# UTILIZATION OF SHEA CATERPILLAR, *Cirina butyrospermi* IN THE PRACTICAL DIETS OF HYBRID AFRICAN CATFISH, *CLAROBRANCHUS* FINGERLINGS

**BY**

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**MTECH/SAAT/2017/7375**

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**FEDERAL UNIVERSITY OF TECHNOLOGY MINNA**

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**A THESIS SUBMITTED TO THE POSTGRADUATE SCHOOL FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGERIA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER TECHNOLOGY IN FISHERIES**

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# ABSTRACT

A 56-days feeding trial was conducted to evaluate Utilization of Shea Caterpillar, *Cirina Butyrospermi* in the Practical Diet of Hybrid African Catfish, *Clarobranchus* fingerlings through their growth performance and nutrient utilization. Five isonitrogenous diets were formulated, containing 40 % crude protein and 9.5 % lipid. Shea caterpillar meal (SCM) and fishmeal (FM) were included at different inclusion levels; DI (0 % SCM, 100 % FM); DII (25 % SCM, 75 % FM); DIII (50 %: 50 % SCM: FM); DIV (75 % SCM, 25 % FM) and DV (100 % SCM, 0 % FM). These diets with one commercial catfish reference diet (CRD) skreting, were fed to the experimental fish. The experiment was completely randomized in triplicate, and twenty fish were allocated per each (50 cm by 30 cm by 20 cm) white plastic bowls, with the mean initial body weight 2.52±0.43 g per fish. The fish were fed at 3 % of their body weight at two equal meals per day throughout the experimental period. At the end of the study, there was significant difference ($P<0.05$) in the growth and body composition parameters evaluated. Fish fed diet DI had the highest mean final weight 20.34±0.59 g, mean weight gain 16.84±0.61 g, and protein efficiency ratio 2.59±0.16; and fish fed diet DII had highest specific growth rate 2.70±0.18 and lowest feed conversion 0.58±0.07 with no significant difference ($P>0.05$) between diet DI and DII. Fish fed diet DV had the lowest mean final weight 16.48±0.19**,** mean weight gain 12.96±0.19, specific growth rate 1.29±0.30, protein efficiency ratio 1.46±0.07 but highest in feed conversion ratio 6.81±4.51. However, there was significant difference ($P<0.05$) in the survival rate of the fish, fish fed diet DII had the highest survival rate 95.00±5.00 while fish fed diet DV had the lowest survival rate 85.00±8.86. The ANPU of the experimental fish was significantly different ($P<0.05$), DVI (CRD) had the highest ANPU (22.05±0.36), followed by DIV (18.91±0.2), while the DI and DII had the least ANPU 13.13±0.04 and 15.62±0.55 respectively. 25%, to 75% inclusions level of Shea caterpillar *Cirina butyrospermi* is recommended for the diet of hybrid catfish *Clarobranchus* in terms of growth performance.

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# CHAPTER ONE

## 1.0 INTRODUCTION

### 1.1 Background to the Study

Aquaculture provides an increasing contribution to the world's food security (Austin, 2013). Its production is a major industry globally, and it will continue to grow as the demand for fish and fish products increases as the supply from natural sources decreases (Delbert & Gatlin, 2010). At an average annual growth rate of 6.2 percent between 2000 and 2012 (9.5 percent between 1990 and 2000), which makes it the world's fastest growing animal food producing sector (FAO, 2012; FAO 2014). FAO, (1997); Adewole and Olaleye (2014); and Ajayi *et al.*, (2016) reported that fish is an important source of high quality protein in human diet, providing about 16 % of the animal protein consumed by the world's population, which accounts for 20 % of animal protein consumed in Africa. Globally, fish provides about 3.0 billion people with almost 20 percent of their intake of animal protein, and 4.3 billion people with about 15 percent of such protein.

Fish has been reported to be a good source of food and means for livelihood to many African populaces, Orire *et al*. (2015). The demand for high quality fish and fishery products is growing significantly every year mostly due to their nutritional fact that they contain plentiful of beneficial healthy substances (FAO, 1986; and Jag *et al.*, 2018). The most important of these are fish lipids, which usually contain high amount of omega-3 fatty acids, mainly α-linolenic acid, eicosapentaenoic acid (EPA), and docosahexaenoic acid (DHA). The omega-3 fatty acids have several beneficial impacts on human health. These include; decreasing the risk of myocardial infarction (Bucher *et al.*, 2002) lowering blood pressure and triglyceride concentration in blood (Harris *et al.*, 1997; Vandongen *et al.*, 1993), enhancing the immune system (Damsgaard *et al.*, 2007) and sustaining proper brain function in human body. They also protect against various psychological disorders, depression and attention deficit hyperactivity disorder in particular (Sinn, 2007) and cancer (Caygill & Hill, 1995). Nevertheless, fatty acids are not the only important nutrients in the fish and fishery products, it is also a good source of easily digestible protein, and its amino acid profile usually contains most of the essential amino acids which is required to humans for balanced diet. They are also rich source of fat-soluble and B-group vitamins (Erkan & Bilen 2010).

It is concluded that freshwater fish farming makes the greatest direct contribution to food security, providing affordable protein food, particularly for poor people in developing countries, in Asia, Africa and Latin America. Inland aquaculture also provides an important new source of livelihoods in less developed regions and can be an important contributor to poverty alleviation (FAO; 2014; and Patricio & Doris, 2016). It is also an important source of other nutrients such as vitamins A, B and D as well as calcium, iron and iodine (FAO 2005).

In the last three decades (1980–2010), world food fish production of aquaculture has expanded by almost 12 times, at an average annual rate of 8.8 percent (FAO, 2012). Global aquaculture production has continued to grow, although more slowly than in the 1980s and 1990s. World aquaculture production attained another all-time high in 2010, at 60 million tons (excluding aquatic plants and non-food products), with an estimated total value of US$119 billion (FAO, 2012). In 2012, farmed food fish contributed a record 66.6 million tons, equivalent to 42.2 percent of the total 158 million tons of fish produced by capture fisheries. Just 13.4 per cent of fish production came from aquaculture in 1990 and 25.7 percent in 2000 (FAO, 2014).

In Asia, since 2008 farmed fish production has exceeded wild catch (freshwater and marine), reached 54 percent of total fish production in 2012 (FAO, 2012). In Europe, aquaculture production is 18 percent of the total and in other continents is less than 15 percent.

Nearly half (49 percent) of all fish consumed globally by people in 2012 came from aquaculture (FAO, 2014). Nigeria is the second largest aquaculture producer in Africa with farmed catfish accounted for approximately 90 percent of Nigeria's domestic annual fish production (Jubril, 2015). Available data shows a growth from 20,000 metric tons in 1994 to 96,000 metric tons in 2000 (Fagbenro *et al.*, 2003; Nwokocha & Nwokocha, 2013).

At present, human population stands at 6.4 billion, it is estimated that the world's human population will be 8.1 billion in 2030 and 9 billion in 2050, (Bamphitlhi & John, 2015). The greatest increase will occur in developing countries (Roppa, 2007). This increase will lead to an increase in animal protein requirements and demand. It has been found that increasing fish production in Nigeria is feasible through the development of fish farming, which is largely due to sustainable climate, availability of cultured fish seed and water availability, hence the potential of aquaculture is very high (FDF, 2004 and Bake *et al.*, 2015). Aquaculture has the potential to become a sustainable practice that can supplement capture fisheries and significantly contribute to feeding this world's growing population (Kathryn *et al.*, 2004). Bake *et al.*, (2015) observed the present shortage and dwindling of animal protein in Nigeria is attributed to the fact that population is continually increasing while the production of animal protein cannot cover the necessary requirement, aquaculture farming therefore, is becoming more important. Aquaculture now accounts for roughly one-third of the world's total supply of food fish and undoubtedly the contribution of aquaculture to seafood supplies will increase in the future (Bake *et al.,* 2015).

However, as in more traditional forms of animal production, nutrition plays a critical role in intensive aquaculture because it influences not only production costs but also fish growth, health and waste production (Delbert & Gatlin 2010). Akankali and Nwafili (2015) reported fish feed and fertilizer play the key role for fish production in the conventional fish culture system, representing about 60-70% of production costs. Rumsey, (1993) and Orire *et al.,* (2015) observed that feed production cost has been considered to be the highest cost in aquaculture practices today, which often ranges from 30 – 70% of total production cost. At present, a large percentage of high quality fish feeds are said to be imported, with about 45,000 metric tons imported in 2010 (FDF, 2012). Therefore, there is a need to exploit not only the known unconventional feed ingredients but also to determine and introduce new and lesser known plants and animal feed resources (Bamphitlhi & John, 2015).

## 1.2 Statement of the Research Problem

Nowadays, it is essential to increase fish production for satisfying the increasingly growing demand of protein. And fish breeding has been found pertinent in increasing fish seed available to farmers in order to help fish production system. However, one of the major constraints facing aquaculture is quality feed (Arnauld, 2016). This includes feed sources especially, protein source (fishmeal and soymeal) which present important environmental challenges (Isaac *et al.,* 2018). For instance, fishmeal has been linked to overfishing of ocean resources, and furthermore, since it is a resource dependent on catch, its production is variable both quantitatively and qualitatively (Sánchez-Muros *et al.*, 2014) and the price of fishmeal is usually high (Falaye *et al.*, 2014). The cultivation of soybeans has been linked to deforestation, high utilization of pesticides and fertilizers (Stamer, 2015). The cost effectiveness in feed production especially fishmeal as well as its unavailability has brought to notice the need to research for various alternative protein sources in feed production (Alceste, 2000 and Orire *et al.,* 2015).

i. The fish feed industry is still relying upon fishmeal and fish oil from the industrial fishing operations despite the increasing demand for food fish and the decline in capture fisheries (Elezuo, 2011).
ii. Fishmeal is used as the main dietary protein source in aquaculture, because of its known nutritional quality and palatability properties (Hardy & Tacon, 2002). And the resulting volatility in price linked to fishmeal poses risks for economic viability of the aquaculture sector (Kobayashi *et al.,* 2015).
iii. Total dependent on fishmeal as the only protein source will affect the whole operation of aquaculture system and consequently reduce the production (Arnauld *et al.,* 2016)**.**
iv. The limitation of feedstuffs of plants' origin as a result of the presence of alkaloids, glycosides, oxalic acids, phytates, protease inhibitors, haematoglutinin, saponegin, monosine, cyanoglycosides and so on, which negate growth and other physiological activities at higher level inclusion (Sogbesan, 2006).

## 1.3 Justification of the Study

Aquaculture which is one of the most rapidly increasing food production systems in the world that uses high quantities of protein sources for fish feed. Consequently, it is indispensable to investigate the alternative sources to replace conventional protein sources for human and cultured animals (Morgane, 2016). Considerable research has been conducted to evaluate the suitability of various feed ingredients as an alternative protein source for the conventional protein concentrates in aqua feed especially fishmeal and soybean meal (Nwanna, 2003; Solomon & Sadiku, 2005, Fagbenro *et al.*, 2010; Elezuo *et al*., 2011; Falaye *et al.*, 2018).

Also, it is very crucial to find an alternative replacement for fishmeal to reduce fish feeding cost and halieutics resources pressure (Monebi & Ugwumba, 2013). In replacement of the fishmeal, the proteinic sources must contain the ten essential amino acids (EAA) required for fishes (Me´dale *et al.*, 2013). Therefore, the use of insects as feed source will reduce economic and environmental costs because they can be fed by-products (Sealey *et al.*, 2011) and thus require little infrastructure or resources (Isaac, 2018). Substantial replacement of fishmeal by insect meal is possible without compromising growth, feed conversion and product quality Stadtlander *et al*., (2017). However, since fishmeal is expensive as a feed ingredient, the use of nonconventional feedstuffs has been reported with good growth and better cost benefit values (Abowei & Ekubo, 2011).

Catfish generally, belongs to the family *Claridae*, they are widely cultured owing to their fast growth rate, high yield potential, high market price, ability to grow on a wide range of artificial and natural food and ability to withstand adverse pond conditions especially low oxygen content (Odedeji, 2007; Oresegun *et al.*, 2007 and Bake *et al.*, 2015). *Clarias gariepinus* and *Heterobranchus* (African catfish) species are of high aquaculture importance in Nigeria (Odedeji, 2007). *Heterobranchus* grows faster and attain bigger size than *Clarias* which matures earlier, more adaptable and has higher fecundity (Idodo–Umeh, 2003). According to Oladosu *et al.,* (1993) and Bartley *et al.,* (2000), inter-specific hybrid fishes transfer desirable traits between species, combine desirable trait of two species into a single group of fishes. The hybrids of *Clarias* and *Heterobranchus* exhibit the fast growing quality of *Heterobranchus* reaching up to 1.0 kg under eight months in ponds and resistant to diseases (Hogendoorn, 1981; Hecht & Lublinkhof, 1985; Ajana & Anyanwe, 1995) as cited by (Odedeji, 2007). The high quality and better taste of its flesh makes it a highly demanded fish, hence there is a need to increase the local production of this specie at cheaper production cost (Sogbesan & Ugwumba 2008).

## 1.4 Aim and Objectives of the Study

### 1.4.1 Aim of the study

The aim of this research was to evaluate the suitability of shea caterpillar meal , *Cirinbutyrospermi* in practical diet of hybrid of catfish, *Clarobranchus.*

### 1.4.2 The objectives of the study

i. to evaluate the nutritive value of shea caterpillar meal (*C. butyrospermi*,).

ii. to determine the suitability of shea caterpillar meal (*C. butyrospermi*,), as a replacement of fishmeal in the practical diets of African catfish (*Clarobranchus).*

## 1.5 Statement of Hypotheses

i. There was no significant difference (P>0.05) between the growth performance of fish fed with shea caterpillar meal (*Cirina butyrospermi*,) and fishmeal as protein sources.

ii. There were no significant differences (P>0.05) in the growth performance of fish fed with shea caterpillar meal (*Cirina butyrospermi*) diets at different inclusion levels.

# CHAPTER TWO

## 2.0 LITERATURE REVIEW

### 2.1 An Overview of Nutrition in Aquaculture

Aquaculture, the farming of aquatic animals and plants, is no different from any other terrestrial farming activity, in that; production is totally dependent upon the provision and supply of nutrient inputs (Albert & Marc, 2015). Cultured fish require protein, lipids, energy, vitamins and minerals in their diet for growth, reproduction, and other normal physiological functions. These dietary requirements vary somewhat among species and within species, relative to stage of life cycle, sex, reproductive state and environment (Csaba, 2011). Feed inputs may include the use of industrially compounded feeds, farm-made aqua feeds, or the use of natural food organisms of high nutrient value such as forage/trash fish and natural/cultivated invertebrate food organisms; feeds and feeding usually representing the largest operating cost item of most fish and crustacean farming operations (FAO, 2006).

Steven and David (2017) said good nutrition in animal production systems is essential to economical production of a healthy, high-quality product. Nwokocha and Nwokocha, (2013) and Agbebi *et al*., (2009) reported that feed is without a question, the single most expensive input in intensive fish culture, especially for catfish which needs a high protein diet (being cannibalistic in nature) Agbebi *et al*., (2009). Feeding is one of the most important factors to consider in fish farming, because it contributes up to 40-65 % of fish production costs depending on the level of aquaculture intensification (Omoruwou & Edema 2011, and Bake *et al.*, 2014). Fish nutrition has advanced dramatically in recent years with the development of new, balanced commercial diets that promote optimal fish growth and health. The development of new species-specific diet formulations supports the aquaculture industry as it expands to satisfy increasing demand for affordable, safe, high-quality fish and seafood products (Steven & David, 2017).

The prominence of fishmeal in the production of animal feeds cannot be disputed; it constitutes the highest cost, thereby making the price of feed to rise exponentially (Olaniyi & Salau, 2013). In formulating nutritive diet for cultured fish, fishmeal is used as the main dietary protein source because of its high nutritional quality and palatability (Hardy & Tacon, 2002).

Fishmeal and fish oil are important feed ingredients in aquaculture, and by 2003 their consumption by the sector had increased to 2.94 million and 0.80 million tones, representing 53.2 and 86.8 percent of global production, respectively (Tacon & Metian, 2008). Naylor *et al.,* (2009) observed the farming of carnivorous fish has placed undue pressure on world fishmeal supplies by using up to five times more fish protein than that which is produced. Make it very crucial to find an alternative replacement for fishmeal, to reduce feeding cost, (Monebi & Ugwumba, 2013). Although, the choice of feed input employed by a farmer for a particular fish or crustacean species depends upon a variety of factors and considerations, with the main ones are:

i. The feeding habit and market value of the target species (i.e., herbivorous, omnivorous, or carnivorous species, higher or lower market value species) and the ability of the target species to use natural available food organisms present within the intended culture system.

ii. The culture system (earthen pond, pen enclosure, raceway, or cage) and intended stocking density (extensive, semi intensive, or intensive) of the target species.

iii. The market availability of existing commercially available formulated commercial feeds for the target species or not.

iv. The local market availability and cost of suitable feed ingredient sources and/or lower value fish species for the production of farm-made feeds; and last but not least

v. The financial resources of the farmer, and his or her ability to purchase feeds and allocate resources (in terms of credit, feeding/labor requirement, feed storage, etc.) for feeding the intended target species and culture system employed (Tacon *et al.*, 2013).

## 2.2 Aqua-feed Industry in Nigeria

Fish feed technology is one of the least developed sectors of aquaculture particularly in Africa and other developing countries of the world (FAO, 2003). Feed, being one of the major inputs in aquaculture production, it is among the fundamental challenges facing the development and growth of aquaculture in the African continent (Gabriel *et al.*, 2007). Fish feed development in Sub-Saharan Africa has not made a significant progress in aquaculture as expected (Gabriel *et al.*, 2007). Hecht (2000) as quoted by (Gabriel *et al.*, 2007), it is observed that the research on inexpensive feed ingredients has not contributed greatly to aquaculture development in Africa and suggested that more research on how best plant protein can be used as fish feed is required.

Nigeria is among the largest fish consumers in the world with over 1.5 million tons of fish consumed annually, yet its domestic fish catch is estimated at 45,000 metric tons per year (Ezenwa & Anyanwu, 2003; Jim, 2003). FDF (2008) reported the estimated population of about 174 million people, the demand for fish stood at 2055 tons, supply from aquaculture stood at 671.493 tons while deficit increased from 1404.067 in 2014 to 1444.752 tons in 2015. This shows a serious gap between demand and supply of fish. Nigeria is blessed with over 12.5 million hectares of water surface with a good percentage could be turned to gold mines if the right feeds could be produced to meet aquaculture and cage culture development (Udo & Dickson, 2017; *Ita et al.,*1985).

Nigeria aquaculture grew more than five times from 16,619 metric tons in 1995 to 85,087 metric tones in 2007 making it one of the fastest growing industries in Africa. This phenomenon growth depends heavily on feed which constitutes about 70% of production cost (Olokor, 2011). However, Nigerian feed resources as observed by Udo and Umoren (2011) have been declining due to the stagnant or diminishing output of important crops. Statistics released by FAO (2008) reported a solely dependence on imports for an expanding livestock/aquaculture industry. Of the estimated 65253 tones of fishmeal available in Nigeria in 2000, 13.4% was sourced from local production and the remaining was imported – predominantly from Norway and Denmark (Shipton & Hecht, 2005 and Udo & Dickson, 2017). This is an evident in the ever-increasing prices of feedstuff and food stuff in the country. The importation of fish and fish products is an urgent reminder that the demand for aquaculture products is at all-time high and will keep increasing. The most important question, however, are “Can aquaculture products being obtained at a competitive price when compared to imports and capture fisheries? To answer this question, aquaculture costs have to be drastically reduced.

Research has shown that most imported feedstuff can be replaced by locally available feedstuff (Agbebi *et al.,* 2009; Tacon, 1990; Gabriel *et al.*, 2007; Otubusin *et al.,* 2009; Okanlawon & Oladipupo, 2010; Faruque *et al.,* 2010 and Nwokocha & Nwokocha, 2013). This, therefore, entails the production of fish feed from locally available materials using local technology in order to reduce the cost and improve availability of feed to farms (Nwokocha & Nwokocha, 2013).

Production of high quality feeds is one of the persistent bottlenecks holding back great rapid expansion of aquaculture in Nigeria. Fagbenro *et al.,* (2003) observed feed cost constitutes about 40 to 60 percentage of the operational cost in aquaculture. This has hindered many investors from investing in aquaculture. Among the constraints face by aqua feed production in Nigeria are, high cost and scarcity of feed ingredients, particularly the protein source tops the list. In Nigeria, the aqua feed industry is dominated by few large commercial feed industries usually based in Europe, Asia or America who run local franchised industries.

Currently in Nigeria, emphasis has been placed on encouraging indigenous feed enterprises that make use of local ingredients in formulating feeds for the fish industry. The task of meeting the increasing demand for aqua feed can best be realized through increased availability of indigenous feed production.

## 2.3 Importance of Protein in Catfish Feed

Protein is the most critical and costly ingredient in aqua feed production and usually, protein sources represent about 60% or more in the cost of the feed (Gabriel *et al.,* 2014). Essential or indispensable amino acids (EAAs) cannot be synthesized by fish and often remain inadequate but are needed for growth and tissue development (Wilson *et al*., 1989).

Since fishmeal is expensive as a feed ingredient, the use of nonconventional feedstuffs has been reported with good growth and better cost benefit values. The utilization of nonconventional feedstuffs of plant origin had been limited as a result of the presence of alkaloids, glycosides, oxalic acids, phytates, protease inhibitors, haematoglutinin, saponegin, momosine, cyanoglycosides, linamarin to mention a few despite their nutrient values and low cost implications (Sogbesan *et al*., 2006).

## 2.4 Fishmeal in Fish Diet

Aquaculture is the largest overall user of fishmeal with pigs and poultry account for around a quarter of total usage, with other livestock types account for the remainder (FAO, 2009). Total estimated amount of fishmeal and fish oil used in the production of aqua feeds has grown over three-fold from 0.96 million tons to 3.06 million tones and from 0.23 million tone to 0.78 million tones, respectively, from 1992 to 2006, (Tacone *et al.*, 2006; Tacon, 2007 and FAO, 2009). The estimate of fishmeal use for aquaculture varies from 46-56 percent and of fish oil use is over 80 percent of total production. It is estimated that aquaculture sector used about 3.06 million tones or 56.0 percent of the world’s fishmeal production and 0.78 million tone or 87 percent of total fish oil production in 2006 (Tacon, 2007).

Fishmeal is known to contain complete EAA profile that is needed to meet the protein requirement of most fish species (Sogbesan *et al*., 2006). It is a prime protein source and known as a high-quality, very digestible feed ingredient (Miles and Chapman, 2006). The prominence of fishmeal in the production of animal feeds cannot be disputed but constitute the highest cost, thereby making the price of the feed to rise exponentially (Olaniyi & Salau 2013, Djissou *et al.*, 2016).

Fishmeal has large unit energy per unit weight which contains protein, lipids (oils), minerals, and vitamins. It is a generic term for a nutrient-rich feed ingredient used primarily in diets for domestic animals, sometimes used as a high-quality organic fertilizer (Caruso, 2015). It can be made from almost any type of seafood but is generally manufactured from wild-caught, small marine fish that contain a high percentage of bones and oil, and usually deemed not suitable for direct human consumption. These fishes are considered 'industrial' since most of them are caught for the sole purpose of fishmeal and fish oil production (Nugroho & Nur, 2018).

Fishmeal plays an important role ingredient for fish feed (Caruso, 2015 and Nugroho & Nur, 2018). A small percentage of fishmeal is rendered from the by-catch of other fisheries, and byproducts or trimmings created during processing (for example, fish filleting and cannery operations) of various seafood products destined for direct human consumption.

On the other hand, there is a reducing of fish production in related to the fishmeal. The use of fish from nature to produce fishmeal is a competition with human needs. Furthermore, the decrease in the availability, sustainability, and the increase in the prices of the fishmeal have stimulated the search for sustainable alternatives for aquaculture feeds. It is also stated that feeding fish to fish is useless and wasteful that because more than 6 kg of wild fish is taken up to produce 1 kg of farmed fish (Schipp, 2008). To this regard, the use of protein-based plant is an alternative way to satisfy the increasing demands of the aquaculture feed industry, to partially or totally replace of fish meal in fish diet (Nugroho & Nur, 2018).

## 2.5. Conventional and Non-Conventional Feedstuffs

### 2.5.1 Conventional feedstuffs

These are the feedstuff that are regularly used in the formulation of fish feed. Their usage is standardized and widely acceptable. Many of these are cheap and readily available in very large quantity. They are usually agro Industrial by - products. Examples include wheat bran, groundnut cake and rice bran. Some are animal based (for example, fish meal, blood meal, shrimp meal), whereas others are plant based (for example, maize, soya bean meal, cotton seed meal).

These are fish feed ingredients such as fishmeal (clupeid), maize, millet, soyabean, groundnut cake, guinea con and oil, which are directly consumed by man and also use for animal feed, (Gabriel *et al.,* 2007; and Ogunseye, 2017).

### 2.5.2 Non-conventional feedstuffs

Nonconventional feed resources (NCFRs) are feeds that are not usually common in the markets and are not the traditional ingredients used for commercial fish feed production (Devendra, 1988; Madu *et al*., 2003; Abowei & Ekubo, 2011). But their utilization is common in the rural area of Sub Saharan Africa, among low income group that are actively engaged in fish farming (Gabriel *et al.,* 2007). These feeds normally come from three sources as reported by (Gabriel *et al.,* 2007).

### i Kitchen wastes

This is being used at household level of aquaculture especially, in backyard fish farming where remnants from household wastes are used to feed the fish. These are used indiscriminately, without any standard. Examples of feed in this category are cassava and yam peels. Faturoti and Akinbote (1986) as reported by Gabriel *et al.*, (2007), recorded 20% substitution with high level of economic performance when cassava peel was fed to tilapia. Oresegun and Alegbeleye (2001) recommended addition of 0.2% methionine with 20% inclusion of cassava peel. Also kitchen remnant like bread, cooked rice and yam are commonly used in the culture of fish.

### ii Plant sources of feed

These are generally known as non-conventional plant feed stuff (NCPF). These are many and abundant, almost in every locality in Africa. Their potential and utilization in aquaculture feed have been reviewed (Wee 1988; Pantastico 1988; Igbinosun, 1991; Ugwumba & Ugwumba, 2003). Their levels of inclusion in aqua feed varies and largely depends on their availability, nutrient level, processing technique, species of fish and cultural farming pattern prevalent in the locality. There are such as low protein content (Gohl, 1981; Devendra, 1985; Oresegun & Alegbeleye, 2001; Ibiyo & Olowosegun, 2004), amino acid imbalance (Otubusin, 1987; Ayinla & Akande, 1988; Eyo, 2001) and presence of antinutritional factors (Tacon & Jackson, 1985; Faturoti & Akinbote, 1986; Oresegun & Alegbeleye, 2001).

### iii Animal sources

The non-conventional feed stuff of animal origin are high quality feed ingredients that could compare to some extent with the conventional types. These are cheaper by virtue of the fact that there is no competition for human consumption. However, the only problem with these feed stuffs is their unavailability in large commercial quantities for the sustenance of aquaculture industry. In most parts of Africa, these are available in small quantities and their production is inconsistent and sporadic in nature. Examples include tadpole meal, maggots, earthworm meal, housefly larvae among others etc. (Anunne 1990; Faturoti *et al.,* 1998; Ugwumba & Abumoye 1998; Ugwumba *et al.,* 2001; Akinwande *et al.,* 2002; Ibiyo & Olowosegun, 2004).

## 2.6 Insect-Based Protein in Animal Feeds

Aquaculture provided only 7% of fish for human consumption in 1974, this share had increased to 44% by 2014 (FAO 2016). In 2014, about 10% of total fish produced (captured and aquaculture) was reduced to fishmeal and fish oil. Fishmeal is made from small wild-caught marine fish that contain a high percentage of bones and oil, and are usually deemed unsuitable for direct human consumption (Van & Oonincx, 2017). Fishmeal is a high-quality feed ingredient for pigs, poultry, and aquaculture and is used extensively. However, it is becoming increasingly scarce and expensive (Van and Oonincx, 2017; Falaye *et al*., 2014). This is partially the result of overexploitation of wild fish stocks (more than 30% of fish stocks in 2013) (FAO 2016; Elezuo, 2011). With reference to Van and Oonincx, (2017) it was reported that between 1988 and 2010, the poultry sector decreased the use of fishmeal from 60 to 12% of the total available amount, whereas the aquaculture sector increased its use of fishmeal from 10 to 56% in the same period. Although increasing fishmeal prices have led to lower inclusion percentages in aqua feed, this effect is offset by the rapid growth of the aquaculture sector (Olsen & Hasan, 2012; Msangi *et al.*, 2013). This triggered the search for alternative sources, for instance the use of plant material. Plant sources have a number of drawbacks such as lower protein content and the presence of anti-nutritional factors, which reduce nutrient availability and counteract with vitamins (Olsen & Hasan, 2012). These drawbacks can partly be mediated by chemical and mechanical processing (Hall, 2015).

However, certain insect species might also serve as alternative protein sources without these drawbacks, in particular the black soldier fly Hermetia illucens (L.) (Diptera: Stratiomyidae). Tests conducted with Atlantic salmon showed that complete replacement of fishmeal had no adverse effects on net growth of the fish, histology, odor, flavor/taste, and texture (Lock *et al.*, 2015). Similarly, meal made from the black soldier fly is a suitable protein source for a number of other farmed fish species, such as African catfish *Clarias gariepinus* (Adeniyi & Folorunsho, 2015; Anvo *et al.*, 2016), channel catfish *Ictalurus punctatus*, and blue tilapia *Oreochromis aureus* (Bondari & Sheppard, 1987).

Srivastava *et al*., (2009) reported insects are believed to have a higher proportion of protein and fat than beef and fish with a high energy value. Depending on the species, caterpillars are rich in minerals such as potassium, calcium, magnesium, zinc, phosphorus and iron, as well as, various vitamins (Bamphitlhi & John, 2012). For instance, mophane worms

[*Imbrasia belina* (Westwood)] have a higher protein, fat, carbohydrate and mineral content than beef and chicken (Jurgens, 2002 and Akpalu *et al.,* 2007).

Anand *et al.,* (2008) reported the protein content of *acridids* ranges from 60 to 66%, indicating that the protein content of *acridids* is higher than that of soybean meal (48%) and fishmeal (50 to 55%). Hassan *et al*., (2009) fed 0%, 50% and 100% grasshopper meal to broiler chickens and reported that it was capable of replacing significant quantities of fish meal in broiler diets. In addition, (Finke *et al.,* 1985) fed Mormon crickets (Anabrus simplex Haldeman) diet to broiler chicks and found that it compared favorably with a corn-soybean meal diet with no significant differences in weight gain or feed/gain ratios. Wang and Shelomi (2017) reported replacing a proportion of plant-derived protein within a given diet with fly larvae could produce birds of equal or higher quality, compared to those reared on conventional feed. The use of live fly larvae to supplement the diet of rural chickens showed high growth rate of chicken as well as size and egg weight (Dahiru *et al.,* 2016).

Furthermore, Fashina-Bombata and Balogun, (1997) and Ajani *et al.,* (2004) reported fed fly maggot meal to Nile tilapia (*O. niloticus*) and found that fly maggot was capable of replacing fishmeal up to 100%. The crude protein content of insects ranges from 40 to 75% on dry weight basis, with beneficial amino acid profile, and a variable fat content (Verkerk *et al.,* 2007). Insects are also valuable sources of minerals and vitamins (Finke, 2013).

Isaac *et al.,* (2018) observed that the fishmeal trap has become a common term in aquaculture expressing the concern that future growth in aquaculture could be constrained by limited marine resources. Five major insect species including the black soldier fly, common housefly, mealworm, locusts and silkworm have attracted interest in academic and industry research. The use of insects as feed source is known to reduce economic and environmental costs because they can be fed by-products (Sealey *et al.,* 2011) and require little infrastructure or resources.

Stadtlander *et al.,* (2017) demonstrated that substantial replacement of fishmeal by insect meal is possible without compromising growth, feed conversion and product quality. In the quest for sustainable feed for aquaculture which currently represents more than half of the World's fish supply, insects may be seen as a substantial part of the answers to the feed supply challenge (Isaac *et al.,* 2018). The sources of plant proteins, because of their very great availability, were the subject of several studies in the replacement partial or total of the fishmeal in the food of several fish species (Imorou *et al.,* 2008, and Richter, 2003). Moreover, the sources of animal proteins like the termites, earthworms, the tadpoles, the snails, the maggots were used in the replacement of the fish meal with various conclusions (Monebi & Ugwumba, 2013; and Madu & Ufodike, 2003).

## 2.7 Nutritional Quality of Shea Caterpillar, *Cirina butyrospermi*

The shea caterpillar, *Cirina butyrospermi*, which feeds exclusively on shea leaves, is very rich in proteins (Dabire, *et al.,* 2017). It is therefore a source of protein in human food and is consumed by many ethnic groups in Nigeria and elsewhere in Africa (FAO, 2013). According to Morgane *et al.,* (2016)**,** crude protein percentage of *C. butyrospermi* caterpillar in his work was 62.74 % which is similar to 63 % obtained for the same species by (Ouedraogo, 1993). And this protein content was higher than the values of 20.2 %, 48.70 % and 52.39 % obtained respectively by (Banjo, *et al.,* 2006; Ogunleye & Omotoso, 2005; and Badanaro, 2014), for *Cirina forda*. Thus this protein was not within the range of 15 to

60 % reported for various forms of edible insects of *Lepidoptera* order from the state of Oaxaca Mexico (Ramos, 1997).

Furthermore, it was reported that protein, lipid and ash contents were within the range established for tropical Africa *Saturniidae* (Malaisse, 2003). Since insects have high feed conversion efficiency (Verkerk *et al.*, 2007; and Labandeira, and Sepkoski, 2015). Chitin is a major crude fiber in insects (Lindsay *et al.*, 1984).

Shea caterpillar *C. butyrospermi* is heavily consumed in Nigeria (Fasoranti & Ajiboye, 1993, Agbidye & Nongo, 2009). As a protein source, caterpillars from butterflies and moths are consumed by several tribes across the world. These include the Pedi of South Africa, the Bisa of Zambia, the Tiv of Nigeria, the Nanti of the Amazon, the Amacimbi of Zimbabwe and the Aka pygmyof Central African rainforest (Mbata & Chidumayo, 2003, Agbidye & Nongo, 2009).

**Table 2.1: Nutrient Contents of Dried *Cirina butyrospermi* by Various Researchers**

| Description (%) | Morgane *et al.*, (2016) | Agbidye *et al.*, (2009) | Yapo *et al.*, (2017) |
|---|---|---|---|
| Crude protein | 62.74 | 74.35 | 55.41 |
| Lipid | 14.51 | | |

| | | | |
|---|---|---|---|
| Ash | 5.10 | 3.10 | 4.89 |
| Nitrogen Free Extract | 12.63 | 2.36 | |
| Fibre | 5.02 | 6.01 | 2.68 |

## 2.8 Why the Use of Insect?

Although, considerable emphasis has been focused on the use of conventional plant protein sources, such as soybean (Nyirenda *et al.,* 2000; Koumi *et al.,* 2009), groundnut (Ovie & Ovie 2007), cotton seed (Mbahinzireki *et al.,* 2001; El-Saidy & Gaber, 2003) and rapeseed meal (Burel *et al.,* 2000), however, their scarcity and competition from other sectors for these conventional crops for livestock and human consumption as well as industrial use make their costs too high and put them far beyond the reach of fish farmers or producers of aqua feeds (Fasakin *et al.,* 1999). And currently, the potential of insect-based protein has attracted much attention not only farmers but also researchers. It seems there are few reasons that can consider in related to the use of insect (Nugroho & Nur, 2018).

One of the main reasons why insects are considered as potentially sustainable sources of animal protein is because of their high feed conversion efficiency (Nakagaki & Foliart 1991; Berenbaum 1995; Gullan and Cranston 2005; Ramos-Elorduy 2008; Premalatha *et al.,* 2011; Looy *et al.,* 2013). The reason for this expectation is that insects are poikilothermic, however, does not necessarily lead to greater efficiency. High efficiency requires optimal diets and therefore knowledge of the nutritional requirements of insect species needs to be established. Furthermore, much like in conventional farming, genetic selection can further help to create efficient strains. There are, however, indications that several insect species accumulate protein very efficiently (Oonincx *et al.*, 2015). Whereas poultry provided with optimized diets converts 33% of dietary protein to edible body mass, yellow mealworms utilize 22–45% of dietary protein, black soldier fly larvae about half (43–55%), and Argentinean cockroaches 51 to 88%. The latter species is able to do so by using endosymbionts. These data illustrate that the starting level of protein efficiency, without optimizing genetic background or diets, is already high compared to conventional livestock.

Moreover, the sources of animal proteins like the termites, earthworms, the tadpoles, the snails, the maggots were used in the replacement of the fish meal with various conclusions (Monebi & Ugwumba, 2013; and Fiogbé 2004). According to Nugroho and Nur (2018), the insects such as crickets, caterpillars and silkworms could be the good source of food in the future. Insects, an edible food that contains protein, vitamins and important amino acids are efficient to be reared. Insects only need six times less feed than cattle and can be cultivated by using organic waste. As consequences, insects produce fewer greenhouse gasses emission (100-1000x) (Frangoul, 2016). The others reasons that could be used as consideration are insects has high feed conversion rate (FCR), low use of water and energy, and nutritious as source of essential protein as well as amino acids for animal feed (Józefiak *et al.*, 2016).

## 2.9 Substitution of Fishmeal in Fish Diet

As fish demand continues to grow, the strategies to increase fish productivity need to be developed. The research based on eco-friendly and sustainable commercial aims should also be strategized to assist aquaculturists in increasing fish productivity (Nugroho & Nur, 2018). In the development and management of an aquaculture enterprise, fish feed plays a vital role in its growth and expansion and constitutes 40–65% of the operational cost in the intensive and semi-intensive aquaculture system (Arnauld, 2016**,** Gabriel *et al.*, 2014, and Jabir, 2012).

Although fishmeal is the principal ingredient of aqua feed, which is often used like principal source of proteins because of its high percentage of proteins and its composition in amino acids meeting the fish requirements (IIuyemi, 2010 and Arnauld, 2016). Its uses leads to a strong pressure of the man on the aquatic environments and thus of the production related to the captures. The resulting volatility in price linked to fishmeal poses risks for economic viability of the livestock sector (Kobayashi *et al.*, 2015). According to Lang *et al.*, (2009), 1 kg of farmed fish is produced from 2–5 kg of wild caught fish. Schipp (2008) stated that feeding fish to fish is useless and wasteful because more than 6 kg of wild fish is taken up to producing 1 kg of farmed fish. To this regard, the use of protein-based plant is an alternative way to satisfy the increasing demands of the aquaculture feed industry, to partially or totally replace of fishmeal in fish diet (Nugroho & Nur, 2018).

The demand for aqua feeds continues to increase, yet the overall global supply of fishmeal and fish oil is relatively fixed (SEAFEEDS, 2003). This implies that there will be increased pressure on the fisheries that supply these commodities unless substitutes become both available and widely accepted (FAO, 2009). It is therefore, crucial to reduce or substitute totally the use of fishmeal in fish diet by replacing it with alternative protein sources because total dependence can affect the whole operation of aquaculture system and consequently reduce the production (Arnauld, 2016).

# CHAPTER THREE

## 3.0 Materials and Methods

### 3.1 Study Location

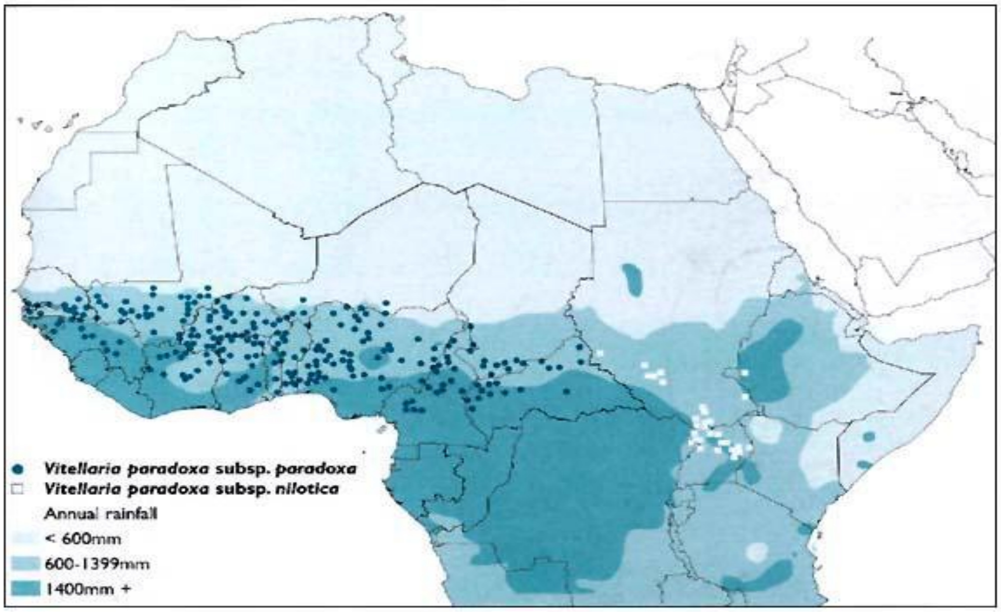


**Plate I:** Shea Trees Distribution in West Africa.
Source: (Hall *et al.*, 1996)


**Plate II:** Shea Trees Distribution in Nigeria.
Source: (Hall *et al.*, 1996)

## 3.2 The Shea Caterpillar, *Cirina butyrospermi*

The forest and its by-products, in addition to timber, firewood and charcoal are of vital importance to the rural population (Agbidye *et al*., 2009). These include various vegetables and fruits, mushrooms, edible insects etc (Agbidye *et al*., 2009; Adeduntan & Bada, 2004; Akanbi & Ashiru, 2002; Latham, 2001). Non-timber forest products are important for food security, health, social and economic welfare of rural communities.

*Cirina butyrospermi*, the pallid emperor moth or shea defoliator, is a moth of the family Saturniidae.The species was first described by John O. Westwood in 1849 as *C. forda* and as C. *butyrospermi* by Vuillet (1911). It is found in western Africa, including Nigeria, Ghana, Zimbabwe, the Democratic Republic of the Congo and South Africa. The adults are pale creamy brown with a small darker spot on each hind wing but lacking true eyespots. There is one generation per year.

### 3.2.1 Scientific classification *Cirina butyrospermi*

| | | |
|---|---|---|
| Kingdom: | Animalia | |
| Phylum: | Arthropoda | |
| Class: | Insecta | |
| Order: | Lepidoptera | |
| Family: | Saturniidae | |
| Genus: | *Cirina* | |
| Species: | ***forda*** | (Westwood, 1849) |
| | ***Butyrospermi*** | (Vuillet, 1911) |

**Plate III:** Shea caterpillar larva *Cirina butyrospermi* on the shea butter tree, *Vitellaria paradoxa* (Adapted from Wikipedia)

**Plate IV:** Excavated pit (pitfall trap) at the base of an infested *V. paradoxa* tree to trap descending *C. butyrospermi* larvae (Agbidye & Nongo, 2009)

**Plate V:** Trapped *C. butyrospermi* larvae in a pit dug around the base of *V. paradoxa* tree (Agbidye & Nongo, 2009).

**Plate VI**: Harvested Shea caterpillar larva (Agbidye & Nongo, 2009).

### 3.3 Collection and Processing of Shea Caterpillar *Cirina butyrospermi*,

*C. butyrospermi*larva is collected from the shea butter tree, *Vitellaria paradoxa*, its only host in Nigeria and throughout the West African sub region (Agbidye & Nongo**,** 2009). The eggs are found on the host plant from May to June and the larvae from June to August each year. The larvae are particularly harvested from shea butter trees in July and August each year (Odeyemi & Fasoranti, 2000; Ande & Fasoranti, 1997). The larvae are either collected from the leaves on the trees or pitfall traps made round the bases of trees with the larvae and descending larvae trapped and collected (Mbata & Chidumayo, 2003; Fasoranti & Ajiboye, 1993). These Caterpillars are either pushed inside out with a thin stick or punctured and the contents squeezed out. Frequently, and especially if large quantities are harvested, they are boiled and dried out in the sun and stored for later use or sold in the local markets. The insect is widely used as an ingredient in vegetable soup (Fasoranti & Ajiboye, 1993). *C. butyrospermi* known as Kontoro in Nupe, Monimoni or Ikanni in Yoruba and 'Igyô' in Tiv, is reported to be widely consumed and marketed in Nigeria (Agbidye *et al.*, 2009).

### 3.4 Experimental Fish

Four hundred and fifty (450) hybrid of African catfish *Clarobranchus* fingerlings were collected from fish farm, Ikhlas Agro Farm Ltd, Oke-Oyi, Ilorin-East, Kwara State, The fish were acclimatized in a (50x30x20cm) rectangular white plastic bowls for a week and fed with commercial fish feed (Strektins) throughout the week of acclimation.

### 3.5 Experimental design

The experiment consisted of five treatments with a commercial reference diet, each in three replicates in a complete randomized design. Each bucket was stocked with twenty hybrid catfish *Clarobranchus* fingerlings.

### 3.6 Experimental Set-up

The experimental set-up consists of eighteen white plastic bowls (50cm x 30cm x 20 cm) installed in a wooden frame. The frame was nailed and brazed firmly to prevent it from collapse.


**Plate VII:** Experimental set-up

## 3.7 Preparation of Feed Ingredients

### 3.7.1 Fishmeal

Danish brand fishmeal was procured from Admumsho Nig. Ltd, Gbagba Phase II, Sango Area, Ilorin, Kwara State.

### 3.7.2 Shea caterpillar *Cirina butyrospermi*

The biological material, shea tree caterpillar *Cirina butyrospermi* was bought from Ishau market, Paikoro Local Government Area of Niger State.

Four kilogram (4kg) of the caterpillars (*Cirina butyrospermi*) bought was sorted and cleared of all kinds of plant debris and stones. It was dried in the sun for some days and place in an oven at 65 ° C for 72 hours and then grinded with machine in the feed mill to obtain the caterpillars' flour.

## 3.8 Nutritional Value of Caterpillar Meal

### 3.8.1 Crude protein

0.5 g of milled sample was weighed in to 250 ml kjeldahl flask; 20 ml of concentrated sulphuric acid was added. 0.5 g mercuric oxide/potassium sulphate catalyst was added; the sample was then transferred to a digestive bock set at 350 $^{0}$C and was allowed to digest until the sample becomes clear or colourless. After digestion the sample allowed to cool, thereafter distilled water was used to make –up to 100 ml using a 100 ml volumetric flask, 10 ml of 40% NaOH was added. To the receiving container 10ml of boric acid was mixed with 2 drops of indicator (bromocresol green and methyl-red) and placed under the condenser until 50 ml of the distillate was collected. The distillate was titrated against 0.1

ml HCL to sharpened point. The crude protein value was obtained using the formula in equation 1.

$$\% \text{ C.P} = \frac{TV \times 0.1 \times 0.014 \times 10 \times 100 \times 6.25}{W} \text{ ........................................ equation 1}$$

Where: TV= Titer value

0.1 = Morality

0.014 = Nitrogen conversion factor.

10 = Dilution factor, 100 = Percentage

6.25 = Protein conversion factor, W = weight of the sample (g).

### 3.8.2 Lipid

Soxhlet extraction method was used by taking the weight of the filter paper; 1g of the sample was weighed, recorded plus the weight of the filter paper. The sample was wrapped and placed inside the soxhlet apparatus for extraction. Petroleum ether was added to continuously extract the fat content at 40$^0$C of the heat until the petroleum ether had siphoned over the barrel. The sample was removed from the flask and oven dry at 100 $^0$C for 5 minutes, the sample was removed and put in desiccators and allowed to cool. Each sample was weighed, recorded and calculated to give lipid percentage, using equation 2.

$$\% \text{ Lipid} = \frac{W2 - W3}{W2 - W1} \times 100 \text{ ........................................................ equation 2}$$

Where:

W1 = Weight of the filter paper

W2 = weight of filter paper + sample

W3 = Weight of the filter pa per + sample after extraction.

### 3.8.3 Moisture content

The indirect distillation method was used by weighing the Petri-dish, 5 g or 10g of the sample was weighed and oven dry at 100 $^0$C for 12hours, and then was allowed to cool in desiccators before reweighing, and equation 3 was used to obtain the moisture content

% M.C = $\frac{W2-W3}{W2-W1} \times 100$ …………………………………………............ equation 3

Where: $W_1$= weight of the Petri-dish

$W_2$= Weight of the Petri-dish + sample

$W_3$= weight of the Petri – dish and sample after heating.

### 3.8.4 Ash

Ash constitutes the residue remaining after all the moisture has been removed as well as the organic materials have been burnt away. The Gooch crucible was weighed and 2 g of the sample was weighed together with the crucible then put inside the muffle furnace and heat at 550 $^0$C for 30-45 minutes until a white or light grey coloured ash results. Then the sample was removed and put inside the desiccators to cool and reweigh. And the equation 4 was used to obtain the ash value.

% Ash = $\frac{C-A}{B-A} \times 100$ ………………………………………………… equation 4

Where:

A = Weight of the Gooch crucible

B = Weight of Gooch crucible + sample

C = weight of the crucible + sample after heating

### 3.8.5 Crude fibre

Crude fibre includes materials that are indigestible in human and animal organisms. 2 g of the sample was weighed, put inside 250 ml conical flask containing 20ml of diluted $H_2SO_4$ and was heated for 30 minutes, and wash again and put inside Gooch crucible to oven dry at 100 $^0$C for 15minutes, then the weight was taken and put inside the muffle furnace and heat at 400 $^0$C for 15 minutes and was allow to cool in desiccators before it was reweighed. Crude fiber was calculated using equation 5.

$$\% \text{ CF} = \frac{W_2 - W_3}{W_1} \times 100 \quad \text{…………………………………………………….. equation 5}$$

Where: CF= Crude fibre

$W_1$= Weight of the sample

$W_2$= Weight of sample and Gooch crucible

$W_3$ = weight of the sample and Gooch crucible after heating

## 3.9 Evaluation of Growth Parameters

Growth performance and nutrient utilization were analyzed in terms of Final Weight Gain (FWG) using equation 6. Feed Efficiency percentage (FE %) was calculated with equation 7. Specific Growth Rate (SGR), Feed Intake (FI), Protein Efficiency Ratio (PER), Apparent Net Protein Utilization (APNU) and percentage survival rate (% SR) were obtained using equation 9, 10, 11, 12 and 13 respectively. These parameters were calculated with the following formulae described and used by various researchers, Halver (1989), Bondi (1989) and Maynard *et al.*, (1979)as reported by Bake *et al.*, (2014).

Final weight gain $= \frac{\text{final weight (g)} - \text{initial weight (g)}}{\text{intial weight (g)}}$ .................. equation 6

Feed efficiency (%) $= \frac{\text{weight gained (g)}}{\text{feed fed (g)}} \times 100$ .............................. equation 7

Percentage weight gain $= \frac{\text{initial weight(g)}}{\text{final weight (g)}} \times 100$ .......................... equation 8

Specific growth rate (%)$= \frac{\text{In final weight (g)} - \text{In initial weight (g)}}{\text{feeding period (Day)}} \times 100$ ....... equation 9

(Brown, 1957)

Feed intake (mg/fish/day)$= \frac{\text{feed feed (g)/Number of fish}}{\text{feeding period (Day)}}$ .................. equation 10

Protein efficiency ratio$= \frac{\text{wet body gain (g)}}{\text{protein intake (g)}}$ ......... equation 11 (Osbome *et al.*, 1919)

Apparent Net Protein Utilization (APNU)$= \frac{\text{P2} - \text{P1}}{\text{Total Protein intake}} \times 100$...equation 12 (Bender and miller, 1953)

Where:

P1 is the Initial Carcass Protein before the fish was fed experimental diet

P2 is the final Carcass Protein after the fish was fed experimental diet

Survival rate (%) $= \frac{\text{number of fish stocked} - \text{mortality}}{\text{number of fish stocked}} \times 100$ .......... equation 13

### 3.10 Other Feed Ingredients

Maize, rice bran and vitamin premix were purchased from the same fish feed store in Ilorin.

### 3.11 Commercial Reference Diet

One catfish commercial reference diet (CRD), Blue Crown was used as commercial reference, and was designated as DVI.

### 3.12 Experimental Diet

Five different diets with varying inclusion level were formulated and pelletized with shea caterpillar, fishmeal, yellow maize, rice bran with vitamins premix. The inclusion levels of Shea Caterpillar Meal (SCM) as a replacement for Fishmeal (FM) was as designated bellow:

**Diet I** (0% SCM, 100 FM);

**Diet II** (25% SCM, 75% FM);

**Diet III** (50:50 SCM /FM);

**Diet IV** (75% BNM, 25%FM)

**Diet V** (100% SCM, 0% FM).

**Diet VI** (Blue Crowm – Commercial Reference Diet).

**Table 3.1: Proximate Composition Of Ingredients Used For The Experimental Diet (Dry Basis)**

| Composition (%) | FM | SCM | MM | RBM |
|---|---|---|---|---|
| Crude protein | 72 | 65.68 | 10.06 | 11.03 |
| Ash | 6 | 3.01 | 0.49 | 10.30 |
| Lipid | 10 | 12.34 | 10.92 | 11.50 |
| Moisture | 9 | 15.81 | 10.03 | 7.20 |
| Crude fibre | 0.00 | 3.70 | 0.44 | 13.60 |

**FM:** Fishmeal, **SCM:** Shear caterpillar meal, **MM:** Yellow maize meal, **RBM:** Rice bran meal

### 3.13 Proximate Composition of Some Ingredients Used For The Experimental Diets (Dry Basis)

The proximate analysis results for some feed ingredients used in the formulation of the experimental diets is shown in Table 3.1 and indicated that Shea caterpillar meal is lower in crude protein (65.68 %), compare to that of Danish fishmeal with high crude protein (72.00%). The lipid content of SCM used in the diets formulation was 12.34 %, which was higher than that of Danish fishmeal, 10.00 %. The percentage composition of the ingredients used in the diets formulation is shown in Table 3.1a, indicated that the DI had 0 % and 100 % inclusion level of SCM and FM respectively; DII had 25 % and 75 % inclusion level of SCM and FM respectively; DIII had 50 % and 50 % inclusion level of SCM and FM respectively; DIV had 75 % and 25 % inclusion level of SCM and FM respectively; while DIV had 100 % and 0% inclusion level of SCM and FM respectively. The commercial reference feed, DVI had crude protein 45.00 % and 8.00 % lipid content.

**Table 3.2a: Inclusion Level, in Percentage of Ingredient Used in Shea Caterpillar Diets at 40% Crude Protein**

| IGREDIENTS | DI | DII | DIII | DIV | DV | DVI (CRD) |
|---|---|---|---|---|---|---|
| SCM% | 0.00 | 11.80 | 23.60 | 35.39 | 47.19 | |
| FM% | 47.19 | 35.39 | 23.60 | 11.80 | 0.00 | |
| RB% | 23.91 | 23.91 | 23.91 | 23.91 | 23.91 | |
| MM% | 23.91 | 23.91 | 23.91 | 23.91 | 23.91 | |
| VIT PREM% | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | |

**N.B: 3% is reserved for Vitamins and Premix and MM and RB are in 1:1.**

**Table 3.2b: Proximate Composition of Experimental Diet Fed Experimental Fish For 56 Days**

| | Diets | | | | | |
|---|---|---|---|---|---|---|
| **Composition (%)** | **DI** | **DII** | **DIII** | **DIV** | **DV** | **DVI (CRD)** |

| | | | | | | |
|---|---|---|---|---|---|---|
| Crude Protein | 39.07 | 38.78 | 37.65 | 37.56 | 37.19 | 40.00 |
| Crude fibre | 4.70 | 4.98 | 5.01 | 5.41 | 5.87 | 4.00 |
| Ash | 9.34 | 10.91 | 11.41 | 10.76 | 12.13 | 8.00 |
| Moisture | 6.19 | 6.39 | 6.87 | 7.37 | 7.52 | 8.00 |
| Lipid | 10.73 | 10.84 | 9.47 | 9.87 | 9.54 | 8.00 |
| NFE | 29.28 | 28.02 | 27.99 | 28.03 | 27.31 | 18.54 |

**Where DVI represented Commercial Diet Reference (CRD) which is Blue crown**
**Source: (Blue Crown, 2019)**

### 3.14 Proximate Composition of Experimental Diets Fed Experimental Fish for 56 Days

The Proximate composition of experimental diet fed experimental fish presented in Table 3.2b showed that crude protein was highest in DI (39.07 %) and lowest in DV (37.19 %). Crude fibre was highest in DV (5.87 %) and lowest in DI (4.7 %). Ash level was lowest in DI but highest in DV, 9.34 % and 12.13 % respectively. Diet DI of the experimental diet has the lowest moisture content (6.19 %), while diet DV has the highest (7.5 %). Similarly, diet DII has the highest lipid content of 10.84 % while diet DIII has the lowest of 9.47 %.

These diets were fed to the experimental fishes at 3% body weight per day and later adjusted as the fish grows. Water exchange was done on a daily bases with the siphoning of feacal matter and uneaten feed. And water quality parameters was also monitored on weekly bases for temperature using clinical thermometer, dissolved oxygen according to the method of winker’s (21, 22), hydrogen iron concentration (pH) with EIL 7045/46 pH meter in the laboratory at room temperature while conductivity was monitored by the use of conductivity meter.

### 3.15.0 Water quality parameters measured

Water quality is the totality of physical biological and chemical parameters that affect the growth and welfare of cultured organisms. Quality of water is, therefore, an essential factor to be considered when planning for high aquaculture production as it determines the health along with the growth conditions of the cultured fishes. Fish perform all their activities in water, because fish are totally dependent upon water to breathe, feed, reproduce, grow, excrete waste and maintain salt balance. The following water quality parameters will be observed according to APHA (1980)

### 3.15.1 Dissolved oxygen

Samples of water were collected in dissolved oxygen bottles without allowing bubbles of water in to it. 2ml of reagent I (magnesium sulphate) was added. The bottle corked to allow precipitation to settle, after then 2ml of concentrated sulphuric acid was added to dissolve the precipitate while a yellow dissolution formed. 10ml of solution was measured in a conical flask and 2.3 drops of starch solution added as an indicator and mixture turn to blue-black colour was titrated with 0.025 sodium thiosulphate until it turns colourles (APHA.1980), the DO value was obtained using equation 14.

DO (mg/l) = $\frac{\mathrm{TV} \times 0.025 \times 8 \times 1000}{\mathrm{V}}$ ………………………………………. Equation 14

Where: TV= Titer value

0.025 = Molarity of sodium thio suphate

8 = Equivalent weight of oxygen

100 = conversion to milligram per litre

V = Volume of the sample

### 3.15.2 Temperature ($^{0}$C)

The temperature of water was measured using mercury thermometer by dipping the thermometer inside water for five (5) minutes and the temperature will be recorded (APHA.1980).

### 3.15.3 Conductivity (Ns/Cm)

The conductivity of the water was measured using conductivity meter by inserting the meter probe in to the sample water and the results recorded.

### 3.15.4 Total alkalinity

The alkalinity of the water samples was determined by taking 50ml of the sample using measuring cylinder in a clean conical flask , 2 drops of methyl orange indicator was added and shaken thoroughly. Titrated using 5ml pipette with 0.02N sulphuric acid until the colour of the solution changed from yellow to orange, total alkalinity was derived with equation 15.

Total Alkalinity (mg/l) = $\frac{\mathrm{TV}\times 0.02\times 50000}{\mathrm{V}}$ ………………………… Equation 15

Where: TV = Titer value

0.02 = molarity of the acid

V = volume of the sample

### 3. 15.5 pH

The parity of positive hydrogen particles (H+) and negative hydroxide particles (OH-) in water decides how acidic or alkaline the water is. pH model PHS-25 operated electronic meter was used to determine the pH of the water sample. Buffer solution was used to standardize the pH meter, the electrode was rinsed with distilled water and dipped into the water sample until the screen showed a fixed reading which is noted and recorded according to the methods of (APHA. 1980).

### 3.16 Statistical Analysis

Data obtained were subjected to one way analysis of variance (ANOVA) using Turkey's test (Steel, 1981; Zar 1984) at 5% probability level. Multiple parameter means comparison of treatments was according to Duncan multiple range tests (Duncan, 1955). All statistics analyses including regression were executed using the software Minitab Release 14 and graphical analyses will be plotted with Microsoft Excel Window 2007.

# CHAPTER FOUR

## 4.0 RESULTS

### 4.1 Growth Performance, Nutrient Utilization and Body Parameters of Hybrid *Clarobranchus* Fingerlings Fed Different Inclusion Levels Shea Caterpillar Meal (SCM)

There was no significance difference (P>0.05) in the mean initial weight of the fish used for the experiment. However, there was significant difference (P<0.05) in the mean final weight, the final mean weights varied between 16.48 g - 20.34 g. Fish fed diet (DV) had the least mean final weight (16.48 g), while fish fed diet (DI) had the highest mean final weight (20.34 g), followed by the fish fed diet DII (20.03g). Similarly, there was significant difference ($P<0.05$) in the mean body weight gain, fish fed diet (DI) had the highest mean body weight (16.84 g) and the least was DV (12.96 g).

In the specific growth rate, there was significant difference ($P<0.05$), fish fed diet DII (2.70 %) and diet DV (1.29 %) had the highest and the lowest respectively. Feed conversion ratio is significantly difference ($P<0.05$), fish fed diet DV had the highest (6.81 %) while the least was DII (0.58 %). There was also significant difference ($P<0.05$) in protein efficiency ratio among the treatments, diet DI had the highest (2.89%), and diet DV has the least protein efficiency ratio (1.46%). The survival rate of the experimental fish was significant difference ($P<0.05$), the fish fed DII had the highest survival rate, (95.00%), while diet DVI, which was commercial reference diet (CRD) had the least (83.33%).

There was no significant difference ($P>0.05$) between the MWG, SGR, FCR and PER of diets I and II, this shown that the fish was able to digested and converted the diets into body tissue with same degree of efficiency. However, the MWG, SGR, FCR and PER of diets III, IV and V was significant difference ($P<0.05$). There was significant difference ($P<0.05$), in the apparent net protein utilization (ANPU) of the experimental fish, as diet VI (CRD) has the highest 25.77±1.00, followed by diet VII (CRD) 22.05±0.36. While the experimental diets, DI and DII had the least ANPU 3.13±0.04 and 7.62±0.55 respectively.

**Table 4.1: Mean Growth Parameters, Nutrient Utilization and Body Parameters of Hybrid *Clarobranchus* Fingerlings Fed Different Inclusion Levels of Shea Caterpillar Meal (SCM)**

| DIETS | MIW | MFW | MWG | SGR | FCR | PER | SR | ANPU |
|---|---|---|---|---|---|---|---|---|
| DI | 2.50±0.0$^{a}$ | 20.34±0.5$^{a}$ | 17.84±0.6$^{a}$ | 2.63±0.1$^{a}$ | 0.62±0.0$^{a}$ | 2.59±0.1$^{a}$ | 89.00±5.00$^{b}$ | 13.13±0.04 |
| DII | 2.57±0.8$^{a}$ | 20.03±0.7$^{a}$ | 17.46±0.6$^{a}$ | 2.70±0.1$^{a}$ | 0.58±0.0$^{a}$ | 2.55±0.1$^{a}$ | 95.00±5.00$^{a}$ | 15.62±0.5 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| DIII | $2.47\pm0.0^{a}$ | $18.14\pm0.7^{b}$ | $15.67\pm0.1^{b}$ | $2.11\pm0.1^{b}$ | $0.89\pm0.1^{b}$ | $1.97\pm0.2^{b}$ | $90.00\pm5.00^{b}$ | 18.40±1.7 |
| DIV | $2.52\pm0.6^{a}$ | $17.01\pm0.3^{c}$ | $14.49\pm0.3^{c}$ | $1.64\pm0.2^{e}$ | $1.93\pm0.9^{d}$ | $1.63\pm0.1^{c}$ | $90.00\pm5.00^{b}$ | 18.91±0.2 |
| DV | $2.52\pm0.0^{a}$ | $16.48\pm0.19^{d}$ | $13.96\pm0.1^{d}$ | $1.29\pm0.3^{f}$ | $6.81\pm4.5^{e}$ | $1.46\pm0.0^{c}$ | $85.00\pm8.86^{c}$ | 17.17±0.5 |
| DVI | $2.55\pm0.0^{a}$ | $18.28\pm0.0^{c}$ | $15.73\pm0.1^{b}$ | $2.04\pm0.1^{c}$ | $0.93\pm0.1^{b}$ | $2.12\pm0.0^{b}$ | $86.00\pm5.77^{c}$ | 22.05±0.3 |

**Values in the same column with different superscript letters are significantly different (p<0.05) from one another.**

**MIW:-**Mean Initial Weight **DI**:- 0% inclusion of shea caterpillar meal **SR:-** Survival Rate

**MFW:-**Mean Final Weight **DII**:- 25% inclusion shea caterpillar meal

**MWG:-**Mean Weight Gain **DIII:-** 50% inclusion shea caterpillar meal

**SGR:-**Specific Growth Rate **DIV:-** 75% inclusion shea caterpillar meal

**FCR:-**Feed Conversion Ratio **DV:-** 75% inclusion shea caterpillar meal

**PER:-**Protein Efficiency Ratio **DVI:-** Blue Crown (CRD)

**ANPU:-** Apparent Net Protein Utility

## 4.2 Carcass Composition of Hybrid *Clarobranchus* Fingerlings Fed Different Inclusion Levels of Shea Caterpillar Meal (SCM)

There was significant difference (P<0.05) in the fat content of hybrid of *Clarobranchus* carcass fed experimental diets. DV had the highest fat content (15.31±1.45) and the least was DI (11.68± 1.13). Considering the ash content of the experimental fish, there was a significant difference (P<0.05), with diet DI had the highest figure, (19.01± 1.23), followed by DIV (18.10±1.24) and diet DIII was the least, (15.60±2.46). The moisture content also, was significant difference (P<0.05), diet DI had the highest moisture content while diet DII was the least, 12.58±4.71 and 6.82±0.86 respectively. The protein content of the experimental fish showed significant difference (P<0.05), the CRD diet, DVI had the highest, 44.62±3.15, while diets DIII, DIV and DV followed, 42.29±3.64, 41.71±1.82, and 41.12±6.13 respectively. Diet DI was the least, (35.75±0.90).

**Table 4.2: Carcass Composition of Hybrid *Clarobranchus* Fingerlings Fed Different Inclusion Levels of Shea Caterpillar Meal (SCM)**

| **Parameters** (%) | **Initial** | **Final** | | | | | |
|---|---|---|---|---|---|---|---|
| | | **DI** | **DII** | **DIII** | **DIV** | **DV** | **DVI** |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Fat | 12.68±1.1[d] | 11.68±1.13[e] | 15.07±1.58[b] | 14.76±1.91[c] | 12.75±2.16[c] | 15.31±1.45[b] | 12.06±2.61[d] |
| Ash | 17.52±0.10[c] | 19.01± 1.23[a] | 16.52±2.94[d] | 15.60±2.46[e] | 18.10±1.24[b] | 15.66±1.01[e] | 17.82±4.57[c] |
| MC | 11.27±1.40[b] | 12.58±4.71[a] | 6.82±0,86[e] | 7.79±1.82[d] | 8.03±0.65[c] | 7.43±0.41[d] | 8.68±1.20[c] |
| CP | 34.54±0.31[g] | 35.75±0.90[f] | 37.62±5.32[e] | 42.29±3.64[c] | 41.71±1.82[d] | 41.12±6.13[d] | 44.62±3.15[b] |
| CF | 1.14±0.20[a] | 0.58±0.03[d] | 0.50±0.02[e] | 0.48±0.02[f] | 0.53±0.08[e] | 0.72±0.03[b] | 0.59±0.21[d] |

**Values in the same row with different superscript letter are significantly different ($p<0.05$) from one another**

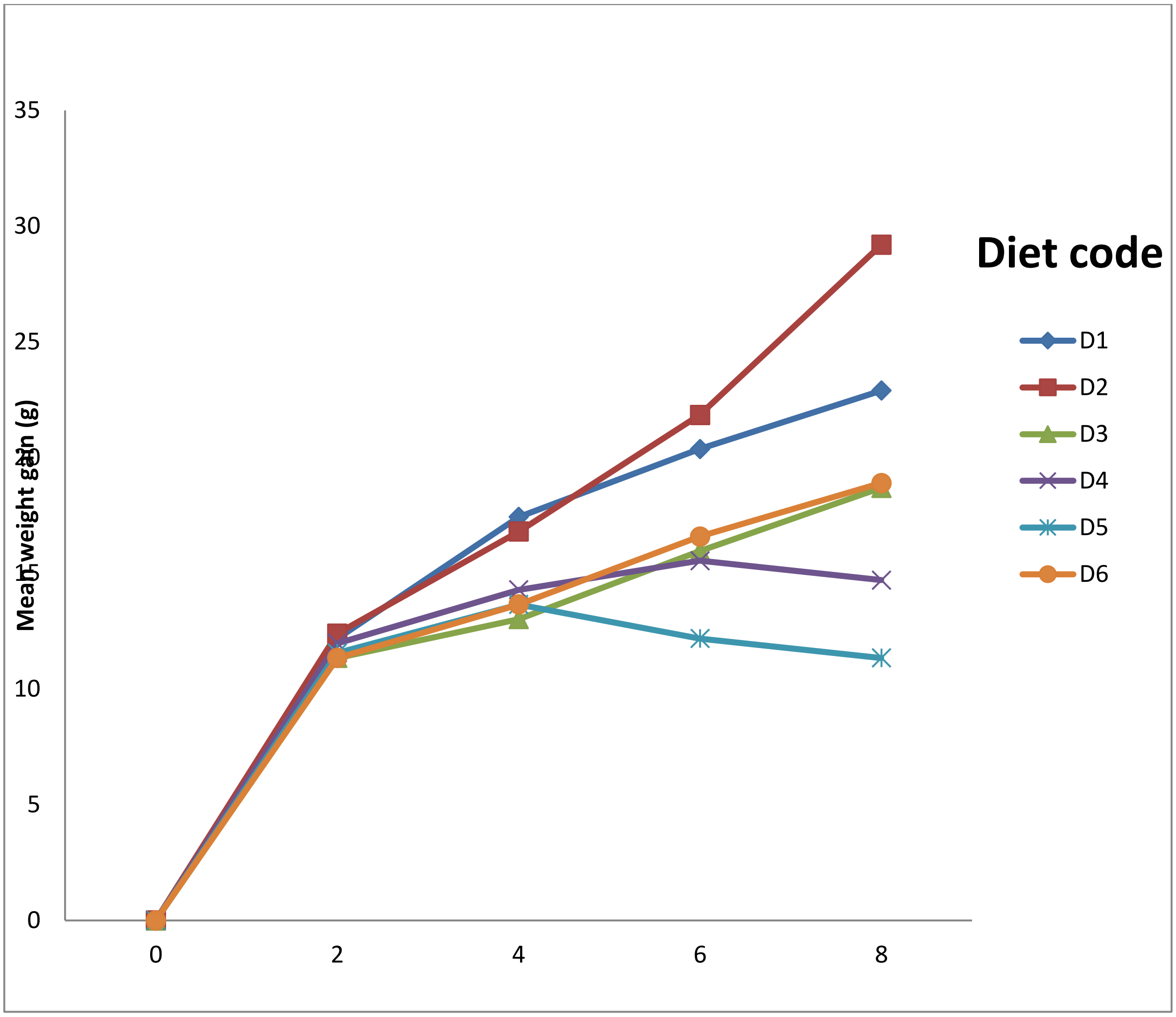


**Figure 4.1: Growth Response of Hybrid *Clarobranchus* Fingerlings Fed Different Inclusion Levels of Shea Caterpillar Meal (SCM) for Eight Weeks**

# CHAPTER FIVE

## 5.0 DISCUSSION

### 5.1 Discussion

The result of the nutrient composition shows that shea caterpillar, *Cirina butyrospermi* meal has high crude protein of 65.68 %. This is a very high value that could completely replace fishmeal in fish feed. The value compares favorably with the result obtained by Morgane *et al.,* (2016) who reported 62.74 % which is similar to 63 % obtained for the same species by (Ouedraogo, 1993), although lesser to 74.35 % accounted for by Agbidye *et al.*, (2009).

The mean growth performance and nutrient utilization indicates that *Clarobranchus* fingerlings fed DI and DII gave a better growth performance and nutrient utilization than the other treatments even the commercial catfish reference diet (CRD). This may likely be due to the high protein content of the Danish fishmeal used in the diet. Although generally, all the fish fed the experimental diets, accepted the feeds, acceptability of the diets however differed among the treatments. This agrees with earlier reports by (Riche *et al.,* 2001; Riche & Garling Jr., 2004; Ahmad, 2008) that when alternative protein sources are used in fish diet, palatability and attractiveness of the diets are usually affected. As suggested by Watanabe *et al*., (1987) and quoted by Bake *et al.,* (2015), proper utilization of dietary protein is dependent on the good quality or amino acid balance of the protein sources.

The mean initial weight of all the experimental fish were not significant different, indicated homogeneous group distribution of the fingerlings fish stocked. The study revealed that the inclusion levels of shea caterpillar meal (SCM) as an ingredient in the diet of *Clarabranchus* fingerlings in response with varying inclusion levels of; 0 %, 25 %, 50 %, 75 % and 100 % for a period of 56 days showed that *Clarobranchus* fingerlings fed at 25 % inclusion of SCM, diet DII attained best growth and competed well with diet DI which is 100 % inclusion of fishmeal, with no significant differences (P<0.05) in their MFW, MWG, SGR, FCR, and PER. While *Clarobranchus* fingerlings fed 100 % inclusion level of SCM exhibited least growth response. The growth parameters response of DIII and DIV differed significantly (P<0.05) compared to diet DI and DII. Although, in this study, there was no feed rejection during the experimental period, the suitability of inclusion of alternative ingredient in a fish diet in terms of growth performance and nutrient utilization has been reported to vary highly among fish species and experimental conditions (El-Sayed, 1999; Bake *et al.,* 2013 Bake *et al.*, 2015). From the present study, the percentage survival rate was good among all the treatments, and this could be attributed to good handling, good water quality management, proper processing and the suitability of SCM meal inclusion in the diet of *Clarobranchus*, with the least being (83.33%) and (95.00%) was the highest.

Within the condition of this experiment, shea caterpillar meal (*Cirina butyrospermi)* was an acceptable source of animal protein in the diet of *Clarobranchus.* The fishes adapted to the diets within 2 – 4 days of commencement of the trial though, acceptability of the diet varied. The health and survival of fish has often been reported in term of relationship between the weight and length increases (Onyi et al., 2013). The low growth response by experimental fish fed diet DV, 50 % inclusion level of SCM could be as a result of low feed intake. The best weight gain and growth response were obtained by fish fed 0 %, 25 % inclusion level of SCM, the weight gain of fingerlings is usually a reliable indicator of nutritional adequacy of the diet (Cho and Bureau, 2000) and there were significant differences between fish fed. The result on the survival rate, indicated that, all the treatment performed well though, there were significant differences among the treatment.

This study has demonstrated that the inclusion of shea caterpillar up to 75 % has significant effect on the growth of *Clarobranchus* fingerlings, hence can replace fishmeal thereby improve its growth performance and feed efficiency. This is in an agreement with suggestion by various authors that the synergetic effect of combination of different protein sources perform better than single protein source in fish diets (Ugwumba *et al.,* 2001 and Sogbesan *et al.*, 2005).

# CHAPTER SIX

## 6.0 CONCLUSION AND RECOMMENDATION

### 6.1 Conclusion

i. It can be deduced from the study that shea caterpillar meal has a high crude protein of 65 % which makes it suitable to be used in aquaculture as a protein source.

ii. And also, shea caterpillar when used alone didn't give a better result but when combined between a range of 25 - 75 % with fishmeal in the diet of hybrid catfish *Clarobranchus* gave a better result without any adverse effects on growth and body compositions of the fish.

### 6.2 Recommendation

i. Inclusion levels of 25 %, 50 % and 75 % of Shea caterpillar meal, *Cirina butyrospermi* are recommended for the diet of hybrid catfish *Clarobranchus* in terms of growth performance, 25 % inclusion levels however, performed best and had the least FCR.

ii. More research should be carried out on the cultivation and conservation of shea caterpillar to make it readily available at all time and avoidable in price.

iii. Further work on utilization of *Cirina butyrospermi* meal as a lipid source for better growth and economy sustenance of aquaculture is recommended.

iv. This type of research should be conducted on other available cultivable species of fish in aquaculture.

Furthermore, the increased use of insects as food and feed is expected to require more volume than can be harvested from nature. Therefore, farming the insects as mini-livestock is advisable. The high environmental impacts connected with meat production and the increase in demand up till 2050 require dietary changes. Insect-based substitutes as protein source are potentially more sustainable but require more advanced cultivation and processing techniques (Smetana *et al.,* 2015). Such advancement is expected as the whole sector of insects as food and feed is just emerging. In comparison to current production practices, this potential abundant food source can contribute to a more sustainable food and feed production, as certain insects can be reared on organic side streams, including manure. However, food and feed safety issues need to be considered. Insect production has great potential with respect to sustainably providing food for the growing population. However, further technological development of this sector and monitoring of the effects of these developments on the environmental impact of insect production are needed.

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