)** | **Requirement (%)** |
|---|---|---|
| First feeding larvae | | 45-50 |
| Fry | 0.02 – 1.0 | 40 |
| Fingerlings | 1.0 – 10.0 | 35-40 |
| Juveniles | 10.0-25.0 | 30-35 |
| Adults | 25-200 | 30-32 |
| | >200 | 28-30 |
| Brood stock | | 40-45 |

The main issue in formulating feed is to meet the protein and essential amino acid requirements of the species. Fishmeal is generally the preferred protein source because of the high quality of the protein and its essential amino acid (EAA) profile, found in the feed composition. However, fishmeal is generally expensive and is not always available. Tilapia can be fed with a high percentage of plant-based proteins. It is economically judicious to replace fishmeal with alternative protein sources including animal by-products, oilseed meal and cakes, legumes, cereal by-products and aquatic plants. Most of these ingredients are deficient in some EAA and hence require supplementation or be compensated with other feedstuffs. Although most of the oilseed cakes/by-products are generally deficient in lysine and methionine, blending of different oilseed cakes often provides balanced amino acid profile. However, they contain many anti-nutritional factors (such as gossypol, glucosinolates, saponins, trypsin inhibitors etc.) which limit their use in compound feeds or require removal/inactivation through specific processing (such as heating, cooking etc). There are also several non-conventional protein sources that may be suitable for *O. niloticus* such as snails, earthworms, corn and wheat gluten, almond cake, sesame cake, brewery waste, etc (FAO, 2017).

*2.3.2. Lipid Requirements*

Dietary lipids are important sources of highly digestible energy and the only source of the essential fatty acids needed by fish for normal growth and development. The polyunsaturated, linolenic and linoleic fatty acids in lipids are dietary essentials for tilapia since the fish cannot biosynthesize them. They are also carriers and assist in the absorption of fat-soluble nutrients such as sterols and vitamins A, D, E and K. Lipids, especially phospholipids, are the main constituents of cellular structure that are important for maintenance of membrane flexibility and permeability. Other important functions of dietary lipids are as precursors of steroid hormones and prostaglandins, improving the flavour of feeds and affecting feed texture and palatability (Lim, 2009).

The minimum requirement of dietary lipids in tilapia diets is 5 percent but improved growth and protein utilization efficiency has been reported for diets with 10-15 percent lipids (FAO, 2017). Plant oils rich in 18:2n-6, such as soybean oil, corn oil, sunflower oil, canola/rapeseed oil and various palm oil products are equally good lipid sources for tilapia (Lim, 2009).

*2.3.3. Other Nutrient Requirements*

Minerals, vitamins, carbohydrates and fibres are other nutritional requirements which may enhance the diet of tilapia. There is little information on the mineral requirements of tilapia. However, like other aquatic animals, tilapia can absorb some of the minerals from the culture water which makes the quantitative determination of these elements difficult.

Vitamin supplementation is not necessary for tilapia in semi-intensive farming systems, while vitamins are generally necessary for optimum growth and health of tilapia in intensive culture systems where limited natural food is available. Several vitamin requirements of tilapia are known to be affected by other dietary factors and these must be taken into consideration in diet formulations. For example, the vitamin E requirement is influenced by dietary lipid level with Nile tilapia requiring 50-100 mg/kg when fed diets with 5 percent lipid and increased to 500 mg/kg diet for diets with 10-15 percent lipid. Apart from dietary lipid level, the unsaturation index of the dietary oil will also affect the amount of vitamin E required. The presence of other antioxidants in the diet, such as vitamin C, has been reported to spare vitamin E in diets for hybrid tilapia (FAO, 2017).

The exact carbohydrate requirements of tilapia species are not known. Usually, inclusion of dietary carbohydrates in feed for aquatic farmed species is limited compared to feed for poultry and other mammals (Hardy, 2011). Carbohydrates are included in tilapia feeds to provide a cheap source of energy and for improving pellet binding properties. Tilapia can efficiently utilize as much as 35-40 percent digestible carbohydrate. Carbohydrate utilization by tilapia is affected by a several factors, including carbohydrate source, other dietary ingredients, fish species and size and feeding frequency (FAO, 2017). Complex carbohydrates such as starches are better utilized than disaccharides and monosaccharides by tilapias. Nile tilapia can utilize high levels of various carbohydrates of between 30 to 70 percent of the diet.

## 1.4 Digestibility Studies in Fish

Digestibility is a measure of the quantity of ingested nutrients retained by the fish and is most commonly measured by indirect methods using inert marker materials. By adding an inert marker to the feed, digestibility can be calculated by comparing the ratio of the marker in the food and faeces to a specific nutrient. To be effective, a marker must be indigestible, non-toxic, completely inert and should move through the gut at the same rate as the digester (Anderson, 1995). Digestibility of fish diets is important because it influences energy and nutrient availability, absorption and utilisation. A feed may appear from its chemical composition to be an excellent source of nutrients but will be of minute actual value unless it can be digested and absorbed in the target fish species. At the same time with chemical analysis, digestibility determination may allow a more thorough assessment of nutritive value of a protein source in a complete fish diet (Hussain *et al. 2011*).

Measurement of Apparent Digestibility Coefficients (ADC) of feed ingredients is an important step in the evaluation and formulation of balanced feeds. The first task in the measurement of digestibility of feeds and feed stuffs is the collection of faecal samples. In aquatic animals, separating faecal material from water and avoiding contamination of the faeces by uneaten feed necessitates approaches that differ significantly from those commonly used to measure digestibility in terrestrial animals and birds. Quantitative collection of fish faeces is very difficult, and therefore, digestibility measurements using direct methods, involving total collection of faecal material, are rarely used with fish. Digestibility measurements in fish must, therefore, rely on the collection of a presentative faecal sample (free of uneaten feed particles) and the use of a digestion indicator to obviate the need to quantify dietary intake and faecal output (indirect method). Faeces can also be stripped out from the fish gut. Collection of faeces from the water may give over-estimation of the digestibility but collection by stripping can give under-estimate of the digestibility.

The inclusion of a digestion indicator in the diet allows the digestibility coefficients of the nutrients in a diet to be calculated from measurements of the nutrient-to-indicator ratios in the diet and faeces (Halver & Hardy, 2002).  Apparent digestibility coefficient can be calculated as follows:

$$ADC\% = 1 - (Y_{diet} \times Parameter_{faeces}) / (Y_{faeces} \times Parameter_{diet})$$

where Y is the inert marker and the parameters can be dry matter, energy, protein, lipids, carbohydrates, phosphorus or other part of the diet, for instance.

### 2.5 Selecting Fish Feed Ingredients

Use of locally available raw materials as ingredients in aquaculture feed contributes to a sustainable utilization of resources as well as potential growth in aquaculture production with less environmental impact. In addition, the evaluation of feed ingredients is critical to feed development. The ingredients studied are organized into the following groups:

- Cereal grains and by-products
- Fruits and tubers
- Molasses
- Vegetable protein concentrates
- Fibrous foods
- Concentrated animal protein
- Fats, oils, and glycerin
- Minerals and micro-ingredients

Likewise, all ingredients have advantages within a formulation. The advantages are normally associated with nutritional contributions, availability of essential nutrients and the disadvantages are related to the antinutritional factors, major imbalance of components, the presence of contaminants, the presence of molds and the possible production of mycotoxins, low or variable quality, poor digestibility, susceptibility to oxidation, cost, availability and sustainability (Nates S. F., 2016).

No single ingredient can be expected to meet all the nutritional requirements of cultured fish. Each feedstuff in any diet formulation should be present for a specific reason i.e., it is a good energy source, it is rich protein source, essential amino acids, essential fatty etc. In addition, each feedstuff in a diet formulation should be the least costly ingredient available for its function in the diet. Knowing the composition of the available ingredients and the basic nutritional requirements of the fish being cultured, it is usually possible to formulate a diet that will promote optimum survival and growth. Diet formulation is an important process which allows for selection of appropriate feed ingredients to be blended. There are major factors to consider in the choice of ingredients when formulating fish feed.

One important consideration in the formulation of fish feed is the quality of the feed ingredients. This refers to the nutrient composition and presence of any anti-nutrients (substances that interfere directly with the absorption of nutrients) (Allan, 2007). It also includes ingredients which are nutritionally balanced, able to be made into pellets, palatable to the fish, and easy to store. Another important consideration would be the quantity of available ingredients needed to formulate the feed. It is critical to know what is available locally and if the supply is regular. Information on the price or cost of feed ingredients used to formulate the fish feed should also be known. In Saint Lucia, formulated feeds are expensive as most of the ingredients are imported and prices are rising continually. Thus, it is necessary to seek cost effective replacement to supply dietary protein from locally produced materials in order to reduce high feed costs.

Feed manufacturers adjust the mix of ingredients to create what are called “Least Cost Feed Formulations.” These are formulations that use spreadsheet and database programs to examine the nutritional characteristics of many ingredients at the same time. The program can then select the mix of ingredients that meet all the nutritional requirements at the lowest manufacturing cost (Fitzsimmons, 2009) but cover all the essential needs. Tilapia feeds are generally formulated using these programs based on specifications for including all required nutrients and energy needs and for ensuring that the diet is highly palatable and digestible according to former experiments. Measures are also taken to ensure that the diet has high water stability and floatability and is manufactured at the least cost. To formulate least cost feeds, the following information is needed:

- Nutrient requirements of fish
- Nutrient and energy concentrations of feed ingredients
- Nutrient and energy digestibility and availability from feed ingredients
- Price and availability of feed ingredients
- Levels of antinutrients or undesirable compounds present in the ingredients

*2.5.1 Pelleting fish feed*

Pelleting is done to give a cylinder shape to the mixed ingredients under temperature, pressure and moisture. Pelleting prevents the segregation of ingredients in a mixing, handling or feeding process. With pellet feed, the fish is more apt to receive a totally mixed ration than one that has been fed separately. Water stability of pellets prepared for fish is especially important because the pellet should remain intact in water until it is ingested. The water stability of the feed pellet depends primarily on how well the individual ingredients bind together. Almost all farmers agree that livestock make better gains on pelleted feed than a meal ration. The most logical reasons are that the heat generated in conditioning and pelleting make the feedstuffs more digestible by breaking down the starches, the pellet simply puts the feed in a concentrated form, and pelleting minimizes waste during the eating process. When pelleted feed is delivered, each animal receives a well-balanced diet by preventing the animal from picking and choosing between ingredients. It also prevents wastage of feed. Pellets designed to sink are simpler to manufacture and are therefore cheaper. But they can be lost in the bottom mud of ponds (James, 2013). Particle size is also important when formulating the pellet (Figure 3), to ensure appropriate consumption for different animal sizes.

Fry Fingerling Adult

Figure 2. Tilapia Feed Pellets

Newly hatched fry are given a complete diet of powdered feed. The feed should be high in protein (about 50 percent) and energy to meet the demands of the fast-growing fry. Feed size is gradually increased in relation to growth. However, tilapia prefer smaller size feed than other commonly cultured species, such as salmon, trout or catfish. The size should be increased through various sizes of crumbles for fingerlings 5 to 40 grams. Fish larger than 40 grams should be fed pellets. An optimal pellet sizes for tilapia are 3⁄32 inch–1⁄8 inch (Riche, 2003). For example, adult fish should not be given powdered feed but rather with larger sized pellets. This allows the fish utilize most of the energy they derive from the feed for growth, rather than for obtaining the feed. When fish are fed particles that are too small, they end up spending a significant proportion of their energy trying to get enough food.

Many ingredients absorb water, which leads to pellets becoming unstable in water. For instance, wheat and rice bran severely reduce the water stability while cereal by-products act as binders (particularly when gelatinization occurs in the processing). Most oilseed by-products allow for good water stability, but animal by-products are rather poor binders. If the compounded feed is heat treated then 20 percent of the feed should be made up of ingredients with a high starch content (corn, wheat, cassava etc.) in order to improve water stability through gelatinization (FAO, 2017).

*2.5.2 Homemade fish feed*

To encourage fish farmers to produce their own aquafeed, the cost must be low and its quality comparable to commercial feed. Thus, the promotion of farm-made feeds concerns sourcing locally available ingredients to provide cheap protein, carbohydrate and fat without excessive sacrifice of the required amino acid requirements of the fish. The aquafeed formulated should fulfil the nutritional requirements of the fish being grown (FAO, 1993). When mixing the feed, one must be aware of the balance in the feed. This means that you need to have some knowledge of the chemical composition of the ingredients, crude protein level, energy level (metabolizable energy), specific amino acid levels, crude fiber levels, fat level, ash level, vitamins, minerals and anti-nutritional factors (Allan, 2007).

*2.5.3 Extruded floating fish feed*

Extrusion is the only known way to make water stable slow sinking or floating feed pellets. The process can best be described as a continuous high temperature, short time, cooking or baking and shaping process (Jauncey, 2007). Extrusion technology is the most efficient way of turning various fishmeal, fish oil, soya bean meal, slaughterhouse by products and any other raw material into palatable feed for aquaculture organisms.

The extrusion process could change the physical properties of ingredients, promote the rupture of covalent cross-linking disulfide bonds (SS) in protein (Aslaksena *et al. 2006*), and promote the hydrolysis of protein and starch. It will enhance the utilization of protein and non-starch polysaccharides (Leng, 2015). In addition, the extrusion process promotes the hydrolysis of cellulose, increases the soluble fibre content and increases feed intake. A reduced amount of anti-nutritional factors and an improved nutrient digestibility have also been reported due to the extrusion. Compared with a pelleted diet, an extruded diet has a higher stability in water and a better nutrient utilization, which leads to lower nitrogen (N) and phosphorus (P) loads during fish culture. Therefore, the extrusion process in aquatic feed has recently attracted more attention.

*2.5.4 Storing raw materials and fish feed*

Most of the raw materials and aquafeeds are composed of highly perishable nutrients, so it is essential that adequate handling and storage procedures are employed to protect the finished feed from the natural elements (i.e. light, heat, humidity, air and water) from the time the feed emerges from the die plate to the time the feed is consumed by the fish (FAO, 1993). Feed should not be stored longer than 90 to 100 days and should be inventoried regularly. Older feed should be used first, and all feed should be regularly inspected for mould prior to feeding. All mouldy feed should be discarded immediately. Mice, rats, roaches and other pests should be strictly controlled in the feed storage area, because they consume and contaminate feed and transmit diseases. Keep feeds and ingredients dry, cool and away from pets (Craig & Helfrich, 2009). Poor storage of feeds and ingredients will waste money and can kill fish. Any ingredient or feed requires special care during storage to prevent deterioration in quality. Stock control is also important to ensure sufficient but not too much of each ingredient available for manufacture when needed. Environmental factors, such as moisture, temperature, light and oxygen influence deterioration and losses in feedstuffs.

High levels of moisture favor growth of fungus or insect infestation. Fungal growth can be retarded using mould inhibition agents (e.g. Myocurb). High temperatures also affect the rate of loss of heat liable vitamins and other nutrients (Allan, 2007). Direct sunlight may induce fat rancidity. It is important to note that a high-quality pellet should be durable and remain in one piece throughout transport in conveyors, during bagging, in storage and in the feeding devices at the fish farm (Sorensen *et al. 2008*).

## 3 MATERIALS AND METHOD

This section is divided into two parts. First the analysis of feed commonly used by aquaculture farmers in Saint Lucia was done. Secondly, a tilapia feed was formulated using the online excel fish feed formulation sheet and then fed to live tilapia in an experimental set up. This feed was also analyzed along with the faeces that was collected to measure digestibility.

### 3.1 Analysis of common feed used in Saint Lucia by aquaculture farmers

Samples of pellet feed commonly used in Saint Lucia by aquaculture farmers were collected. The samples were namely Banana Supplement and Poultry Grower. The ash, protein, lipid and moisture content were determined with the assistance from the lab at Iceprotein. The composition of the feed was compared to the results from the analysis conducted by Iceprotein lab. Each sample was prepared by grinding into a fine powder and weighed for the analysis (Figure 4).

Figure 3. Preparation of feed samples for analysis

The ash content was determined by using the dry ashing method. The procedure involved putting samples in muffle furnace at a high temperature of between 500°C for 24 hours. The method is used because minerals are not destroyed by heating, and that they have a low volatility compared to other food components. Water and other volatile materials are vaporized and organic substances are burned in the presence of the oxygen in air to $CO_2$, $H_2O$

and $N_2$. Most minerals are converted to oxides, sulphates, phosphates, chlorides or silicates. The feed samples were weighed before and after ashing to determine the concentration of ash present.

To determine the protein content, the Kjeldahl method was used. The Kjeldahl method of nitrogen analysis is the worldwide standard for calculating the protein content in a wide variety of materials ranging from human and animal food, fertilizer, waste water and fossil fuels (Blamire, 2003).

The Kjeldahl method consists of three major steps, which were carefully carried out in sequence:

1. The sample was first digested in strong sulfuric acid in the presence of a catalyst, which helps in the conversion of the amine nitrogen to ammonium ions,
2. The ammonium ions were then converted into ammonia gas, heated and distilled. The ammonia gas was led into a trapping solution where it dissolves and becomes an ammonium ion once again,
3. Finally, the amount of the ammonia that has been trapped is determined by titration with a standard solution, and a calculation was made.

### 3.2 Experimental system

The experiment was conducted in a partial recirculation system (Figure 5) at Verid located in Saudarkrokur, Iceland. Four tanks of equal sizes each holding 800 liters of water were used. The water temperature was adjusted to 28°C and oxygen was maintained throughout the system at 5.0 mg/L. Uneaten feed was cleared from the system through a mechanical filter and by syphoning daily.

Figure 4. Experimental set up

### 3.3 Experimental Fish

A total of 80 tilapias (*Oreochromis niloticus)* with an average weight of 450 grams was used for this experiment. The tilapia (Figure 6) was acquired from an aquaponics system in Iceland. The fishes were equally distributed into the four tanks, each holding 20 fishes. The feeding trial ran for one week using the formulated diet (Table 4). The fish were anaesthetized using 2ml phenoxyethanol in 2 gallons of water and faeces were stripped post feeding.

Figure 5. Tilapia which was fed with experimental diet

Table 4. Composition of Commercial Pellets samples (from label on feed bag)

<table>
<tr><th>Pellet Sample</th><th>Ingredients Facts</th><th>Parameter</th><th>%</th></tr>
<tr><td rowspan="6">Banana Supplement (Pig Ration)</td><td rowspan="6">Corn, Soybean, wheat, Calcium Carbonate, Dicalcium Phosphate, Salt, Amino Acid Supplements, Vitamin Supplements, Trace mineral supplements, Antioxidants, Preservatives.</td><td>Crude Protein</td><td>25.00</td></tr>
<tr><td>Crude Fat</td><td>2.39</td></tr>
<tr><td>Crude Fibre</td><td>4.13</td></tr>
<tr><td>DM</td><td>87.51</td></tr>
<tr><td>Moisture</td><td>12.49</td></tr>
<tr><td>Ash</td><td>6.28</td></tr>
<tr><td rowspan="6">Poultry grower</td><td rowspan="6">Grain Products, Plant protein, animal fat, Vitamin B12, salt, dicalcium phosphate,</td><td>Crude Protein</td><td>20.00</td></tr>
<tr><td>Crude Fat</td><td>4.5</td></tr>
<tr><td>Crude Fibre</td><td>4.5</td></tr>
<tr><td>DM</td><td>N/A</td></tr>
<tr><td>Moisture</td><td>N/A</td></tr>
<tr><td>Ash</td><td>N/A</td></tr>
</table>

### 3.4 Tilapia feed experimental diets

Tilapia feed was formulated using an online excel feed formulation model (Table 5). The feed formulator estimated the content of crude protein, crude fat, crude ash and moisture of the diet (Table 6). Ingredients used in the formulation was acquired from Laxa Feed Mill in Akureyri, Iceland. The most accessible ingredients for tilapia diet in Iceland was used in making the experimental feed since all the ingredients from (Table 11) was not accessible in Iceland. Preparation steps in formulating fish feed pellets were then followed. The ingredients used were finely grounded into similar particle sizes. A sieve was used to remove larger particle sizes. Each ingredient was then weighed and portioned according to information generated from feed formulated. The ingredients were mixed thoroughly in a large mixer. Moisture was added to form a cake like mixture. A pellet machine (mincer) was used to formulate the extrusion (Figure 6). A knife was used to cut pellets into similar sizes of 2mm. The pellet was then placed in an oven at 60°C to dry. The fishes were fed three times a day for the first few days, then a feed belt was installed so they could feed overnight.

Table 5. Ingredient composition of the experimental diet fed to Tilapias for estimating nutrient digestibility

| Ingredient | Diet 1 (%) |
|---|---|
| Fishmeal | 10 |
| Shrimp shell meal | 3.4 |
| Soybean (full fat) | 27 |
| Canola | 40.5 |
| Corn (gluten) meal | 3.4 |
| Wheat | 6.7 |
| Binder (Inert) | 1 |
| Vegetable Oil | 6.7 |
| Vitamin Premix | 1 |

Table 6. Estimated content of crude protein, crude fat, crude ash and moisture of diet

| Parameter | Diet % |
|---|---|
| Crude Protein | 33.57 |
| Crude Lipid | 15.33 |
| Ash | 8.06 |
| DM | 92.35 |
| Fibre | 6.62 |
| Moisture | 7.65 |
| DE(MJ/kg) | 15.27 |

Figure 6. Pellet preparation using pellet machine (mincer)

## 3.5 Faeces collection

To collect faeces, fish were anaesthetized using 2ml phenoxyethanol in two gallons of water and pressed along the abdomen closer to the anus. However, this method deemed unsuccessful and faeces were then collected manually from the fish tank throughout the period. This was done at the end of the feeding period and each replicate was pooled. Faeces collected were then stored in a freezer until analyzed.

## 3.6 Formulation of possible Saint Lucia tilapia diet

A theoretical tilapia diet was formulated by using an excel-fish diet formulator. The excel program consists of a database covering the chemical composition of 90 different ingredients and calculate key elements in the selected fish formulation according to amount of added ingredients. The compositional limits were set according to the nutritional requirements of tilapia, described in chapter 2 of the literature review and the essential amino acid need with references to the best current available knowledge, NRC 2011 figures. The formulation was made for grower feed, i.e. crude protein limits set in the range of 28-35%, crude lipid level >15%, ash content > 16% and crude fiber content > 10%. Ingredients, which were considered as available or easily accessible in Saint Lucia (listed in the appendix) were tested in various ratios in the diet formulator and then selected in different ratios, with the aim to fulfill the nutritional needs of tilapia as closely as possible. The selection of used ingredients was also made considering practical evaluation, access to ingredients and the price (real and/or likely) of ingredients.

# 4 RESULTS

The results from the analysis are presented in this section. A second tilapia feed was formulated using the online excel fish feed formulation sheet. The results of the amino acid profile generated from the formulator is also presented in this section.

## 4.1. Analysis of samples

The composition and chemical analysis of the pellet feed used in Saint Lucia, the formulated fish feed and faeces collected from tilapias are presented in Table 7 and 8. It shows that the current pelleted feed being used by fish farmers are below the recommended nutritional requirements for optimal tilapia growth. The experimental fish feed however, does contain the necessary nutritional requirements for optimal growth under normal conditions. The tilapia faeces collected was not high in protein and lipids which suggest that is was utilized by the fish.

Table 7. Composition of samples

| Test Sample | Crude Protein % | Crude Lipid % | Ash % | Dry Matter % |
|---|---|---|---|---|
| Banana supplement | 13.4 | 2.72 | 11.94 | 91.15 |
| Poultry grower | 21.14 | 0.64 | 12.75 | 91.10 |
| Formulated feed | 38.92 | 10.5 | 4.48 | 94.59 |
| Tilapia Faeces | 2.38 | 0.2 | 8.9 | 8.31 |

Table 8. Analyzed chemical composition of two feeds from Saint Lucia, experimental feed formulated and tilapia faeces. CHO is a calculated number –total NFE. ADC is apparent digestibility coefficient (%).

| | Dry Matter (%) | Protein in DM (%) | Ash in DM (%) | Fat in DM (%) | CHO in DM (%) |
|---|---|---|---|---|---|
| Banana Supplement | 91.15 | 14.72 | 4.91 | 2.98 | 77.38 |
| Chicken Feed | 91.10 | 23.21 | 9.77 | 0.71 | 66.32 |
| Formulated Feed | 94.60 | 41.14 | 11.05 | 11.07 | 36.74 |
| Tilapia Faeces | 8.32 | 28.57 | 27.25 | 2.89 | 41.30 |
| ADC % | 59.5 | 71.8 | | 89.4 | 54.4 |

The results of the digestibility studies show the protein digestibility is not very high and probably affected by relatively high levels of plant protein in the feed. The carbohydrate (CHO) composition in the analysis is a calculated number of nitrogen free extracts (NFE) and is not distinguishing between better digestible starch and less digestible fibres. Some of the selected ingredients, primarily the canola meal, contain relatively high amount of fibres. High fibre content may have affected the protein digestibility. The protein digestion might also be affected by other anti-nutritional factors. The lipid digestibility is acceptable, close to 90%, which is in line with lipid digestibility in fishes fed on either vegetable oil or fish oil, in general.

## 4.2 Formulating tilapia feed using local ingredients accessible Saint Lucia

The maximum inclusion level of each feedstuff used in formulating tilapia feed was dependent on several factors such as the level of dietary protein, the essential amino acid profile, life stage of the fish, economics, estimated availability, etc. The ingredients were primarily selected based on their nutrient composition generated from the excel feed formulator, since real composition analysis of this domestic raw materials are not available. Although the ingredients are listed as shown in (Table 9) they were not all used in the formulation. The most common domestic ingredients were selected in formulating the feed, except for fishmeal which must be imported.

Nutritional values and other relevant information are provided in (Table 10) from the combination of feed ingredients used in making the formulated feed (Table 9). The formulated tilapia feed contained all the essential amino acid requirements for tilapia within the recommended range. The amino acids Leucine, Lysine, Arginine P + T and Phenylalanine are all present in excess. Although the feed formulating program shows methionine ratio below the requirement of tilapia, methionine content is considered acceptable since the methionine + cysteine ratio (M+C) is higher than required.

Table 9. Ingredients, considered easily accessable in Saint Lucia from (Table 11) and amount of selected ingredients in local feed formulation.

| Ingredients - | Ingredient volume - kg/100 kg (or %) |
|---|---|
| Fish meal (50% CP) | 12 |
| Poultry offal meal | 18 |
| Shrimp shell meal | - |
| Trash fish (mixed) | - |
| Copra (coconut) meal | 27 |
| Soybean (ful fat) | 19 |
| Cassava flour | - |
| Corn (7.5% CP) | - |
| Rice bran | 6 |
| Wheat (10% CP) | 10 |
| Vegetable oil | 2 |
| Bone meal | 5 |
| Salt (NaCl) | - |
| Vitamin premix | 1 |

Table 10. Calculated composition of key elements in practical feed, formulated by mixing ingredients easily accessible in Saint Lucia. Cost is an estimate in $US /kg.

| Parameter | % Diet | Parameter | % Diet % |
|---|---|---|---|
| DM% | 91.94 | Cholesterol% | 0.07 |
| Ash% | 11.16 | Astaxanthin (mg/kg) | 0.00 |
| GE MJ/kg | 18.23 | Arginine% | 2.76 |
| DE MJ/kg | 12.61 | Histidine% | 0.93 |
| CP% | 31.78 | Isoleucine% | 1.27 |
| Dig CP% | 27.37 | Leucine% | 2.77 |
| Lipid % | 14.08 | Lysine | 2.12 |
| Fiber % | 5.58 | Methionine% | 0.56 |
| LOA (18:2n-6)% | 2.80 | M + C% | 1.18 |
| LNA (18:3n-3)% | 0.36 | Phenylalanine% | 1.62 |
| ARA (20:4n-6)% | 0.01 | P + T% | 2.68 |
| EPA (20:5n-3) | 0.04 | Threonine% | 1.52 |
| DHA (22:6n-3)% | 0.14 | Tryptophan% | 0.42 |
| Total n-3% | 0.55 | Valine% | 1.86 |
| Total n-6% | 2.82 | Ca% | 2.62 |
| n3:n6 | 0.19 | Available P% | 1.53 |
| Total phospholipid% | 1.93 | Cost/kg ($US) | 1.02 |

The calculation of key elements in the feed formula (Table 10) were also derived from the feed formulator and the essential amino acid content compared to the minimum level on tilapia feed (Figure 8).

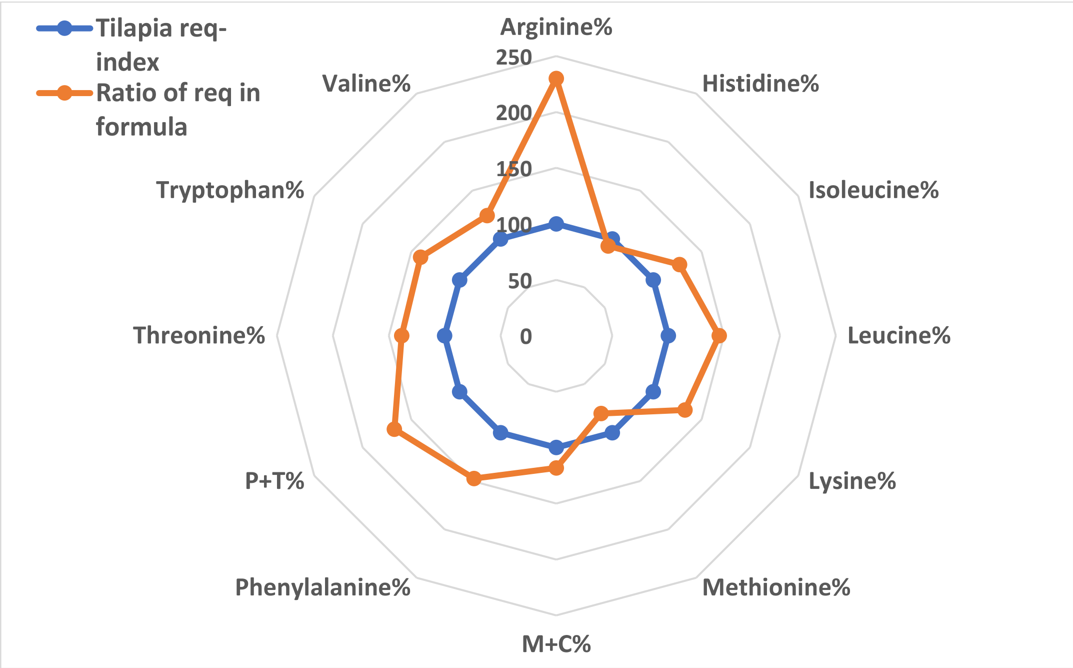


Figure 7. Essential amino acid profile of the calculated feed formula compared to the essential amino acid requirement of tilapia (set as an index 100).

## 5 DISCUSSION

The goal of an aquaculture farm in Saint Lucia is to make profit. Profitability is determined by the difference between total revenue and total cost. Therefore, cost minimization is one way to achieve more profit. In many aquaculture operations today, feed costs account for over half of the operating costs. Globally, fish meal has been traditionally used as the main feed source in the aquafeed industry. However, it has become very expensive. Fish meal is not manufactured in Saint Lucia and is imported at a high cost. This has prompted farmers to seek alternatives and formulate their own fish feed using available local ingredients to reduce costs. Extension Officers of the Department of Fisheries in Saint Lucia have relayed farmers concerns with regards to poor quality fish feed. It is believed that knowledge of alternatives will help improve their production.

If farmers are to be successful in feed preparation it is important that they examine the ingredients available locally. One objective to be met in using local ingredients is to derive a balanced diet at the lowest cost possible. Farmers require knowledge of the nutrient requirements of the fish, the physical and chemical properties of ingredients and processing methods. Since tilapia fetch a relatively low market price, a cost-effective feeding regime is dependent upon a careful selection of feedstuffs and feed ingredients, utilization of an optimum feed formulation, selection of multi-purpose equipment for feed preparation, optimization of feed dispersion and minimization of feed waste (FAO, 1993).

Tilapia are omnivorous, meaning they will eat a variety of things, including plants and animals. Tilapia, like other finfish, require specific dietary nutrients for optimal growth and growth is negatively affected when not fed balanced diet. It is important to prepare diets including optimal dietary protein, amino acids, crude lipid, minerals, vitamins and energy for each phase of the tilapia culture cycle (*i.e.* for larvae/fry, juveniles, production and brood stock.

The level of protein in fish feed is of fundamental importance because it influences growth. From a nutritional standpoint, fishmeal is the preferred animal protein supplement in the diets of farm animals and often the major source of protein in diets for fish and shrimp (IFAS, 2016). Fishmeal carries large quantities of energy per unit weight and is an excellent source of protein, lipids (oils), minerals, and vitamins. Potential alternative sources of protein include plant protein sources such as meals made from oilseeds, grains, or legumes. However, most of these sources do not have amino acid profiles that satisfy essential the nutritional requirements of fish as well as fish meal does. Many studies have been conducted to evaluate the replacement of fish meal by the low-cost, locally available plant and animal protein sources such as soybean meal, poultry offal meal, shrimp shell meal, trash fish, meat & bone meal, etc., in practical diets for tilapia.

In formulating tilapia feed, soy-bean meal appears to be a reasonably good feed component for aquaculture diets. It contains about 47-50 percent protein, 5-6 percent ash, 21 percent lipid and about 40 percent carbohydrates. It has a lysine content that approaches that of fishmeal, but for most aquaculture diets it is deficient in the sulphur-containing amino acids and in tryptophan. Because of these amino acid deficiencies, soy-bean meal cannot be used as the only source of protein and is generally compounded with other feedstuffs when it is used in aquaculture rations. Poultry by products appear to be excellent protein and lipid sources containing 60 percent crude protein, 14-21 percent lipid and about 8 percent ash. Besides being a valuable protein source, meat and bone meal also contributes to the energy component of the diet and is a good source of calcium, phosphorus and trace minerals. Shrimp shell meal is a good ingredient for fish because of its high crude protein content and digestibility. It is also reported to stimulate fish growth.

The nutritive value of mixed rations depends on the nutrient composition of the individual feed components and the ability of the animal to digest and absorb the nutrients. It is important to formulate a feed using ingredient that would cover the amino acid profile of the fish. Although a range of possible available ingredients which could be used to make tilapia feed in Saint Lucia was listed in this paper, it was not necessary to formulate a fish feed using all the ingredients at once. Based on the experiment, it is evident that the protein quality of a feed ingredient is dependent upon the amino acid composition of the protein and the biological availability of the amino acids present. In general, the closer the EAA pattern of the protein approximates to the dietary EAA requirement of the species, the higher its nutritional value and utilization. Among all the essential amino acids required by fish in general and tilapia in particular, methionine is often one of the most limiting EAA in feeds. Deficiency of essential amino acids leads to poor utilization of the dietary protein and consequently reduces growth and decreases feed efficiency (Koprucu, 2005).

Lipids are also important as it is required by fish as a source of available energy, as structural components of bio-membranes, carriers of fat-soluble vitamins, precursors to eicosanoids, hormones and vitamin D, and as enzyme co-factors. They are highly digestible in fish and are a preferred nutrient source for energy. Minerals are important for normal skeletal development of fish, but some also have a vital role in the functioning of enzymes and other metabolic functions. Vitamins are complex organic compounds required in small amounts for normal growth, reproduction, health and general metabolism. Diets lacking adequate levels of vitamins and minerals can result in reduced growth and development disorders. Carbohydrates include fibre, starches and sugars and while not usually considered essential, they can be an effective source of energy and improve food conversion efficiency when included at moderate amounts (Royes & Chapman, 2015). Carbohydrates can also help to bind a diet together (i.e. the pellet will not crumble easily). Tilapia can also tolerate and utilize relatively high carbohydrate level in their diet compared to many other species.

A feed ingredient may appear from its chemical composition to be an excellent source of nutrients but will be of little actual value unless it can be digested and absorbed by the fish. Knowledge of nutrient digestibility of the various feed ingredients used in formulating fish feeds is desirable so that effective substitution of one ingredient for another may be achieved. Together with chemical analysis, digestibility determination may allow a more thorough estimation of the nutritive value of a protein source in a complete feed for fish. Generally, the protein quality of dietary ingredients is the leading factor affecting fish performance, and protein digestibility is the first measure of its availability by fish. The analysis showed that the apparent digestibility values are relatively high, particularly for protein and lipids, which are of great importance in feed formulation as they are the backbone of growth and nutrient utilization for the fish. The possible effect of anti-nutritional factors, particularly on protein digestibility, must be considered when protein raw materials are carefully selected in a feed formulation. Balance of all-important chemical components is of major importance and must fulfil the nutritional requirement of the fish species. A nutritious and balanced diet will give good growth and may lead to more successful aquaculture operation.

# 6 CONCLUSION

The results from the analysis showed that the current feed being used to feed fish in Saint Lucia does not meet the nutritional requirements for optimal growth of tilapia. The banana supplement feed only contains about half of the recommended protein requirement of tilapia.

The findings may explain why it takes the tilapia longer than six or seven months to reach a marketable size of 450 grams, when fed this domestic diet. The objective of feeding fish is to provide the nutritional requirements for good health, optimum growth, optimum yield and minimum wastage within reasonable cost. For this to occur, feed quality needs to be improved. Dietary nutrients are the source of stored energy for fish digestion, absorption, growth, reproduction and the other life processes. The nutrients within the feed should be easily accessible to the fish. It is recommended that fish farmers seek information on sources of local ingredients available that would meet nutritional requirement for optimal growth. Carefully formulated and balanced diet is fundamental for successful fish farming. Importation of some ingredients, not found domestically, may be economically feasible. The development of specific diet formulations supports the aquaculture (fish farming) industry as it expands, to satisfy increasing demand for affordable, safe and high-quality fish.

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APPENDIX

Examples of commonly used ingredients used in making tilapia feed, accessible in Saint Lucia

| Ingredient | Description | Nutrient Composition | Cost/kg (US$) |
|---|---|---|---|
| **Fish Meal** | Most of the world's fish meal is made from whole fish; pelagic species e.g. tunas are used most for this purpose. Some countries in the Caribbean make fish meal from unsold fish, processing waste and from offal, that is the heads, skeletons and trimmings left over when the edible portions are cut off. Fish meal is usually a good source of protein. | C Protein: 52.00%<br>Lipid: 7.6%<br>Fiber: 3.1%<br>Ash: 25.2% | $1.80 |
| **Shrimp Shell Meal** | Made up of shrimp waste consist of head, shell and some meat portions. Fresh water shrimp (*Macrobrachium rosenbergi)* waste could be used. It is high in crude protein, however a portion of the CP that is contained in shrimp meal is in the form of chitin, which is not readily digestible. | C Protein: 42.6%<br>Lipid: 7%<br>Fiber: 20.00%<br>Ash: 30.4% | $0.50 |
| **Cassava Flour** | The cassava plant, made up of the roots, leaves and stem, is a good source of carbohydrate and protein. The different parts of the plant can be used as fish feed. The leaves can be used as silage, dried for feed supplementation and as leaf meal for feed concentrates. The root peel, broken roots, fibre and bagasse from starch extraction and garri processing can be dried and used directly as animal feed or as substrate for single cell protein production. | C Protein: 12.50%<br>Lipid: 7.2%<br>Fiber: 6.5%<br>Ash: 5.2% | $1.40 |
| **Wheat** | As with many other cereal grains, wheat is primarily a source of energy in the form of carbohydrates. The glutenous nature of wheat makes it an excellent pelleting aid. 10% wheat in a formula will often enhance pellet durability, particularly in rations with little other natural binder. | C Protein: 10.00%<br>Lipid: 1.7%<br>Fiber: 0.8%<br>Ash: 0.6% | $0.75 |
| **Soybean** | Soybeans are one of the world's best non-fish sources of essential omega-3 fatty acids, healthy proteins, and unsaturated fats. High-quality soy protein is fed to farmed fish to support their growth and healthy development. Soybean meal is the most important protein source used to feed farm animals. Can be replaced with fishmeal in tilapia feed. | C Protein: 37.5%<br>Lipid: 21.0%<br>Fiber: 2.3%<br>Ash: 5.72% | $0.75 |
| **Corn** | Corn also called maize, is a grain most routinely used in commercial fish feed and poultry diets in the Caribbean because it has a good energy content and is easy to digest. The amino acid profile of the protein in corn complements the amino acid profile of the other ingredients, such as soybean meal, typically used in feed. | C Protein: 8.3%<br>Lipid: 11.5%<br>Fiber: 2.4%<br>Ash: 1.2% | $0.50 |
| **Copra (Coconut)** | Copra meal is often used as a protein source in the diets of fish. Copra meal, or coconut meal, is an important feed ingredient and the by-product of the oil extraction from dried coconut kernels. | C Protein: 19.2%<br>Lipid: 7.6%<br>Fiber: 3.1%<br>Ash: 5.4% | $0.70 |
| **Rice bran** | Rice bran is the most important rice by-product. The bran fraction contains 14-18% oil. Rice bran that has not been defatted is a useful binder in mixed feeds. Defatted rice bran can be used at higher levels than ordinary rice bran. Rice bran is often adulterated with rice hulls, as it should have a crude fibre content of 10-15% (Feedipedia , 2015). | C Protein: 8.1%<br>Lipid: 12.0%<br>Fiber: 18.8%<br>Ash: 10.0% | $1.00 |
| **Vegetable Oil** | Used as energy sources, provide essential fatty acids, attractant, coating of pellet to reduce abrasion. | C Protein: 0%<br>Lipid: 100%<br>Fiber: 0%<br>Ash: 0% | $4.25/litre |

| | | | |
|---|---|---|---|
| **Trash fish** | Trash fish is usually considered to be any unwanted fish or unsold fish. It can be prepared by sun drying or cooked. It is easy to prepare and contains a substantial amount of crude protein. | C Protein: 19.4%<br>Lipid: 1.0%<br>Fiber: 0.2%<br>Ash: 1.0% | $0.40 |
| **Poultry Products** | The poultry products not used for human consumption can be turned into valuable feed ingredients for fish, defined as poultry meal and feather meal. Feathers are heat and pressure treated in order to make the protein more available to animals, while poultry products are simply cooked as a pre-treatment. A further drying process may be used to form a meal. Use of these ingredients in fish feed is a responsible use of valuable nutrients that might otherwise go to waste. | C Protein: 60.00%<br>Lipid: 14.0%<br>Fiber: 1.9%<br>Ash: 8.0% | $1.00 |
| **Meat & bone meal** | Meat and bone meal are derived from slaughter by-products recycled for use in animal feeds. They are pressure cooked (rendered) to produce a nutritional and economical feed ingredient. | C Protein: 48.4%<br>Lipid: 10.0%<br>Fiber: 1.8%<br>Ash: 33.6% | $0.40 |
| **Vitamin Premix** | Vitamin Premix and minerals are added to the feeds to ensure that the fish obtain all the nutrients they require. These are the same vitamins and minerals as those used in supplements for humans. Minerals are vital for normal growth and development in fish, such as bone formation and body processes such as enzyme activation. | C Protein: 13.5%<br>Lipid: 3.9%<br>Fiber: 3.1%<br>Ash: 3.0% | $5.00 |
| **Salt** | Salt is used to cover the animal requirements for sodium (Na) and chlorine (Cl). Salt is the cheapest available source for these two nutrients. | C Protein: 0%<br>Lipid: 0%<br>Fiber: 0%<br>Ash: 90% | $0.50 |

**NB: Prices are estimates and are subjected to change.**

### Feed formulation guidelines for fish farmers in Saint Lucia:

**Step 1.** Use finely ground ingredients of similar particle size. Individual ingredients should be ground using a hammer mill, or other type of grinder or even a mortar and pestle.

**Step 2.** Weigh or measure ingredients. Take particular care when weighing micro-nutrients (vitamin and mineral premixes) as these are used in very small quantities and are very expensive.

**Step 3.** Mix all ingredients thoroughly. If large batches are to be prepared, the dry ingredients can be mixed in a large cake mixer or even in a cement mixer. Poor mixing will result in variation of daily nutrient intake. Good mixing can also improve palatability.

**Step 4.** Mix vitamins and minerals with small amount (e.g. 10% of total batch) first then blend into larger mixture (to help ensure the vitamins and minerals are evenly distributed within the mixture).

**Step 5.** Add the oil and then mix for at least another five minutes. To ensure oil is well mixed throughout the ingredients, it is useful to warm the oil or make an emulsion with warm water. Mix with dry ingredients slowly.

**Step 6.** Add water and mix well to form a mash with a cake-like consistency. Water should be added slowly and small test batches of the mixture extruded through the pellet machine (mincer) to see how easily the mixture passes through the die and how the pellets hold together. As a general rule, the total moisture content of the mash should be in the range of 45 to 55% to produce good pellets. If moist ingredients like trash fish, minced poultry etc. are used, less moisture will be needed (e.g. 25-45%). Adjustments must also be made depending on the type of binders, if any, are used.

**Step 7.** Pass the feed mash mixture though a pellet machine (mincer) with a 1, 2, or 3 mm die depending on the size of the fish that is being fed. It is usually best to use the largest diameter pellet that fish will readily eat.

**Step 8.** Cut the extrusion, (which look like noodles) into similar lengths to the closest pellet diameter (i.e. 2 mm long for 2 mm diameter pellets for fish). Pellets can be cut off with a knife during extrusion or broken into smaller lengths after they have been dried.

**Step 9.** The moist pellets should be dried to a moisture content of 10% or less. Ideally, this should be at low temperature (less than 60 ºC) and with good airflow to dry the pellets as quickly as possible to ensure that heat-sensitive micronutrients such as vitamins are not destroyed. This can be achieved using:

- fan-forced oven (e.g. set at <60 ºC) for several hours,
- simple drying cabinet (with hot air supplied by a heater blower),
- solar dryer or
- simply by spreading the pellets in the sun.

**Step 10.** When pellets are dry and cool they should be stored in bags or containers that can be sealed against insects, rats or other pests and to keep out moisture. Avoid using plastic bags because feeds can sweat and this encourages growth of mold.