

**UNIVERSITY OF EDUCATION, WINNEBA**

**GROWTH PERFORMANCE, BLOOD PROFILE, CARCASS, ORGANOLEPTIC  
ATTRIBUTES AND COST BENEFIT OF BROILERS FED DIETARY SHEA  
CATERPILLAR (*Cirina butyrospermi*) MEAL**

**BASHIRU SEIDU**

**MASTER OF PHILOSOPHY**

**ANIMAL SCIENCE**

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**UNIVERSITY OF EDUCATION, WINNEBA**

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**BASHIRU SEIDU**

**(200024366)**

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Graduate Studies, in partial fulfilment  
of the requirements for the award of the degree of  
Master of Philosophy  
(Animal Science)  
in the University of Education, Winneba**

**2023**

## **DECLARATION**

### **STUDENT'S DECLARATION**

I, BASHIRU SEIDU, declare that this thesis, with the exception of quotations and references contained in published works which have all been identified and duly acknowledged, is entirely my original work, and it has not been submitted, either in part or whole, for another degree elsewhere.

**NAME:** BASHIRU SEIDU

**SIGNATURE:** .....

**DATE:** .....

### **SUPERVISORS' DECLARATION**

We hereby declare that the preparation and presentation of this work was supervised in accordance with the guidelines for supervision of thesis as laid down by the University of Education, Winneba.

**NAME:** Mr. Fritz R. K. Bonsu (Principal Supervisor)

**SIGNATURE:** .....

**DATE:** .....

**NAME:** Dr. William K.J. Kwenin (Co-Supervisor)

**SIGNATURE:** .....

**DATE:** .....

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## **DEDICATION**

This work is dedicated to my parents, Mr. and Mrs. Seidu Dabo, my wife Gazala Saeed and children namely: Ziinah, Abdul-Manaf, Fatima and Bashira.

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## ABSTRACT

Two studies were carried out in 14 weeks to determine growth performance, haematological and biochemical attributes, carcass, organoleptic attributes, and cost benefit of broilers fed dietary shea caterpillar meal. In experiment one, 75 four-week-old Cobb 500 broiler chicks were randomly allocated to five dietary treatments with 3 replicates in a Complete Randomized Design. The five treatments were labelled as T1 (SC0 %), T2 (SC25 %), T3 (SC50 %), T4 (SC75 %), and T5 (SC100 %). The control diet was T1 (SC0%). Parameters measured include proximate and amino acid analyses, feed intake, water intake, average weekly body weight, body weight gain, feed conversion ratio, blood profile, carcass characteristics, organoleptic attributes and cost-benefit assessment. Data collected were subjected to a one-way analysis of variance with the support of GenStat 11<sup>th</sup> Edition (2008). The results showed that shea caterpillar meal has 60.42% crude protein and 15 amino acids. There was no significant difference ( $P>0.05$ ) across all the means in terms of weekly feed intake and total weight gain. The inclusion of shea caterpillar meal in the diets of broilers had no adverse effect on the blood profile, organoleptic attributes and carcass characteristics. Cost-benefit analysis showed that as the inclusion of SCM increased up to 50%, the cost of feed decreased and profit was high. In experiment two, 75-day-old Cobb 500 broiler chickens were randomly assigned to five treatments with 3 replicates in a Complete Randomized Design. The treatments were labelled just like experiment one. The parameters taken were similar to experiment one except for biochemical and organoleptic attributes. In the starter phase, there was a significant difference ( $P<0.05$ ) among all the treatment means for total feed intake, total water intake, total weight gain and feed conversion ratio. Cost of feed per bird reduced as the inclusion levels of SCM increased and

more profit was observed from birds fed with 25% SCM. In the finisher phase, total feed intake was not significant ( $P>0.05$ ), but total weight gain and mean FCR were significant ( $P<0.05$ ) among treatments. Carcass parameters showed a significant difference ( $P<0.05$ ) among some treatments means while haematological indices were not significant except lymphocyte values. These results show that moderate inclusion of 50 % shea caterpillar in broilers' diets enhances growth performance and yields relatively high profit.

## ABBREVIATIONS

AMSA	American Meat Science Association
ANOVA	Analysis of variance
BSFL	Black soldier fly larvae
CRD	Complete Randomised Design
EC	<i>Escherichia coli</i>
EDTA	Ethylene Diamine Tetra Acetic Acid
EWM	Earthworm Meal
GH¢	Ghana Cedi
GSSS	Ghana Statistical Service
HMM	Housefly maggot meal
IFP	International Food Policy
MSD	Meteorological Service Department
NRC	National Research council
PBS	Phosphate buffered solution
SC	Shea Caterpillar
SCM	Shea Caterpillar Meal
UEW	University of Education, Winneba

## CHAPTER ONE

### 1.0 INTRODUCTION

#### 1.1 Background of the Study

Globally, poultry production contributes to job creation, income, improvement of nutrition, and food security (Adei & Asante, 2012). Poultry also provides micro-nutrients to combat micro-nutrient nutrient deficiency ('hidden hunger') in human beings (Mottet & Tempio, 2017). Poultry especially broilers bring quick returns on investment at a relatively shorter period as compared to many other farm animals. However, in the poultry industry, conventional sources of feed ingredients such as maize, soya bean, and protein are scarce and very expensive. The high cost of protein has resulted in adulteration and sub-standard animal protein feed in the market, which harms the quality of animal protein in poultry diets (Anang *et al.*, 2013).

Feed cost alone accounts for more than 70 percent of the total cost of poultry production (Banson *et al.*, 2015) which affects the growth rate of the sector. A search for a suitable alternative, non-conventional feedstuff especially protein sources is necessary and timely for saving the poultry industry from total collapse. One possible alternative source of animal protein feed is an insect like the shea caterpillar (*Cirina butyrospermi*). The shea caterpillar is an edible insect from the family Saturniidae (Anankware, 2017). The shea caterpillar is locally called 'Tantuni' or 'Ware' 'Tantuni' in Dagaare/Wale. The shea caterpillars or silk moths arise seasonally on shea-nut trees (*Butyrospermum parkii* or *Vitellaria paradoxa*) around June each year (Bama *et al.*, 2018) and feed exclusively on the leaves of the host tree.

Shea caterpillars serve as a source of food, employment, income, and used as feed ingredient in fish diet (Coulibaly *et al.*, 2017; Payne, 2020). In addition, these insects are less expensive compared with other animal protein sources and provide rich source of protein, iron, and amino acids (Anvo *et al.*, 2016a; Yapo *et al.*, 2017; Payne *et al.*, 2020a). Amino acids are major constituents of structural and protective tissues, like skin, feathers, ligaments, soft tissues, organs, and muscles. Also, amino acids and small peptides may serve a variety of metabolic functions and as precursors of many important non-protein body constituents (NRC, 1994). The iron in shea caterpillar (Yapo *et al.*, 2017) can support the formation of red blood cells which enables the birds to perform different metabolic activities. Therefore, shea caterpillars can be considered as a potential alternative and affordable source of animal protein feed in the diet of poultry to minimize production costs and improve profitability.

## **1.2 Problem Statement**

Poultry production is constrained by the high cost of feed, the incidence of diseases, bad weather in the northern sector, scarcity of chicks, and the importation of dressed chicken products (Butler, 2016; Hagan, 2020). The poultry industry also suffered from the COVID-19 pandemic restrictions which caused the unavailability of feed resources leading to an increase in prices (Obese *et al.*, 2021). This trend usually affects poultry production and consumption, which may result in low intake of the animal source of protein leading to protein malnutrition among vulnerable people, especially children. Hence, there is a need to search for an alternative to the traditional sources of protein feed which are relatively cheaper sources of protein feed in the diets of poultry. Insects have been implicated in the new drive and the shea caterpillar (*Cirina butyrospermi*) can be considered for that purpose

(Anankware, 2017). Shea caterpillar is rich in protein, iron, fat, minerals, and amino acids (Yapo *et al.*, 2017). Furthermore, shea caterpillars are a major source of food in the human diet in West Africa (Anvo *et al.*, 2017) and a delicacy in the northern part of Ghana (Anankware, 2017) and are available during the rainy season.

Despite the potential of the shea caterpillar, as a rich source of protein in the human diet (Payne *et al.*, 2020a; Yapo *et al.*, 2017) and feed ingredients in livestock and fish diet (Anvo *et al.*, 2017) there is relatively limited information on the utilization of shea caterpillar meal (SCM) as a source of animal protein ingredient for poultry especially broilers in Ghana. There is, therefore, the need to determine the effect of shea caterpillar meal as an animal protein feed ingredient in broiler diets.

### **1.3 Main Objective of the Study**

The main objective of this study was to determine the suitability of shea caterpillar meal as a protein feed ingredient in the production of broilers.

#### **1.3.1 Specific Objectives**

The specific objectives of this study were to:

- i. Determine the nutritional composition of shea caterpillar meal (SCM).
- ii. Determine the ideal inclusion level of shea caterpillar meal.
- iii. Assess growth, carcass characteristic, haematological and biochemical indices of broilers fed varying levels of shea caterpillar meal.
- iv. Determine organoleptic attributes of broilers fed varying levels of shea caterpillar meal.
- v. Determine cost-benefit efficiency of incorporating SCM in broiler diets.

## **1.4 Research Questions**

- i. What is the nutritional composition of shea caterpillars' meal?
- ii. What will be the ideal inclusion level of shea caterpillar meal in the poultry diet?
- iii. How will varied levels of shea caterpillar meal given to broilers influence growth, carcass characteristic, and blood profile?
- iv. How varied levels of shea caterpillar meal fed broilers will influence organoleptic attributes?
- v. What will be the cost-benefit of incorporating varied levels of shea caterpillar meal in the diets of broilers?

## **1.5 Significance of the Study**

This study will help to provide information on the nutritional composition and an ideal inclusion level of shea caterpillar meal in the poultry diet. It will also provide an alternative protein feed ingredient in ration formulation to poultry production. Besides, it will partly address the issue of limited information on the utilization of shea caterpillar meal in broiler diets to other researchers and serve as a reference document for future use.

## **CHAPTER TWO**

### **2.0 LITERATURE REVIEW**

#### **2.1 Importance of Poultry Production in Ghana**

Poultry encompasses a collection of domesticated species, comprising turkeys, chicken, Guinea fowls, ducks, game fowls notably pheasant and quails, and ratites like emus and ostriches (Ravindran, 2013). Fowls meat and eggs offer not only superior protein but also significant vitamins and minerals. Poultry meat is solid healthy meat and is the cheapest of all livestock meats. Furthermore, there are certainly not many taboos on the consumption of poultry eggs and meat as human food in Ghana. In addition, a chicken provides a meal for a normal household without the need for a freezer to store left-overs unlike meat from other livestock such as pigs and ruminants (Ravindran, 2013). In addition, poultry especially broilers is unique, efficient and economic converters of vegetable food into animal protein and delivers a rapid income to farmers (Koney, 2004).

According to Butler (2016) poultry is kept to provide the required protein content as a substitute for red meat. Besides, poultry does not destroy agricultural lands through overgrazing as in the case of ruminants like cattle. Furthermore, poultry does not also destroy established farms like maize, rice, and yam farms.

According to Koney (2004) traditional poultry is raised for domestic usage and as a source of revenue through the sale of eggs and live birds. Koney (2004) added that these local birds are used to meet social commitments, perform rituals, and are used at festivities. Furthermore, poultry keeping is not strenuous and many people including women, retired

workers, differently-abled, or physically challenged individuals can conveniently take care of fowls.

## **2.2 Constraints of Poultry Production in Ghana**

Ghana's poultry industry is still facing a lot of problems in spite of the benefits obtained from it. Some of these challenges include the high cost of fish meal and its adulteration by some feed producers, lack of capital, disease outbreaks, for instance, Avian influenza, the expensive price of inputs, inadequately skilled labour, marketing problems, competition with cheap imported poultry products and accessibility to flexible loans (Adei & Asante, 2012; Anang *et al.*, 2013). Hagan (2020) reported that the challenges threatening poultry farmers in the Ejisu Municipality in Ghana were many. The key ones include the high cost of feed, medicines, vaccines day-old-Chicks, diseases, transportation, and absence of innovative technology. Hagan (2020) added that the price of feed accounted for the majority of the cost of production and posited that farmers should seek cheaper alternatives of feed ingredients for their birds to maximise profit. This is so because when the expenditures on inputs and ingredients are high, many farmers will either choose to reduce the scope of the business or close the industry altogether, which will result in diminished output and unemployment (Hagan, 2020).

According to Butler (2016), poultry farmers in Wa Municipality of Ghana encountered many constraints such as inadequate capital, high feed cost, cost of equipment, high incidence of diseases, bad weather conditions, expensive price of vaccines, high cost of veterinary services, lack of knowledge to manage sick birds, as well as low patronage of live birds due to limited restaurants and hotels in the municipality. Butler (2016) added that due

to the lack of hatchery in the region, farmers had to purchase day-old chicks from Sunyani, Techiman, and Kumasi and the cost of transportation is usually high and at times farmers lose most of the birds due to frequent breakdown of vehicles.

A study conducted by Tuffour & Oppong (2014) also posited that poultry farmers in Accra, the capital of Ghana, realized low income due to the high cost of labour used to provide services in the poultry sector. In a related study, the main issues of broiler production in order of severity, include high cost of feed, lack of access to credit, competition from cheap imported poultry products, and lack of government support. The study revealed that feed cost, which is the main constraint to broiler production should be subsidized by the government to help boost domestic production in the country (Etuah *et al.*, 2013).

According to Ahiale *et al.* (2019), the key constraints confronting poultry production in Mampong Municipality include an extraordinary occurrence of predators, countless competition from foreign importations, high cost of feed, and stealing of birds by thieves. Ahiale *et al.* (2019) added that issues such as pests and disease, lack of capital or credit facilities, lack of market, and mortality were considered minor challenges to the poultry farmers in the study area. A new development that affected the poultry sector was COVID-19. Restrictions and closures of major markets in Ghana have led to shortages of some feed ingredients including maize, wheat, soybean, concentrates and fish meal, resulting in sudden price surges (Asante & Mills, 2020; Obese *et al.*, 2021) that brought untold burden on poultry farmers who were already battling the expensive feed cost. Among all these challenges affecting poultry farmers, high feed cost is a universal problem as well as

importation of poultry products, lack of capital, cost of vaccines, and day-old chicks. Strong measures should be taken by the government to redeem the poultry sector from collapse.

## **2.3 Insects**

The word insect is derived from *insectum*, which means “with a notched or divided body” (Van Huis, 2016). Insects are creatures within the arthropod with an external exoskeleton, jointed appendages three legs in pairs, compound eyes, and two antennae (Van Huis, 2016).

### ***2.3.1 Economic Importance of Edible Insects***

Worldwide, the highest generally consumed insects in descending orders are beetles (31 %), caterpillars (18 %), wasps ants and bees(14 %), grasshoppers, locusts and crickets (13 %), plant hoppers, scale insects, and true bugs (10 %), termites (3 %), dragonflies (3 %), and flies (2 %) (Van Huis, 2016). In Ghana, there are nine edible insects found to be consumed by at least 30 percent of Ghanaians (Anankware *et al.*, 2016). The termite (94.7 %) is the most accessible insect while the shea tree caterpillar is the least available with 37 % (Anankware *et al.*, 2016).

Edible insects can be used as a sustainable source of income and food to fight food shortages in the future and during periods of drought (Yapo *et al.*, 2017; Payne *et al.*, 2020b; Hlongwane *et al.*, 2020). Edible insects are used in traditional diets, as well as a source of protein in other Africa dishes (Hlongwane *et al.*, 2020). In addition, insects serve as pollinators in plant reproduction. Insect rearing does not need too much land to commence production (Van Huis, 2016).

### ***2.3.2 Influence of Insects Meal on Poultry Growth Performance***

Insects are well-planned as a possible replacement for fish meal and soybean meal in compounded feed for poultry diets (Khan, 2018). Based on several studies, insects meals obtained from black soldier fly, housefly, mealworms, earthworm, silkworm, shea caterpillar, grasshoppers, locust, and crickets, are used productively as an alternative protein feed ingredient in poultry ration (Khan, 2018). Substituting fish meal completely with the larvae of Westwood *Cirina forda* did not lead to any significant differences in growth performance at the starter or finisher phases of broiler chickens suggesting that the compounded larval diets contained a protein source, which is comparable in quality to that present in the fish meal (Oyegoke *et al.*, 2006). In similar studies, fish meal as substituted with silkworm caterpillar meal did not show a significant difference in terms of feed consumption, body weight gain, feed conversion ratio, and nutrient digestibility of birds (Ijaiya and Eko, 2009). But, there were economic returns in the starter phase. Also, black soldier fly larva (Mohammed *et al.* 2017) replaced with a fish meal did not show a significant difference in terms of feed intake and live weight gain (growth performance). However, there was a significant difference in haemoglobin, red blood cells and packed cell volume of birds fed the experimental diet.

Furthermore, replacing fish meal with House fly maggot meal did not initiate a significant difference in feed intake, feed conversion ratio, weight gain, and nutrient retention with a higher level of the test diet on broilers (Adeniji, 2007). On the other hand, fish meal substituted with pupae meal of silkworm improved growth performance and reduced the cost of feed (Dutta *et al.*, 2012). Similarly, feeding broiler chicks with Yellow Mealworm (*Tenebrio molitor*) larvae meal as an alternative to fish meal enhanced feed intake, body

weight gain, and carcass characteristics but did not enhance feed conversion ratio (Campus, 2009; Biasato *et al.* 2017). Also, Anankware (2017) reported that larvae meal of black soldier fly as a replacement for fish or soybean meal for broilers increased feed intake, live weight, and carcass characteristics like wings and drumstick weight. It also reduced mortality suggesting that the meal can completely substitute soybean meal and moderately substitute fish meal in feed. Based on these findings, it can be deduced that feeding birds with insect-based diets enhanced growth performance, reduced cost, and improved carcass traits, but did not suggest any insect meal to be the sole protein source for feeding poultry birds.

### ***2.3.3 Biology and life Cycle of Shea Caterpillar***

The shea caterpillar or ‘Night’ butterfly caterpillar (*Cirina butyrospermi*) is an important edible insect from the family Saturniidae and order Lepidoptera (Anankware, 2017). The shea caterpillar is locally called ‘Kantuli’ in Frafra (Anankware, 2017), ‘chitoumou’ in Southwestern Burkina Faso (Payne, 2020), ‘Taatul’ in Sissali, and ‘Tantuni’ or ‘Ware’ ‘Tantuni’ in Dagaare/Wale. Shea caterpillars or silk moths occur seasonally due to their univoltine life cycle (Bama *et al.*, 2018). The moth emerges from its pupal stage every year in June, after the maiden rainfall. The Silk moth or ‘Night’ butterfly lives for about three days during which period it mates and lays eggs at night on the leaves of nearby shea-nut trees. The eggs will hatch after an average period of 30 days (Rémy *et al.*, 2017). After hatching the larva prey exclusively on the leaves of the shea plants. The pupae burrow into the earth, preferably permeable soil, beneath the shea trees, and pupate and emerge the next season as adult night butterflies, and the cycle is continuous (Rémy *et al.*, 2017).

### ***2.3.4 Gathering, Processing, and Ingestion of Shea Caterpillar***

The harvesting of shea caterpillars happens early in the morning just like how shea-nut fruits are collected in many communities. According to Payne (2020) caterpillar collection commences early in the morning before sunrise by men, women, and children between July and August every year. People use a torch to provide light and a bucket moving from shea tree to shea tree, across all areas regardless of land ownership to pick the caterpillars manually and load them in their buckets (Payne, 2020).

The harvested caterpillars are washed properly and then cook in pots over a fire with some ash and salt to help preserve them. If the shea caterpillars are to be sun-dried for sale, the shea caterpillars are spread out on a tarpaulin sheet for some days until the caterpillars are considered dried enough and ready for sale. The dried caterpillars are then taken to markets for sale using a large empty can (bowl) as a measuring vessel in Burkina Faso (Payne, 2020).

In Northern Ghana, the fresh caterpillars are processed in the same manner as in Burkina Faso and sold either in bulk or in smaller quantities in villages where these caterpillars are harvested. Treated caterpillars can be stored in sacks with transparent rubber lining to extend their shelf life by market women, who will then sell them to retailers or directly to consumers. The measuring container normally used either to purchase or sell shea caterpillar is called 'kokoolaa' in Wali/Dagaare which means porridge bowl, whose content is equivalent to an approximate weight of 1.53kg and sold in Wa market in the Upper West region of Ghana. Harvesting shea caterpillar and other processes are done manually in Northern Ghana and there is no need to apply chemicals to aid caterpillar collection.

### **2.3.5 Importance of Shea Caterpillar**

In Africa, approximately 470 species of insects are documented as palatable, and caterpillars are consumed most trailed by termites, grasshoppers, and beetles, (Van Huis, 2020). Shea caterpillars serve as a source of food and food security, create seasonal jobs, bring income and their frass or droppings improve soil fertility and as a feed ingredient for fish farming (Coulibaly *et al.*, 2017; Payne, 2020), In Ghana, shea caterpillars are sold for revenue and consumed as food by children, men, and women in the five northern regions (Anankware, 2017). In addition, food security is guaranteed during the caterpillar season (Payne, 2020).

### **2.3.6 Nutritional Composition of Shea Caterpillar**

Shea caterpillars are a rich source of protein, (amino acids), fats, and both macro and micro minerals in human diets which can minimize protein deficiency in children (Anvo *et al.*, 2016a; Yapo *et al.*, 2017; Cox *et al.*, 2020; Payne *et al.*, 2020a). According to Chahal *et al.* (2008), proteins form muscles and tissues of the body, therefore, it is essential for the growth and development of the animal body. Proteins help in maintaining the loss of body tissues and muscles. Furthermore, proteins help in the repair of body cells as well as in the production of new cells. Proteins also supply energy to the body and are essential for the formation of eggs and feathers of birds. The minerals in caterpillars generally serve as constituents of skeletal structure, help in regulating acid-base equilibrium, and act as components or activators of enzymes and other biological systems (Chahal *et al.*, 2008).

**Table 2.1: Proximate Composition of Shea Caterpillar**

PARAMETERS	COMPOSITION (%)	REFERENCES
Dried matter	28.71	
Crude protein	55.41	
Moisture	7.92	
Ash	4.89	Yapo <i>et al.</i> (2017)
Sugar	3.07	
Fibre	2.68	
Energy (kcal/100g)	492.31	
Dried Matter	95.66	
Crude Protein	62.74	
Crude Lipid	14.51	Anvo <i>et al.</i> (2016a)
Chitin (Fibre)	5.02	
NFE (Carbohydrate)	12.63	
Ash	5.10	
Energy (kcal/100g)	432	

NFE: Nitrogen Free Extract

### **2.3.7 Proximate Composition of Shea Caterpillar**

Proximate analysis of the shea caterpillar shows the nutritional facts of these insects as indicated in Table 2.1, confirming their high protein content. The protein content is as high as 55% (Yapo *et al.*, 2017) and 62% (Anvo *et al.*, 2016a).

### **2.3.8 Amino Acid Content of Shea Caterpillar**

Knowledge of the crude protein content alone of a feed or an ingredient is not a sufficient measure of its usefulness to farm animals. The composition of the amino acid is required to assess the quality and how effectively that feed can meet the essential amino acid requirements of farm animals (Chahal *et al.*, 2008), especially poultry. This is because, chicks require all ten essential amino acids plus glycine for proper growth (Chahal *et al.*, 2008). Shea caterpillars are very important in meeting the protein (amino acid) needs of humans and these insects contained both indispensable and dispensable amino acids (Yapo

*et al.*, 2017). Amino acids acquired from dietary protein are used by poultry to carry out a diversity of functions. Amino acids are major constituents of structural and defensive tissues, like skin, feathers, bone matrix, ligaments, soft tissues, organs, and muscles. Moreover, amino acids and small peptides may serve a variety of metabolic functions and as precursors of many important non-protein body constituents (NRC, 1994).

### ***2.3.9 Influence of Shea Caterpillar Meal on Performance of Poultry (Chicken)***

There is limited information on the use of shea caterpillar meal as a feed ingredient in the diets of poultry. The available information of interest was the work done by Anvo *et al.* (2017). Anvo *et al.* (2017) reported that partial feeding African catfish with shea caterpillar meal as a replacement for fish meal enhance growth performance and nutritional utilization at a 50 % inclusion level.

## **2.4 Sources of Feed Ingredients for Poultry in Ghana**

Poultry feed refers to a compounded combination of diverse edible ingredients which provide nourishment to birds (Koney, 2004). The conventional feed ingredients normally used in feeding fowls include maize, wheat, cassava, sorghum, cottonseed cake, copra cake, palm kernel cake, fish meal, meat meal, blood meal, soya bean, groundnut cake, wheat bran, rice bran, and maize bran, premix, oyster shell, bone meal, and dicalcium phosphates (Koney, 2004). The modern intensive system of keeping poultry introduces the technique of compounding more nutritious feed for birds to meet their daily nutrient requirement.

The ingredients used to formulate these compounded feed performed various functions and which include; protein in feed supplies energy to the body. Also, protein is essential for the

formation of the egg, wool, and hairs of farm animals. Protein delivers the basic cellular matrix within which the bone mineral matter is deposited (Chahal *et al.*, 2008). The carbohydrates are a major source of energy and form the bulk of about 70% to 75% of poultry feed (Koney, 2004). Carbohydrates also are vital components of production, temperature control, and proper functioning of the different parts of the animal body (Chahal *et al.*, 2008).

Fats help in the absorption of calcium and phosphorus (Chahal *et al.*, 2008). Fats in diet delays the sensation of hunger, as it needs a longer period to pass through the digestive tract than carbohydrate and protein. Besides, certain fat-soluble vitamins like vitamins, A, D, E, and K are absorbed in the blood in the presence of fat (Chahal, *et al.*, 2008).

Vitamins are essential for good health and play important role in the growth of the animal body. Additionally, vitamins provide resistance against diseases and increase the productivity potential of poultry. Furthermore, vitamins are essential constituents of certain enzyme systems, standardize body metabolism, and coagulation of blood (Chahal *et al.*, 2008).

The minerals serve as components of the skeletal structure. Minerals help in regulating acid-base equilibrium and also act as a component or an activator of enzymes in biological organisms (Chahal *et al.*, 2008).

These ingredients are obtained from different sources. The protein in feed comes from two main sources namely plant and animal sources. The plant sources include soya beans meal, cottonseed cake, copra cake, and palm kernel cake while the animal sources are derived

from fishmeal, meat meal, blood meal, and milk (Koney, 2004). The sources of carbohydrates are maize, sorghum, millet, wheat, and rice as high energy and wheat bran, rice bran, and maize bran as low energy source. Also, sources of fat include cottonseed, copra, groundnut cake, fishmeal, vegetable oil, and soya bean meal. Additionally, accessible sources of minerals include dicalcium phosphate, limestone, bone meal, oyster shell, common salt, and trace minerals. The common sources of vitamins include vitamin premix, yeast, alfalfa grass, and green forage crops (Koney, 2004; Chahal *et al.*, 2008).

## **2.5 Nutrient Requirement of Broilers**

Broilers are young female or male chickens not more than ten weeks old with growth characteristics to produce meat. Quality broiler meat should have a tender, uniform yellow skin, and a live weight of about 1.8kg to 2.5kg at the end of ten weeks (Koney, 2004).

Preparation of a well-adjusted diet is basic to cost-effective chicken production and the procedure depends on the knowledge of the nutrient requirement of chicken and the nutritional attributes of nutrient sources. The nutrients necessary for birds differ according to age, species, and purpose of production. To meet the optimum market weight of 1.8kg to 2.5kg (Koney, 2004), the ideal nutrient requirements of table birds must be met since the feed provided should contain ingredients that will meet the bird's requirements. Broilers require a crude protein content of 23 %, 20 %, and 18 % for 0-3 weeks, 3-6 weeks, and 6-8 weeks respectively and other nutrients for starter and finisher diets as indicated in Tables 2.2, 2.3, and 2.4.

## 2.2: Nutrient Requirements of Broilers as percentages or units per kg of diet

Nutrient (%)	Weeks 0-3	Weeks 3-6	Weeks 6-8
ME kcal/g	3200	3200	3200
Crude protein	23.00	20.00	18.00
<b>Amino acids</b>			
Arginine	1.25	1.10	1.00
Glycine+Serine	1.25	1.14	0.94
Histidine	0.35	0.32	0.27
Isoleucine	0.80	0.73	0.62
Leucine	1.09	0.93	1.20
Lysine	1.10	1.00	0.85
Methionine	0.50	0.38	0.32
Methionine+Cytine	0.90	0.72	0.60
Phenylalanine	0.72	0.65	0.56
Phenylalanine+Tyrosine	1.22	1.34	1.04
Proline	0.55	0.60	0.46
Threonine	0.80	0.74	0.68
Tryptophan	0.20	0.18	0.16
Valine	0.90	0.82	0.70

Source: (NRC, 1994)

**Table 2.3: Nutrient Requirements of Broilers as percentages or units per kg of diet**

Nutrient (%)	Weeks 0-3	Weeks 3-6	Weeks 6-8
<b>Fat</b>			
Linoleic	1.00	1.00	1.00
<b>Macronutrients</b>			
Calcium (%)	1.00	0.90	0.80
Chlorine (%)	0.20	0.13	0.12
Magnesium(Mg)	600	600	600
Non Phytate Phosphorus	0.45	0.45	0.35
Potassium (%)	0.30	0.30	0.30
Sodium (%)	0.20	0.15	0.13
<b>Trace Minerals (Mg)</b>			
Copper	8	8	8
Iodine	0.35	0.35	0.35
Iron	80	80	80
Manganese	60	60	60
Selenium	0.15	0.15	0.15
Zinc	40	40	40

Source: (NRC, 1994)

**Table 2.4: Nutrient Requirements of Broilers as percentages or units per kg of diet**

Nutrient (%)	Weeks 0-3	Weeks 3-6	Weeks 6-8
<b>Fat-Soluble Vitamins</b>			
A (Iu)	1,500	1,500	1,500
D3 (Icu)	200	200	200
E (Iu)	10	10	10
K (Mg)	0.50	0.50	0.50
<b>Water-Soluble Vitamins</b>			
B1(Mg)	0.01	0.01	0.007
Biotin (Mg)	0.15	0.15	0.12
Choline(Mg)	1,300	1,000	750
Folecin(Mg)	0.55	0.55	0.50
Niacin (Mg)	35	30	23
Pantothenic Acid(Mg)	10	10	10
Pyridoxine(Mg)	3.5	3.5	3.0
Riboflavin(Mg)	3.6	3.6	3
Thiamine(Mg)	1.60	1.80	1.80

Source: (NRC, 1994)

## 2.6 Haematological Characteristics in Farm Animals

Haematology refers to the study of the numbers and morphology of cellular elements of blood namely the red blood cells, white blood cells, and platelets, and these results are used in the diagnosis and monitoring of diseases (Merck Manual, 2012). Blood transports nutrients and materials to the entire body. Thus, whatever affects the blood (drugs, pathogenic organisms, or nutrients) will affect the whole body either positively or unfavourably in terms of growth, health, maintenance, and reproduction (Etim *et al.*, 2014).

A readily accessible and rapid means of assessing the clinical and nutritional well-being of livestock during feeding experiments may be the use of blood analysis since diet has effects on blood composition (Togun *et al.*, 2007; Etim *et al.*, 2014).

Haematological lessons are of environmental and physiological significance in supporting understanding of the connection of blood characteristics to the environment and could be beneficial in the selection of animals that are genetically resistant to certain diseases and

environmental conditions ((Ovuru & Ekweozor, 2004; Isaac *et al.*, 2013). Isaac *et al.* (2013) revealed that animals with decent blood composition are probable to display good and better performance. Esonu *et al.* (2006) testified that haematological components reflect the physiological alertness of an animal to its core and peripheral environments which include food and nourishment. Blood parameters that are frequently measured under haematological profile are red blood cell and white blood cell, Packed cell volume or (Haematocrit), mean cell volume, mean cell haemoglobin concentration, and mean cell haemoglobin, total proteins, albumin, globulin, triglycerides, cholesterol, High-Density Lipoprotein, and Low-Density Lipoprotein (Etim, 2013).

Red blood cells function as a carrier of haemoglobin. According to Isaac *et al.* (2013), RBCs are involved in the transport of oxygen and carbon dioxide in the body of animals. Hence, a small red blood cell count denotes a reduction in the level of oxygen that would be carried to the tissues and the level of carbon dioxide returned to the lungs (Isaac *et al.*, 2013). White blood cells help to fight infections, defend the body against pathogens and produce as well as dispense antibodies in immune response (Etim *et al.*, 2014). Therefore, animals with reduced white blood cells are exposed to a high risk of disease infection, while those with enough cells can resist diseases (Etim *et al.*, 2014).

Blood platelets are involved in blood clotting. Low platelet concentration recommends that the process of clot-formation will delay resulting in excessive loss of blood in the case of injury to an animal. Isaac *et al.* (2013) reported that Packed Cell Volume is associated with the conveyance of oxygen as well as absorbed nutrients. Haemoglobin has the physiological role of conveying oxygen to tissues of the animal to release energy for other body functions

as well as deliver carbon dioxide out of the body of animals (Isaac *et al.*, 2013; Etim *et al.*, 2014). According to Peters *et al.* (2011) haemoglobin, PCV, and MCH are major indices for evaluating circulatory erythrocytes and are important in the diagnosis of anaemia. High PCV interpretation showed a rise in the number of red blood cells (RBCs) or a reduction in circulating plasma volume (Chineke *et al.*, 2006). MCH and MCHC show blood level conditions. A low value is a sign of anaemia (Aster, 2004).

**Table 2.2 shows the Normal Reference Values for blood haematological and biochemical parameters of poultry.**

**Table 2.5: Haematological and Biochemical Reference Values of Chicken**

PARAMETER	NORMAL REFERENCE RANGES	
RBC(x10 <sup>12</sup> /L)	1.5-3.5*	4.21-4.84**
HGB(g/dl)	9.27-13.00*	11.60-13.68**
PVC (%)	22.0-35.0%*	35.9-41.0**
MCV (fL)	90.0-140.0*	81.60-89.10**
MCH (pg.)	33.0-47.0*	27.20-28.90**
MCHC (g/dl)	26.0-35.0*	32.41-33.37**
WBC (x10 <sup>9</sup> /L)	1.2-3.0*	4.07-4.32**
Lymphocyte	45.0-70.0*	
Total protein (g/L)	3.0-4.9*	
Albumin (g/L)	2.6-3.58***	
Glucose (mmol/L)	117-299***	
Cholesterol (mmol/L)	2.0-4.5***	
Triglycerides (mmol/l)	0.55-0.92***	
HDL (mmol/L)	1.5-1.9***	
LDL (mmol/L)	1.3-2.6***	

Sources: \*Jain, (1993) as cited in Aengwanich *et al.* (2004), \*\* (Etim *et al.*, 2014)  
 \*\*\*Cynthia (2011).

### **2.6.1 Effects of insect meal on haematological and biochemical attributes**

Various insects' meals have been fed to birds without any haematological and biochemical effects on performance (Akpodiete and Okagbare, 2002). Substituting a fish meal with maggot meal in broilers and layers diets did not display a significant effect ( $P > 0.05$ ) on biochemical indices (Akpodiete and Okagbare, 2002; Biasato *et al.*, 2017).

Similarly, substituting a fish meal or soya bean meal in broiler diets with black soldier fly larvae meal in broiler diets did not reveal any significant ( $P > 0.05$ ) effect on growth performance, carcass characteristics, and blood profile (Opoku *et al.*, 2018). Also, Anankware (2017) reported that using black soldier fly larvae meal as a substitute to fish meal revealed an increased feed intake and carcass characteristics like wings and drumstick weight and decreased mortality of birds. In another study, housefly maggot meal as a protein source replaced with soybean meal did not affect body weight, body weight gain, and feed intake of the broiler chicks (Elahi *et al.*, 2020). Elahi *et al.* (2020) added that insignificant changes were detected for a decrease in blood biochemical indices in platelets and an increase in packed cell volume, red blood cells, and total protein. It, therefore, suggests that the inclusion of insects in poultry diets may influence feed intake, weight gain, haematological and biochemical parameters in various ways.

### **2.7 Carcass Characteristics of Poultry**

The American Meat Science Association (AMSA) (2015) showed that the carcass is the most significant component in meat studies since it finally resolves the value of the meat animal for both the farmer and the butcher. The carcass weight is believed to be more valuable than the live weight and an actual picture of the benefits of the birds are detected

when the components of the carcass are measured (Kerketta, 2012 as cited in Esther, 2017). The meatiest parts of a fowl are the flight muscles on its chest, termed breast meat, and the mobile muscles on the first and second sections of its legs christened the thigh and drumstick respectively (Esther, 2017). Hence the current study used the breast meat of Cobb 500 broiler chicken for the exercise due to the significance of the breast muscle in carcass evaluation activities.

### ***2.7.1 Effects of Insects on Carcass Characteristics of Poultry***

Various studies have been conducted on carcass characteristics using edible insects with several results in poultry. Hwangbo *et al.* (2009) stated that maggot addition in broiler chickens' diets significantly improved breast muscle, dressing percentage, and thigh muscle. However, no differences were detected for liver, abdominal fat, and meat colour. A similar study by Ballitoc and Sun (2013) reported that replacing Yellow mealworms (*Tenebrio molitor*) with fish meal enhanced carcass output and weight of internal organs like gizzard without any adverse effect in broiler chickens. Also, using Yellow mealworms and Black soldier fly to replace soybean meal 25 % and 50 % inclusion in Barbary partridge diet significantly influence carcass weights like caecal weight, intestinal and caecal length of all the insect-based treatments except the control (Loponte *et al.*, 2017).

Another study by Balolong *et al.* (2020) reported that increasing levels of black soldier fly larvae as protein feed sources did not show a significant difference between treatments in the carcass and organoleptic attributes. Anankware. (2017) posited that larva meal of black soldier fly replaced partially with fish meal and completely with soybean meal improves the live weight of birds, feed intake, wings, and drumstick weight, and enhanced health. On the other hand, substituting a fish meal or soya bean meal in broiler diets with the same fly meal

in broiler diets did not reveal any significant difference ( $P>0.05$ ) in carcass characteristics (Opoku *et al.*, 2018).

## **2.8 Sensory Attributes of Broiler Breast Meat**

The sensory or organoleptic analysis of broiler meat involves the inspection of the meat or product by the use of sense organs that is, taste, sight, smell, touch, and hearing for various quality attributes like appearance, flavour, aroma, texture, and sound as well as toughness.

Sensory evaluation gives assurances that inferior products are not released into the market. Sensory evaluation is also used to estimate the shelf life of food products as sensory characteristics of the product depreciate ahead of microbial quality (Sharif *et al.*, 2017).

### **2.8.1 Appearance/colour**

Appearance is the first characteristic and plays an important role in the identification and final selection of food (Tlhong, 2008). The appearance of a feed influences desire and acceptance before the feed touches the mouth. This is because people eat with their sight before they taste or smell (Sharif *et al.*, 2017).

### **2.8.2 Flavour**

Flavour refers to a sensory phenomenon that is used to signify the sensations of taste, odour, and mouth-feel (Tlhong, 2008). Flavouring constituents are pungent compounds that are regarded by the combination of taste and odour and perceived by the nose and mouth (Tlhong, 2008). Taste assists in the identification, acceptance, and appreciation of food by taste buds on the tongue (Sharif *et al.*, 2017).

### **2.8.3 Aroma**

Aroma is the first complement of taste and is volatile compound that is perceived by the odour receptors of olfactory tissues of the nasal cavity. To provoke a sensation of smell, the stuff must be in a gaseous state. Furthermore, the aroma is valuable in perceiving fresh, rancid, or occasionally poisonous food (Tlhong, 2008; Sharif *et al.*, 2017).

### **2.8.4 Texture/tenderness**

The texture is perceived by the senses which are, touch, mouth-feel, sight, and hearing (Sharif *et al.*, 2017). The texture is a prerequisite in the acceptance of numerous foodstuffs, for example, the tenderness of the meat. It also includes the consistency, thickness, fragility, chewiness, and shape of particles in food (Sharif *et al.*, 2017).

### **2.8.5 Juiciness**

Juiciness refers to the impression of soggianness during the first few chews produced by the rapid release of meat fluid (Tlhong, 2008). According to Esther (2017) juiciness is one of the most significant meat sensory quality attributes for consumption.

### **2.8.6 Effects of Insect Meal on Sensory Attributes of Broiler Chickens**

Studies by Gunya *et al.* (2018) recommended that the inclusion of earthworm (*Eisenia foetida*) meal (EWM) in broiler chickens diet resulted in improved chicken aroma and juiciness of meat. However, birds flavour values reduced with high percentage of earthworm meal suggesting moderate inclusion rate. According to Balolong *et al.* (2020) replacement of black soldier fly larvae meal as protein feed source did not show significant difference between treatments in the carcass and organoleptic attributes.

In a similar study, Kim *et al.* (2021) reported that dietary replacement of soybean meal with Black soldier fly resulted in satisfactory results for the meat quality but did not influence carcass weight at high inclusion levels signifying that a small percentage of Black soldier fly addition is advantageous.

## **2.9 Inferences from Literature Review**

The poultry sector is perhaps the fastest developing and most flexible of all livestock sectors. Poultry such as broilers improves nutrition and provides meat with high-quality nutrients, generating income and employment. Broilers or table birds bring rapid returns on investment as a result of their short maturity period.

However, in Ghana broiler production is on the verge of collapse due to serious competition with cheap imported frozen chicken, high cost of feed, marketing problems, lack of access to flexible loans, and the recent impact of COVID-19 which led to shortages of feed. This makes the broiler business too expensive for many farmers and other stakeholders in Ghana. This development poses a fundamental threat to food security and the livelihood of many farmers, traders, and other stakeholders in the poultry business. This calls for the need to identify and utilize cheaper alternative ways of feeding broilers using available non-conventional feed ingredients to reduce cost, maximize profits and eventually improve the standard of living of Ghanaian farmers in the poultry industry. Insects such as black soldier fly meal, housefly maggot meal, yellow mealworms, and shea caterpillar have been used in poultry nutrition without harmful effects and can therefore be considered as a possible supplement for fish meal and soybean meal in the poultry industry. Insects like shea caterpillars with a crude protein content of 55 to 63 percent are a source of food as well as

income. In addition, shea caterpillars are a rich source of amino acids, fats, and both macro and micro minerals. However, these edible insects appear seasonal on shea trees either in June or July each year during short drought periods in Northern Ghana. The shea tree leaves are the main source of feed for these insects. Due to their seasonal nature, a pilot study has shown that shea caterpillars can breed artificially.

In Ghana, the shea caterpillar is a delicacy in the five northern regions but not much has been done in terms of shea caterpillar utilization as a feed ingredient for poultry. The purpose of this study is to evaluate the growth performance, blood profile, carcass, organoleptic attributes, and cost benefit of broilers fed dietary shea caterpillar (*cirina butyrospermi*) meal.

## **CHAPTER THREE**

### **3.0 MATERIALS AND METHODS**

#### **3.1 Location and Duration of Experiment**

The study was carried out at the Poultry Section of the Department of Animal Science, University of Education, Winneba, Mampong campus. Two experiments were carried out for 14 weeks. Experiments One and Two lasted for 5 and 9 weeks respectively. Experiment One started from January 15, 2021, to February 20, 2021, and experiment Two commenced from 15<sup>th</sup> March, 2021 to 17<sup>th</sup> May, 2021.

#### **3.2 Study Area**

The study area was Mampong. Mampong is a town positioned in the North-Eastern part of the Ashanti region within longitudes 0° 05''W and 1° 30''W and latitudes 6°55''and 7°30''N (Ghana Statistical Service, 2014). The Municipality covers an area of about 2,346km<sup>2</sup> with a total population of 88,051. The Municipality lies within the wet semi-equatorial forest zone lying between the Guinea Savannah to the North and Rain Forest to the South. It has a bimodal rainfall pattern with an average annual rainfall of 1,270 mm. The major rainy season begins from March to August while the minor occurs between September to November. The harmattan dried season is from December to February. The average annual temperature is 27°C with variations in mean monthly temperature ranging between 22°C - 30°C (Ghana Statistical Service, 2014). The average daily temperature is between 25°C and 30°C while the average relative humidity of the area is 91.5% (Meteorological Service Department, 2008).

### **3.3 Feed Ingredients**

Nine feed ingredients involving eight conventional and one non-conventional feedstuff were used for the study and they include maize, anchovy fish meal, wheat bran, soya bean, oyster shell, premix, dicalcium phosphate, and salt as well as shea caterpillar.

### **3.4 Source of Dietary Feed Ingredients**

The conventional ingredients were bought from the market by the Poultry Unit of the Department of Animal Science and the dried shea caterpillars were purchased from Wa market in the Upper West Region of Ghana. The dried caterpillars were bagged in sacks with a rubber lining to prevent entry of moisture and stored in the poultry feed house.

### **3.5 Preparation of Shea Caterpillar Meal (SCM)**

The dried shea caterpillars were further sun-dried for three consecutive days for a maximum of four hours per day at an ambient temperature. The caterpillars were then milled at the Poultry Unit using a hammer mill with a 2mm sieve and ground for a second time by a normal commercial grinding mill and kept in sacks. The milled shea caterpillars were placed in a clean, dried, moisture-free area inside the poultry feed room until it was used in the feeding trial. The texture and particle sizes of the milled shea caterpillars were similar to fish meal. The colour was light yellow and the scent was like dried ground okro.

Plates 3.1, 3.2, and 3.3 show the dried caterpillars, 2mm hammer milled and corn shea caterpillar (SC) respectively.



**Plate 3.1: Dried SC**



**Plate 3.2: Hammer milled SC**



**Plate 3.3: Corn mill SC**

### **3.6 Proximate Analysis of Shea Caterpillar meal, Fish meal, and Experimental Diets.**

Samples of shea caterpillar meal, fish meal, and experimental diets were subjected to proximate analysis according to the Association of Official Analytical Chemists (AOAC 2006) to determine moisture content, dried matter, crude protein, ash, fibre, crude fat, nitrogen free extract and metabolizable energy.

### **3.7 Determination of Amino Acids**

Amino acid composition of shea caterpillar meal and fish meal were analysed to determine both indispensable and dispensable amino acids using High-Performance Liquid Chromatography (HPLC) as described by Anankware (2017).

### **3.8 Management of Chicks**

A total of two hundred and eight-two (282) Cobb 500 broiler day-old chicks were purchased from Topman farms Kumasi and used for the study. The chicks were kept in the prepared

broody house. Glucose in water was provided for three consecutive days. The birds were also given a starter diet for four weeks during the brooding period and the recommended vaccination schedule was followed. The chicks stayed in the deep litter brooder house for 4 weeks and all routine activities were duly followed.

Table 3.1 shows the feed formula of the brooder phase for Experiment One.

**Table 3.1: Feed Composition of the Starter Diet for Experiment one**

FEED INGREDIENTS	PERCENTAGE
Maize grain	54.5
Wheat bran	11
Soya bean meal	11
Tuna fish meal	12
Fish meal anchovy	8
Oyster shell	2
Dicalcium phosphate	0.5
Premix	0.5
Salt	0.47
Toxin binder	0.03
Total (kg)	100
<b>Calculated analysis</b>	
Crude protein (%)	21.9
Crude fibre (%)	3.26
Ether extract (%)	2.89
M E (kcal/kg)	2,768.81

### 3.9 Experimental Chicks and Design

In Experiment One, 75 four weeks old Cobb 500 birds were selected at random and assigned to five treatments with three replicates in a Complete Randomised Design (CRD). Each replicate had five chicks housed in partitioned pens with dimension of 1.8m x 0.88m x 2.2m. The pens were swept, properly washed and disinfected with omnicide and sawdust evenly placed on the floor as litter at a height of 4cm. Feed and water were supplied *ad libitum*.

In experiment two, 75 one day old Cobb 500 birds were selected at random and allocated to five treatments with three replicates in a Complete Randomised Design (CRD). Each replicate was made up of five chicks kept in partitioned pens during the brooding and finisher phases. The dimensions of the pens were the same as experiment one. The pens were prepared as usual with the windows covered with black polyethene sheets. Six electric bulbs and four small clay pots with charcoal were used to supply regular heat during the brooding phase. Feed and water were provided *ad libitum*. The chicks were obtained from Darko farms LTD in Kumasi. The recommended vaccination schedule was followed.

### **3.10 Experimental Diets**

The composition of the five experimental diets for the starter and finisher phases is shown in Tables 3.2 and 3.3. For Experiments One and Two, T1 represents the control diet, (0 % shea caterpillar meal: 100 % fish meal, T2 means (25 % shea caterpillar meal: 75 % fish meal), T3 implies (50 % shea caterpillar: 50 % fish meal), T4 means (75 % shea caterpillar meal: 25 % fish) and T5 denotes (100% shea caterpillar meal: 0% fish meal).

**Table 3.2: Feed Composition of Broiler Finisher Diets for Experiment One and Two**

Feed ingredient	T1 SC (0%)	T2 SC (25%)	T3 SC (50%)	T4 SC (75%)	T5 SC (100%)
Maize grain	57.7	57.7	57.7	57.7	57.7
Fish meal anchovy	<b>16</b>	<b>12</b>	<b>8</b>	<b>4</b>	<b>0</b>
Shea Caterpillar	<b>0</b>	<b>4</b>	<b>8</b>	<b>12</b>	<b>16</b>
Wheat Bran	14	14	14	14	14
Soya bean meal	9	9	9	9	9
Oyster Shell	1.5	3.5	3.5	3.5	3.5
Premix	0.4	0.4	0.4	0.4	0.4
Dicalcium	1	1	1	1	1
Salt	0.37	0.37	0.37	0.37	0.37
Toxin binder	0.03	0.03	0.03	0.03	0.03
Total(kg)	100	100	100	100	100
<b>Calculated analysis</b>					
Crude protein (%)	20.47	20.47	20.47	20.47	20.47
Ether Extract (%)	3.45	3.66	3.88	4.09	4.31
Crude Fibre (%)	3.42	3.7	3.97	4.25	4.52
Lysine (%)	1.58	1.56	1.52	1.49	1.46
Methionine (%)	0.50	0.46	0.43	0.40	0.37
Calcium (%)	0.65	0.51	0.37	0.23	0.09
Phosphorus (%)	0.75	0.67	0.59	0.51	0.43
M E (kcal/kg)	2762.39	2791.43	2820.47	2849.51	2878.55

M E- Metabolizable Energy

**Table 3.3: Feed Composition of Broiler Starter Diets (0 - 4 Weeks) for Experiment Two**

Feed Ingredients	TREATMNETS				
	T1 (SC0%)	T2 (SC25%)	T3 (SC50%)	T4 (SC75%)	T5 (SC100%)
Maize grain	53.7	53.7	53.7	53.7	53.7
Fish meal	<b>17.3</b>	<b>12.97</b>	<b>8.65</b>	<b>4.33</b>	<b>0</b>
Shea caterpillar	<b>0</b>	<b>4.33</b>	<b>8.65</b>	<b>12.97</b>	<b>17.3</b>
Wheat bran	14.0	14.0	14.0	14.0	14.0
Soya bean meal	12.4	12.4	12.4	12.4	12.4
Oyster shell	1.5	1.5	1.5	1.5	1.5
Premix	0.3	0.3	0.3	0.3	0.3
Dicalcium	0.5	0.5	0.5	0.5	0.5
Salt	0.27	0.27	0.27	0.27	0.27
Toxin binder	0.03	0.03	0.03	0.03	0.03
Lysine	0.02	0.02	0.02	0.02	0.02
Methionine	0.01	0.01	0.01	0.01	0.01
Total(kg)	100	100	100	100	100
<b>Calculated analysis (%)</b>					
Crude protein (%)	23.03	23.03	23.03	23.03	23.03
Ether Extract (%)	3.42	3.66	3.89	4.13	4.36
Crude fibre (%)	3.76	4.06	4.36	4.66	4.96
Lysine (%)	1.76	1.72	1.69	1.66	1.63
Methionine (%)	0.54	0.51	0.48	0.44	0.41
Calcium (%)	0.22	0.56	0.41	0.26	0.10
Phosphorus (%)	0.82	0.72	0.64	0.55	0.46
M E (kcal/kg)	2768.25	2799.69	2831.05	2862.41	2893.85

M E- Metabolizable Energy

### 3.12 Cost of Ingredients Used to Compound Experimental Diets:

*Table 3.4: Cost of Feed Ingredients on a per kilogram basis (Cost per Kg GH¢)*

Ingredients	Weight per bag (Kg)	Cost per bag (GH¢)	Cost per kg (GH¢)
Maize	100	350	3.5
Fish meal	50	430	8.6
Shea caterpillar	50	299	5.98
Wheat bran	25	42	1.68
Soya bean	50	280	5.6
Oyster shell	50	42	0.84
Premix	25	330	13.2
Toxin binder	25	300	12
Dicalcium	50	88	1.76
Salt	50	115	2.3
Lysine	50	850	17
Methionine	50	1,350	27

### 3.13 Vaccination Schedule

For experiment one, the first Gumboro (intermediate) and first Newcastle disease vaccinations (H-Hitchner 1) were administered through drinking water on the seventh (7<sup>th</sup>) and fourteenth (14<sup>th</sup>) day respectively. The second Gumboro (intermediate plus strain) vaccination (Lasota) was done on the 21<sup>st</sup> day of age. The second Newcastle disease vaccination was administered when the birds were 28 days of age. Administration of provitamin by label Vita-X was given to boost the appetite of the birds.

For experiment two, the first Gumboro (intermediate), first Newcastle disease (H-Hitchner 1), 2<sup>nd</sup> Gumboro (intermediate plus strain), 2<sup>nd</sup> Newcastle vaccinations (Lasota) were administered on the 7<sup>th</sup>, 14<sup>th</sup>, 21<sup>st</sup>, and 28<sup>th</sup> days respectively. The prophylactic and vaccination schedule was duly followed as recommended for experiments One and Two as presented in appendices 1 and 2.

### **3.14 Parameters Measured**

The parameters measured for experiments One and Two include proximates, growth performance, haematological and biochemical attributes, carcass characteristics, and microbial analysis.

### **3.15 Data Collection Procedures**

Data was collected separately for Experiments One and Two.

### **3.16 Feed Consumption**

For both experiments, the weekly average feed intake per bird per replicate was calculated by deducting feed leftover in the feeding trough at the end of the week from the total feed supplied for the week divided by the number of birds in a replicate. The mean feed intake was then divided by the number of days to get feed intake per bird per day.

### **3.17 Water Intake**

Water was measured daily before being offered to the birds. Water intake was measured as the difference between the amount of water supplied and the quantity leftover on daily basis per replicate. These were added up at the end of each week to obtain weekly water intake per week. The weekly consumption value was then divided by the number of birds to obtain weekly water consumption per bird per replicate.

### **3.18 Live Weight and Live Weight Gain**

For experiment one, the birds in each cage were batch weighed at the commencement of the feeding trial and successively at the end of every week. The batch weight of the birds in each replicate was divided by the number of birds in the batch to get the average live weight

per bird. The initial average live weight per bird was deducted from week one weekly average, week one weekly average subtracted from week two weekly average, week two deducted from week three weekly average, and this was done consecutively up to the 5<sup>th</sup> week to obtain the live weight gain per week.

In experiment two, the birds in each replicate were batch weighed continually at the end of every week till the ninth week. The live weight gain per week was determined in the same way as in Experiment One.

### **3.19 Feed Conversion Ratio (FCR)**

The weekly feed conversion ratio was determined by dividing the average weekly feed consumed by the live weight gain during the five weeks for experiment one and nine weeks for experiment two. The average feed conversion ratio (AFCR) was determined by the summation of the five weeks of FCR divided by five for experiment One and by nine for experiment Two.

### **3.20 Haematological and Biochemical Analysis**

At the end of the 4th and 8th week for Experiment One and Two respectively, blood samples were collected from 15 birds, one bird per replicate. The blood samples were taken by inserting a sterilised 5mls syringe into the right-wing vein of each bird and drawing 2 millimetres of blood which was immediately discharged into sterilised vacutainer test tubes containing Ethylene Diamine Tetra Acetic Acid (EDTA) after the area was disinfected with cotton wool dampened with methylated alcohol spirit. The blood samples in each tube were shaken to uniformly mix with the EDTA to prevent coagulation. The samples collected were sent to Mampong Government Hospital laboratory for haematological analysis. The samples

were analysed for red blood cells, White Blood Cell, Platelets, Haemoglobin, Packed Cell Volume, Granulocyte, Lymphocytes, Mean Corpuscular Haemoglobin/Mean Cell Haemoglobin, mean cell volume and Mean Corpuscular Haemoglobin Concentration, Red Cell Distribution width standard deviation, and Red Cell distribution width coefficient of variation as well as Platelets Distribution Width using three-part Rayto Haematology Analyzer.

Again, blood samples were collected from 15 different birds from the five treatments involving three birds per treatment. The blood samples were collected carefully from the wing vein of each bird after the area was disinfected with cotton wool moistened with methylated alcohol spirit using 5mls sterilized syringes and dispensed gently into plain vacutainer tubes without EDTA and kept in a vacuum flask with ice cubes for blood biochemical analysis. Both total lipid and protein parameters such as total cholesterol, triglycerides, high-density lipoprotein, low-density lipoprotein as well as total protein, albumin, and globulin respectively were determined. The analysis was carried out at the A.B.C Medical Diagnostic Services Laboratory at Agona in the Ashanti region using Mindray BA 88A semi-auto Chemistry Analyser. The chemical used for the analysis was the ELITech brand. The biochemical analysis was not done for Experiment Two.

### **3.21 Carcass Parameters**

At the end of the 35<sup>th</sup> and 63<sup>rd</sup> day for experiments one and two respectively, fifteen birds each (males) were selected at random from the five treatments with three replicates each. One bird from each replicate was tagged on their shanks using pieces of nylon bags with different colours numbered 1, 2, and 3. The birds were starved overnight and only water was

provided. Ante-mortem fasting was done. Then, the birds' initial live body weights were taken using a kitchen electronic scale before the birds were all euthanized. Euthanization was done by cutting the carotid arteries and allowing the birds to bleed for about two to five minutes since proper bleeding of carcass improves the taste of meat and stores better for longer periods. After that their bleed weights were taken. The slaughtered birds were scalded in warm water and de-feathered manually. The following measurements were taken: de-feathered weight, dressed carcass weight, head weight, neck weight, wing weight, thigh weight, drum stick weight, shanks weight, breast weight, liver weight, heart weight, full gizzard weight, empty gizzard weight, intestine weight and weight of proventriculus as well as abdominal fat for Experiment Two. The dressing percentage was also calculated mathematically as follows:

$$\text{Dressing \%} = \text{Carcass weight} \div \text{live weight} \times 100\%$$

For Experiment One, three samples of drumsticks, breast and thigh from each treatment were used for proximate analysis at Kwame Nkrumah University of Science and Technology, Kumasi (KNUST) Nutrition Laboratory.

### **3.22 Mortality**

Mortality was recorded only once throughout the study period in Experiment One. One bird each from replicate T1R1 that is, the control and T2R2 were found dead on 10<sup>th</sup> February 2021. The dead birds were not subjected to post-mortem examination. Hence the cause of death was not known. No death was recorded in Experiment Two.

### **3.23 Cost-Benefit Analysis of Using Shea Caterpillar in Broiler Diet**

The cost of feed per kg for each of the experimental diets was determined based on the usual market prices of the ingredients at the time of the experiment. The cost of including the shea caterpillar and the conventional feed in the broiler diet was determined using the price per kilogram of conventional feed and the shea caterpillar, cost of feed per replicate, cost per kilogram body weight gain, selling price per kilogram of chicken, selling price of broilers and profit on feed alone. The price per kilogram cost of feed was determined by multiplying the quantity of each ingredient by the unit cost of the ingredients to get the cost of ingredients. The cost of ingredients was summed up to obtain the total feed cost. Then, the total feed cost was divided by a hundred to obtain the per kilogram cost of feed. The cost of feed per replicate was calculated by multiplying the per kilogram cost of feed by the total feed consumed per replicate. The cost per kilogram body weight gain was also determined by dividing the cost per bird by kilogram weight gain. The current selling price per kilogram of chicken (GH¢28) was used. The selling price of a bird was determined by multiplying the per kilogram selling price of broilers by the kilogram body weight gain. The profit on feed was calculated by subtracting the cost of feed from the selling price of a bird. The data were subjected to analysis.

### **3.24 Microbial Analysis**

Microbial analysis was carried out on the shea caterpillar meal.

#### ***3.24.1 Determination of coliform load in milled shea caterpillar***

A sample of shea caterpillar was subjected to microbial analysis according to the procedure in Merck Manual 12<sup>th</sup> Edition. The total coliforms of the feed ingredient (Shea Caterpillar)

were tested using Merk's Chromo cult coliform Agar. Ten (10) fold serial dilution was made with phosphate-buffered solution (PBS) up to  $10^{-4}$ . One milliliter (1ml) of each dilution was inoculated by pour plate method triplicate. The plates were incubated in an inverted position at 37°C for 24 hours.

#### **3.24.2 Total plate count**

Dark-blue to violet colonies were counted as *Escherichia coli* (*E. coli*) and the salmon to red as other coliforms. Indole test was conducted on salmon to red colonies on a plate to differentiate *E. coli* from other coliforms and the colouration turned into chilly red indicating that the observed colonies were *E. coli*.

#### **3.25 Sensory Evaluation of Broiler Chicken Breast Meat**

A date was set for the sensory evaluation of experiment one. Eight untrained student panellists consisting of five males and three females with an age range of 20 to 25 years were selected from the University of Education, Mampong campus by invitation and their willingness to participate in an organoleptic evaluation exercise or experiment.

The concept of sensory evaluation was explained comprehensively to the participants during the preliminary training session. All the participants were willing to take part in the activity after they were informed. A five-point hedonic scale was developed and key terms such as tenderness, flavour, colour, juiciness, and toughness were clearly explained to the participants. For each organoleptic attribute, participants were guided during the training on how to score on a 5 point hedonic scale crafted for the study, where 1 is very unacceptable, 2 is acceptable, 3 is moderate, 4 is slightly acceptable and 5 is very desirable.

### ***3.25.1 Meat Cooking and Evaluation***

The breast meat was obtained from 5 birds (one per treatment) of the 15 birds selected for carcass analysis. Only the flesh without skin from each breast was carefully removed from the bone with a sharp knife and cooked. The meat was boiled on 5 gas cookers in stainless aluminium saucepans. Two hundred millilitres of clean, fresh water and two grams of iodised salt were used for cooking the meat. The cooking lasted for 40 minutes with a temperature above 100<sup>0</sup>C as was indicated by a food thermometer used.

After cooking, the scanty leftover water was drained from the saucepans, and the meat was allowed to cool at room temperature. Each sample was cut into 8 pieces (replicates) according to a standard size of 2cm by 2cm by 2cm cubes. The total pieces obtained were forty (40) and each cut portion weighed 34g. Each sample was wrapped in 15cm by 15cm aluminium foil identified with three-digit codes labelled as 001, 002, 003, 004 and 005 for T5 (SC100 %), T4 (SC75%), T3 (SC50%), T2 (SC75%) and T1 (SC0%) respectively. Eight plates with five wrapped pieces of meat on each were served to participants with each plate having a sample from each treatment. Samples of breast meat served were eaten at a time by all participants, their mouths were rinsed each time they finished a sample till all the samples were consumed within one hour.

After eating, each participant was given a five (5) point hedonic scale with treatment codes of three-digit numbers on each of them. The five point hedonic scale was filled after consumption of meat from all treatments using the aluminium foil as a guide. After responding to the guide by the respondents, they were collected for analysis and the

recovery rate was 100 percent. The ultimate sensory attributes used in this study are simplified in Table 3.5.

**Table 3.5: Scale used to rank Breast Meat of Cobb 500 broiler chickens**

<b>RANK</b>	<b>COLOUR</b>	<b>FLAVOUR</b>	<b>TENDERNESS</b>	<b>JUICINESS</b>	<b>TOUGHNESS</b>
1	V. unacceptable	V. unacceptable	V. unacceptable	V. unacceptable	V. unacceptable
2	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
3	Moderate	Moderate	Moderate	Moderate	Moderate
4	S. acceptable	S. acceptable	S. acceptable	S. acceptable	S. acceptable
5	V. desirable	V. desirable	V. desirable	V. desirable	V. desirable

V=Very, S=Slightly

### 3.26 Statistical Analysis

The data collected were subjected to one-way analysis of variance (ANOVA) using GenStat Eleventh Edition software (2008). Differences between means were separated using the Least Significance Difference (LSD) test at 5% level significant in both Experiments. Means of treatments were summarized in tables for easy comprehension. The statistical model used was defined as:

$$Y_{ijklm} = \mu + \beta_1 X_{1i} + \beta_2 X_{2j} + \beta_3 X_{3k} + \beta_4 X_{4l} + \beta_5 X_{5m} + \epsilon_{ijklm}$$

Where:

$Y_{ijklm}$  represents the response variable being measured (e.g., proximates, microbial analysis, feed intake, body weight gain, feed conversion ratio, haematology and biochemical profile, carcass characteristics, and organoleptic attributes).

$\mu$  is the overall mean or the intercept term, representing the baseline or average response when all the explanatory variables are zero.

$\beta_1, \beta_2, \beta_3, \beta_4,$  and  $\beta_5$  the coefficients associated with the explanatory variables  $X_1, X_2, X_3, X_4,$  and  $X_5,$  respectively.

$X_{1i}$  represents the first treatment, Shea caterpillar meal at 0 % (T1, control treatment).

- $X_{2j}$  represents the second treatment, Shea caterpillar meal at 25 % (T2).  
 $X_{3k}$  represents the third treatment, Shea caterpillar meal at 50 % (T3).  
 $X_{4l}$  represents the fourth treatment, Shea caterpillar meal at 75 % (T4).  
 $X_{5m}$  represents the fifth treatment, Shea caterpillar meal at 100 % (T5).  
 $\epsilon_{ijklm}$  represents the random error term.

## CHAPTER FOUR

### 4.0 RESULTS

#### 4.1 Proximate Compositions

##### 4.1.1 Proximate composition of the shea caterpillar and fishmeal

The proximate composition of the shea caterpillar and fish meal is shown in Table 4.1.

**Table 4.1: Proximate Composition of Shea Caterpillar and Fishmeal**

Parameters (%)	Shea caterpillar	Fishmeal
Moisture content	11.08	11.95
Ash content	3.9	16.91
Crude protein	60.42	54.51
Crude fat	10.4	6.28
Crude fibre	7.9	-
Nitrogen Free Extract	6.3	10.35
Metabolizable energy (kcal/kg)	3306.76	2892.82

The analysis showed a high crude protein content of 60.42%, ash content of 3.9%, fat of 10.4%, crude fibre of 7.9%, and carbohydrate of 6.3% as well as 3306.76 Kcal/kg of metabolizable energy. On the other hand, the proximate composition of fish meal showed a moisture content of 11.95%, crude protein content of 54.51%, ash content of 16.91%, crude fat of 6.28 %, nitrogen-free extract of 10.35% as well as 2892.82 kcal/kg of metabolizable energy.

#### 4.1.2 Proximate composition of broiler starter diets

The proximate composition of broiler starter diets is presented in Table 4.2.

**Table 4.2: Proximate Composition of Broiler Starter Diets for experiment two**

Parameters	TREATMENTS				
	T1	T2	T3	T4	T4
MOISTURE	12.09	12.35	11.65	11.1	11.45
ASH	11.14	8.85	5.99	8.04	6.0
CP	24.96	23.86	22.99	21.02	23.64
CF	6.44	6.52	6.82	6.95	7.3
Fibre	3.5	3.7	4.05	4.65	4.75
NFE	41.87	42.4	48.78	49.24	46.86
M E (kcal/kg)	2915.76	3089.93	3093.22	2987.85	3111.92

KEY: CP- Crude Protein, CF- Crude Fat, NFE- Nitrogen Free Extract, ME- Metabolizable Energy.

Results of the proximate analysis of the broiler starter diets in Table 4.2 showed that moisture content was 12.35 % for T2 and 11.1 % as the lowest in T4. The numerical ash content of dietary treatment one was 11.14% and treatment three was 5.99%. Crude protein was 24.96% in T1 and T4 recorded 21.02%. The amount of crude fat in descending order was 7.3 %, 6.95 %, 6.82 %, 6.52 % and 6.44 % for treatments T5, T4, T3, T2, and T1 respectively. In terms of crude fibre and nitrogen-free extract, the control diet (T1) had the lowest value of 3.5 % for crude fibre and 41.87 % for nitrogen-free extract. The highest value for crude fibre was 4.75% for dietary treatment five (T5) and 49.24% for NFE in treatment four (T4). Metabolizable energy ranged from 2915.76kcal/kg in T1 to 3111.92kcal/kg in T5.

#### 4.1.3 Proximate composition of broiler finisher diets

The proximate composition of broiler finisher diets is shown in Table 4.3.

**Table 4.3: Proximate Composition of Broiler Finisher Diets for Experiments one and two**

Parameter (%)	TREATMENTS				
	T1	T2	T3	T4	T5
MOISTURE	11.3	11.4	11.2	11.3	11.4
ASH	11.5	10.6	8.75	7.55	8.4
CP	23.42	24.07	23.77	23.2	24.52
CF	4.5	5.3	5.7	5.98	5.6
Fibre	3.9	3.85	4.5	5.65	5.75
NFE	45.38	44.78	46.08	46.32	44.33
M E (kcal/kg)	2822.94	2891.43	2958.55	2968.76	2916.87

KEY: CP- Crude Protein, CF- Crude Fat, NFE- Nitrogen Free Extract, ME- Metabolizable Energy

The moisture content was similar in all treatments. The ash content of 11.5% was recorded in Treatment T1 and T4 recorded 7.55%. Crude protein content of 24.52% was the highest in T5 and the lowest was observed in T4 23.3 %. Numerically, crude fat value was 4.5% in the control diet (T1) and T4 had 5.98 % as the highest. Treatments with more shea caterpillar had high crude fibre. The nitrogen-free extract stretched from 44.33% in T5 to 46.32% in T4. Metabolizable energy ranged from 2822.94kcal/kg in treatment T1 to 2968.76kcal/kg in T4 (Table 4.3).

#### 4.1.4 Amino acid composition of the shea caterpillar and fish meal

The amino acid composition of the shea caterpillar and fishmeal is shown in Table 4.4.

**Table 4.4: Amino Acid Composition of the Shea Caterpillar Meal and Fishmeal**

Amino acid	Shea caterpillar (mg/100g)	Fish meal (mg/100g)
Leucine*	2.51	1.95
Lysine*	3.78	1.39
Phenylalanine*	2.59	5.83
Histidine*	4.03	-
Isoleucine*	3.69	1.95
Threonine*	3.09	1.58
Tryptophan*	5.49	6.72
Valine*	3.07	1.73
Methionine*	1.18	1.75
<b>Total EAA</b>	<b>29.34mg/100g</b>	<b>22.89mg/100g</b>
Alanine**	7.35	1.57
Aspartic acid**	2.92	1.58
Glutamic acid**	8.67	-
Glycine**	2.85	-
Serine**	5.95	1.59
Proline**	7.35	1.68
Asparagine**	-	1.56
Glutamine**	-	1.39
Tyrosine**	-	4.80
Total NEAA	<b>35.09mg/100g</b>	<b>14.17mg/100g</b>
Total EAA+NEAA	<b>64.52mg/100g</b>	<b>37.01mg/100g</b>

\*Essential Amino acid, \*\* Non- Essential Amino Acid

This study revealed that the shea caterpillar has fifteen amino acids. A total of 29.43mg/100g of the amino acid in the shea caterpillar flour was made up of nine essential amino acids while 35.09mg/100g was from six non-essential amino acids. The highest essential amino acid was tryptophan 5.49mg/100g and the least was methionine 1.18mg/100g. In terms of non-essential amino acids, glutamic acid (8.67mg/100g) was dominant, followed by alanine (7.35mg/100g) and proline (7.35mg/100g). The least was glycine (2.85mg/100g) (Table 4.4).

The amino acids composition showed that fish meal contained 8 essential and 7 non-essential amino acids. The total essential amino acid content was 22.894mg/100g while that of the non-essential amino acid was 14.117mg/100g. For the essential amino acid, tryptophan recorded the highest value of 6.719mg/100g followed by phenylalanine with 5.834mg/100g and the least was lysine with 1.386mg/100g. In terms of non-essential amino acids, tyrosine had 4.811mg/100g as the highest and glutamine was the lowest at 1.386mg/100g (Table 4.4).

#### 4.1.5 Composition of fresh and dried broilers thigh, drum stick, and breast meat

The composition of fresh and dried broiler chickens thigh, drumsticks, and the breast meat is shown in Tables 4.5 and 4.6.

**Table 4.5: Composition of Fresh Broiler Thigh, Drum stick, and Breast Meat**

PARAMETER (%)	TREATMENTS					SEM	P-Value
	T1	T2	T3	T4	T5		
MOISTURE	68.78 <sup>a</sup>	65.78 <sup>b</sup>	67.54 <sup>b</sup>	65.72 <sup>bc</sup>	63.69 <sup>c</sup>	0.796	0.010
ASH	1.22 <sup>b</sup>	1.08 <sup>c</sup>	1.52 <sup>b</sup>	1.74 <sup>a</sup>	1.63 <sup>b</sup>	0.1355	0.029
CP	23.51 <sup>c</sup>	26.74 <sup>a</sup>	24.54 <sup>b</sup>	25.51 <sup>b</sup>	25.44 <sup>b</sup>	0.523	0.015
FAT	4.17 <sup>c</sup>	5.46 <sup>b</sup>	5.40 <sup>b</sup>	5.79 <sup>b</sup>	7.35 <sup>a</sup>	0.336	0.001
NFE	2.32 <sup>a</sup>	0.94 <sup>d</sup>	0.95 <sup>d</sup>	1.24 <sup>c</sup>	1.90 <sup>b</sup>	0.0656	0.001
ME(kcal/kg)	1292.06 <sup>c</sup>	1468.80 <sup>b</sup>	1384.80 <sup>d</sup>	1460.89 <sup>c</sup>	1609.01 <sup>a</sup>	0.809	0.001

<sup>abc</sup> Means bearing the same superscript are not significantly different (P>0.05)

KEY: CP- Crude Protein, NFE- Nitrogen Free Extract, ME- Metabolizable Energy.

For the fresh carcass analysis, there was a significant difference (P<0.05) among all the treatments in terms of moisture, ash, crude protein, crude fat, nitrogen-free extract, and metabolizable energy. Birds fed the control diet had better moisture content while those fed T4 and T5 were similar. The similarity was also observed in birds fed T2, T4, and T5 in

terms of moisture. The ash content of birds served T4 was the best compared with the other treatments. However, the performance of birds fed T1, T3 and T4 were similar, but significantly different from T2. The crude protein value of birds fed dietary treatment two was the best, while birds fed T4 and T5 were similar but significantly different from T2 and T3. In terms of crude fat, birds fed T5 performed better while birds fed T2, T3, and T4 were similar and those fed the control diet had the lowest crude fat content. The nitrogen-free extract content of birds fed the control diet was the best among all the treatments followed by birds fed T5. The birds fed T2 and T3 were similar but different from T4. The performance of birds fed T5 was the best among all the treatment means followed by birds fed T2, T4, and T3 and T1 in descending order in terms of energy level. Hence, birds fed 100 percent shea caterpillar (T5) had the best energy content than the control diet which was the least (Table 4.5).

**Table 4.6: Composition of Dried Broiler Thigh, Drum Stick, and Breast meat**

Parameters (%)	TREATMENTS					SEM	P-Value
	T1	T2	T3	T4	T5		
ASH	3.900 <sup>c</sup>	3.150 <sup>d</sup>	4.690 <sup>b</sup>	5.090 <sup>a</sup>	4.490 <sup>b</sup>	0.1046	0.001
CP	75.30 <sup>b</sup>	78.15 <sup>a</sup>	75.41 <sup>b</sup>	74.43 <sup>c</sup>	70.05 <sup>d</sup>	0.1818	0.001
FAT	13.35 <sup>d</sup>	15.95 <sup>c</sup>	16.64 <sup>b</sup> <sup>c</sup>	16.89 <sup>b</sup>	20.25 <sup>a</sup>	0.242	0.001
NFE	7.45 <sup>a</sup>	2.75 <sup>e</sup>	2.92 <sup>d</sup>	3.59 <sup>c</sup>	5.21 <sup>b</sup>	0.0347	0.001
ME (kcal/kg)	4138.88 <sup>e</sup>	4292.44 <sup>b</sup>	4266.55 <sup>c</sup>	4261.1 <sup>d</sup>	4430.65 <sup>a</sup>	0.781	0.021

<sup>abc</sup> Means bearing the same superscript are not significantly different (P>0.05)

KEY: CP- Crude Protein, NFE- Nitrogen Free Extract, ME- Metabolizable Energy.

There was a significant difference (P<0.05) across all the treatment means in terms of ash, crude protein, crude fat, nitrogen-free extract, and metabolizable energy. Birds fed dietary T4 were the best in terms of ash content followed by T3 and T5 which were similar. The

lowest ash content was observed from birds fed the control diet. The crude protein value of birds served T2 was the best whereas the performance of birds fed T1 (control) and T3 were similar. Crude protein value observed from birds fed 100 percent shea caterpillar (T5) was the lowest and T2 recorded highest when birds were fed SC25 %. As the inclusion rate of shea caterpillar decreased, the crude protein content in the dried carcass also increased from T4, T3 to T2. The fat value of birds fed T5 was the best among all the treatment means and all the treatments that contained shea caterpillar meal had better fat content than the control diet. Nitrogen-free extract of birds fed the control diet was the best, just like in the fresh carcass, followed by fowls fed 100 percent shea caterpillar meal while the least value was observed from birds fed T2. Birds' performance in dietary T5 was the best among all the treatment means in terms of metabolizable energy level. Hence, birds provided 100 percent shea caterpillar (T5) had the best energy content than the control diet (Table 4.6). Hence, birds fed the experimental diets at varied percentages contained better energy levels than birds fed the control diet Table 4.6.

## **4.2 Experiment One**

### ***4.2.1 Effect of shea caterpillar meal on growth performance of broiler chickens***

Effect of shea caterpillar meal on growth performance of broilers fed different levels of shea caterpillar meal for five weeks are presented in Table 4.7.

**Table 4.7: Effect of Varying Levels of Shea Caterpillar Meal on Feed Intake**

Weeks	TREATMENTS					SEM	P-Value
	T1	T2	T3	T4	T5		
5	709	630	696	586	553	38.3	0.065
6	958	971	888	882	842	32.1	0.081
7	1092	1162	1091	986	977	66.6	0.306
8	1050	1217	1136	1231	1084	54.5	0.152
9	1166	1156	922	1171	1158	88.1	0.275
T.F. I (g/bird)	4975	5134	4733	4855	4615	1769	0.329

TFI-Total Feed Intake, SEM-Standard Errors of Means P-Probability

**4.2.1.1 Effect of shea caterpillar meal on weekly feed consumption of broiler chickens**

There was no significant difference ( $P>0.05$ ) among all the dietary treatment means throughout the five weeks. However, as the birds grew there was a consistent increase of feed intake in all the treatments throughout the study period. In terms of total feed intake, birds fed diet that contained 25% shea caterpillar meal (T2) had the highest feed intake numerically (5,134g/bird) while the least amount of feed was consumed by birds in T5 (4615g/bird) (Table 4.7). Total feed intake however, was not significantly affected by the shea caterpillar in the diets.

#### 4.2.1.2 Effect of shea caterpillar meal on water intake of broilers chickens

Effect of shea caterpillar meal on water intake of broilers is shown in Table 4.8.

**Table 4.8: Effect of Shea Caterpillar Meal on Water intake of Broilers in millitres**

Wks.	TREATMENTS					SEM	P-Value.
	T1	T2	T3	T4	T5		
5	1918 <sup>a</sup>	1911 <sup>a</sup>	1909 <sup>a</sup>	1378 <sup>b</sup>	1446 <sup>b</sup>	48.6	<.001
6	2562 <sup>a</sup>	2102 <sup>b</sup>	2164 <sup>b</sup>	1910 <sup>c</sup>	2049 <sup>bc</sup>	57.2	<.001
7	2312	2401	2384	2346	2191	113.2	0.707
8	2195	2712	2544	2773	375	128.5	0.051
9	2541	2608.	2020.	2669.	2661.	185.4	0.146
TWI	11,528	11,735	11,022	11,075	10,722	386.1	0.400

<sup>abc</sup> Means bearing the same superscript are not significantly different (P>0.05)

P-Probability, T.W.I: Total water intake

Water intake of birds fed the control (T1) was not significantly different from birds fed T2 and T3, but was significantly different from T4 and T5 in the first week. The level of water consumption in T1, T2, and T3 was similar (Table 4.7). Water intake of birds on T1 (control) was higher as compared with that of water intake of birds fed the shea caterpillar meal (T2 T3, T4 and T5) in the second week. Water intake of birds fed T2, T3 and T5 had similar value but were significantly higher than that of birds fed on the T4 diet. Water intake of birds did not show any significant difference among all the treatment means from the third to the fifth week. There was marginal increase of water intake within the treatments on weekly basis (Table 4.8).

#### 4.2.1.3 Effect of shea caterpillar meal on weekly body weight of broiler chicks

Effect of shea caterpillar meal on weekly body weight (BWT) of broiler chicks (4 - 9weeks)

is shown in Table 4.9.

**Table 4.9: Effect of Shea Caterpillar Meal on weekly Body Weight of Broiler Chicks**

PARAMETERS	TREATMENTS					SEM	P-Value
	T1	T2	T3	T4	T5		
INITIAL.WT.	720.0	726.7	733.3	720.0	726.7	7.30	0.682
WT1	1160 <sup>a</sup>	1173 <sup>a</sup>	1233 <sup>a</sup>	1045 <sup>b</sup>	1080 <sup>b</sup>	23.6	0.001
WT2	1540 <sup>a</sup>	1473 <sup>ab</sup>	1500 <sup>a</sup>	1325 <sup>c</sup>	1380 <sup>bc</sup>	33.5	0.006
WT3	1948 <sup>a</sup>	1843 <sup>a</sup>	1875 <sup>a</sup>	1610 <sup>b</sup>	1640 <sup>b</sup>	43.7	<.001
WT4	2421 <sup>a</sup>	2278 <sup>a</sup>	2390 <sup>a</sup>	2017 <sup>b</sup>	2002 <sup>b</sup>	73.2	0.005
WT5	2794 <sup>a</sup>	2746 <sup>a</sup>	2778 <sup>a</sup>	2393 <sup>b</sup>	2304 <sup>b</sup>	86.5	0.005

Means bearing the same superscript are not significantly different (P>0.05)

SEM-Standard Errors of Means, WT-Weight.

There was a significant difference (P<0.05) among the treatment means from week one to five except for initial weight where there was no significant difference. By week one of the experiment, the live body weight (LBW) of birds fed T3, T2, and T1 were similar, but significantly different from T4 and T5. In the second week, the performance of birds on T1, T3, and T3 were similar but were significantly different (P<0.05) from birds on T4. Live body weight during week three showed a similar trend to that of week one (Table 4.9). Also, the performance of birds in weeks 4 and 5 showed a similar pattern as in week one. In week 4, a higher growth rate was recorded in the control while T5 had the least. Similarly, in week 5 the least performance was recorded in T5 while the best growth performance was in T1, the control (Table 4.9).

#### 4.2.1.4 Effect of shea caterpillar on body weight gain of broiler chickens (4-9weeks)

Effect of shea caterpillar on body weight gain of broilers is presented in table 4.10

**Table 4.10: Effect of Shea Caterpillar Meal on Body weight Gain of Broiler Chicks**

PARAMETERS	TREATMENTS					SEM	P-Value
	T1	T2	T3	T4	T5		
WTG1	440 <sup>a</sup>	447 <sup>a</sup>	500 <sup>a</sup>	325 <sup>b</sup>	353 <sup>b</sup>	25.8	0.004
WTG2	379.7 <sup>a</sup>	299.3 <sup>a</sup>	266.3 <sup>b</sup>	280.0 <sup>b</sup>	300.0 <sup>b</sup>	17.75	0.009
WTG3	408.0 <sup>a</sup>	370.3 <sup>a</sup>	375.0 <sup>a</sup>	285.7 <sup>b</sup>	260.3 <sup>b</sup>	21.39	0.003
WTG4	473	435	515	407	362	60.8	0.477
WTG5	373	468	388	376	302	44.8	0.218
TWTG	2074 <sup>a</sup>	2019 <sup>a</sup>	2045 <sup>a</sup>	1673 <sup>b</sup>	1577 <sup>b</sup>	92.1	0.008

<sup>ab</sup> Means bearing the same superscript are not significantly different ( $P > 0.05$ )

SEM-Standard Errors of Means, WTG-Weight Gain, TWTG-Total Weight Gain, G-Gram.

There was a significantly different ( $P < 0.05$ ) among the treatment means in weeks one to three except in weeks 4 and 5. Average body weight gain (BWG) for week 1 showed no significant differences among dietary treatments T1, T2, and T3, but were significantly higher as compared to treatments T4 and T5. Birds on treatments T1, T2, and T3 performed better than birds on dietary treatment T4 and T5 (Table 4.10).

In week 2, the mean BWG of birds fed T1 (control) and T2 were similar but significantly higher than birds fed dietary T3, T4 and T5. The mean body weight gain for week three were similar among dietary treatments T1, T2, and T3, but were all significantly higher from treatments T4 and T5. Birds on dietary treatment T1, T2, and T3 performed better. (Table 4.10). In terms of total weight gain, there were no significant differences of birds in dietary treatment T1, T2, and T3, but were significantly different from birds on T4 and T5. The performance of birds on dietary treatments T1, T2, and T3 was better (Table 4.10).

#### 4.2.1.5 Effect of shea caterpillar meal on feed conversion ratio of broiler chickens

The Effect of shea caterpillar meal on feed conversion ratio of broilers (4 - 9 weeks) is presented in Table 4.11.

**Table 4.11: Effect of Shea Caterpillar Meal on Feed Conversion Ratio of Broilers**

PARAMETERS	TREATMENTS					SEM	P-Value
	T1	T2	T3	T4	T5		
1	1.62	1.42	1.40	1.82	1.59	0.1524	0.344
2	2.54	3.27	3.34	3.19	2.82	0.2135	0.106
3	2.69	3.13	2.97	3.47	3.75	0.237	0.065
4	2.53	2.94	2.26	3.08	3.01	0.449	0.657
5	3.15 <sup>ab</sup>	2.61 <sup>b</sup>	2.36 <sup>b</sup>	3.13 <sup>ab</sup>	3.83 <sup>a</sup>	0.250	0.016
AV.FCR	2.50	2.67	2.47	2.94	3.00	0.1449	0.080

<sup>ab</sup> Means bearing the same superscript are not significantly different ( $P>0.05$ )

SEM-Standard Errors of Means, AV.FCR-Average Feed Conversion Ratio

There were no significant differences ( $P>0.05$ ) among all the treatment means from week one to four except week five. Birds fed dietary T1, T4 and T5 had similar FCR while birds fed T1, T2, T3 and T4 also recorded similar values. The average FCR for chicks on all the dietary treatments showed no significant difference among the treatment means (Table 4.11).

### 4.3 Effects of Shea Caterpillar on Haematological Parameters of Broilers (4-9 weeks)

Effects of shea caterpillar on haematological parameters of broilers (4-9weeks) is presented in Table 4.12.

**Table 4.12: Effect of Shea Caterpillar Meal on Haematological Parameters of Broilers**

PARAMETERS	TREATMENT					SEM	P-Value	NRR
	T1	T2	T3	T4	T5			
WBC (10 <sup>9</sup> /L)	64.70	62.90	58.70	58.5	67.9	6.15	0.787	1.2-3.0 *
LYM (10 <sup>9</sup> /L)	58.00	56.90	54.60	54.4	62.1	5.18	0.824	45.0-70.*
RBC (10 <sup>12</sup> /L)	1.780	1.97	1.91	1.79	1.957	0.13	0.741	1.5-3.5*
HGB(g/dl)	7.20	7.97	7.90	7.07	7.30	0.38	0.374	9.27-13.0*
MCHC(g/Dl)	31.13	31.37	31.17	30.20	30.13	0.48	0.284	26.0-35.0*
MCH (pg.)	40.60	40.53	40.53	39.50	37.73	1.22	0.441	33.0-47.0*
MCV(FL)	130.20	129.2	130.10	131.0	124.9	2.66	0.539	90.0-140 *
RDW-CV	4.22 <sup>b</sup>	11.87 <sup>a</sup>	11.87 <sup>a</sup>	11.83 <sup>a</sup>	12.73 <sup>a</sup>	1.87	0.046	
RDW-SD (FL)	67.30	64.40	64.70	65.40	66.1	3.01	0.961	
HCT%/PCV	23.17	25.37	25.93	23.47	24.20	1.44	0.614	22.0-35%*
PLT (10 <sup>9</sup> /L)	19.00	27.30	20.00	18.70	32.0	4.51	0.214	
MPV (FL)	5.97	6.40	5.90	5.70	6.07	0.29	0.570	
PDW	0.10	0.12	0.12	0.12	0.11	0.01	0.384	

<sup>ab</sup> Means in the same row bearing the same superscript are not significantly different (P>0.05)

\* Jain. (1993) as cited in Aengwanich *et al.* (2004). SEM=Standard Error of Means.

NRR ; Normal Reference range

*Red Blood Cell (RBC), White Blood Cell (WBC), Platelets (PLT), Platelets Distribution Width (PDW), Packed Cell Volume (PCV)/Haematocrit (HCT), Lymphocytes(LYM), Red Cell Distribution Width Standard Deviation (RDW-SD), Red Cell Distribution Width Coefficient of Variation (RDW-CV), Mean Corpuscular Volume/Mean Cell Volume (MCV), Mean Corpuscular Haemoglobin (MCH), Haemoglobin (Hb) and Mean Corpuscular Haemoglobin Concentration (MCHC).*

There was no significant difference (P>0.05) among all the haematological indices except RDW-CV. Birds on all the treatments showed similar values (Table 4.12). However, values obtained for RBC were within the normal reference ranges and WBC values were above the reference range. Red Cell Distribution Width Coefficient of Variation (RDW-CV) of birds on all the treatments was higher than the control (Table 4.12).

#### 4.4 Effect of Shea Caterpillar Meal on Blood Biochemical Parameters of Broilers.

Effect of shea caterpillar meal on blood biochemical parameters of broiler chickens is presented in Table 4.13.

**Table 4.13: Effect of Shea Caterpillar Meal on Blood Biochemical Indices of Broilers**

PARAMETERS	TREATMENTS					SEM	P-Value	NRR
	T1	T2	T3	T4	T5			
Total Protein (g/l)	33.3	27.3	27.0	25.0	22.0	2.49	0.085	3.0-4.9*
Albumin (g/l)	11.67	9.67	10.67	10.67	8.33	0.955	0.217	2.6-3.6*
Globulin (g/l)	21.67 <sup>a</sup>	17.67 <sup>ab</sup>	16.33 <sup>ab</sup>	14.33 <sup>b</sup>	13.67 <sup>b</sup>	1.706	0.050	
Cholesterol (mmol/L)	2.70	2.50	2.97	2.67	2.67	0.2082	0.637	2.0-4.5*
Triglyceride(mmol/L)	0.53	0.70	1.23	0.97	0.80	0.1125	0.255	0.5-0.9*
HDL (mmol/L)	1.17	1.07	1.50	1.07	1.10	0.1125	0.096	1.5-1.9*
LDL (mmol/L)	1.30	1.10	1.17	1.17	1.20	0.1164	0.239	1.3-2.6*

<sup>ab</sup> Means bearing the same superscript are not significantly different ( $P>0.05$ )

NRR; Normal Reference range, \*Cynthia, (2011), Low Density Lipoprotein, HDL-High Density Lipoprotein, SEM=Standard Error of Means.

There were no significant differences ( $P>0.05$ ) among all the treatment means in terms of total protein, albumin, total cholesterol, triglyceride, high-density lipoprotein, and low-density lipoprotein except globulin. All the values obtained for total protein and albumen from the dietary treatments were above the normal reference ranges. Values obtained for total protein and globulin followed a pattern, the values decreased with an increase in the level of the shea caterpillar from 25% to 100%. Also, values obtained from T3 and T4 for triglyceride were above the normal reference range. The normal reference values for HDL and LDL were below the reference range for all the treatments apart from T3 and T1 respectively. There was a significant difference among all the dietary treatment means in terms of globulin. The blood globulin content of birds on the T1 (control), T2, and T3 was better than birds in dietary treatment T4 and T5 (Table 4.13).

#### 4.5 Effect of Shea Caterpillar Meal on Carcass Characteristics of Broilers (4-9 weeks)

Effect of shea caterpillar meal on carcass characteristics of broiler chickens (4-9 weeks) is shown in Table 4.14.

**Table 4.14: Effect of Shea Caterpillar Meal on Carcass Characteristics of Broilers**

PARAMETERS	TREATMENTS					SEM	P-Value
	T1	T2	T3	T4	T5		
Live wt.(g)/bird	3167	2973	3000	2467	2633	196.60	0.149
Bled wt.(g)/bird)	3090	2845	2856	2404	2554	189.10	0.162
Defeathered wt.	2956	2648	2749	2294	2433	177.10	0.147
Dressed carcass	2521	2290	2311	1900	1970	153.30	0.083
Head	82.70 <sup>a</sup>	71.30 <sup>ab</sup>	71.30 <sup>ab</sup>	60.00 <sup>bc</sup>	55.70 <sup>c</sup>	4.78	0.018
Wings	136.30 <sup>a</sup>	115.70 <sup>ab</sup>	122.00 <sup>ab</sup>	89.30 <sup>c</sup>	107.30 <sup>bc</sup>	8.09	0.022
Breast	887 <sup>a</sup>	861 <sup>a</sup>	781 <sup>ab</sup>	571 <sup>c</sup>	712 <sup>bc</sup>	52.90	0.011
Neck	120.0 <sup>a</sup>	89.00 <sup>bc</sup>	102.00 <sup>ab</sup>	90.70 <sup>bc</sup>	76.70 <sup>c</sup>	7.06	0.014
Drumstick	168.30	169.00	154.00	127.30	137	10.27	0.057
thigh	231.00	202.70	233.30	190.00	181.7	14.39	0.094
Feet	114.30	110.30	101.30	90.70	96.30	7.10	0.189
Full Gizzard	60.30	53.70	61.00	69.00	49.30	4.12	0.055
Empty Gizzard	47.7	38.3	39.3	37.7	37.0	2.97	0.147
Heart	9.67 <sup>b</sup>	14.67 <sup>a</sup>	15.00 <sup>a</sup>	11.33 <sup>b</sup>	11.33 <sup>b</sup>	0.745	0.002
Liver	53.3 <sup>ab</sup>	47.7 <sup>ab</sup>	45 <sup>bc</sup>	41 <sup>c</sup>	58 <sup>a</sup>	3.61	0.042
Intestine	95.0	115.7	116.3	116.0	127.3	7.56	0.118
Proventriculus	9.33	9.33	10.33	10.33	10.00	0.650	0.668
Dressing (%)	79.5988 <sup>a</sup>	77.0062 <sup>c</sup>	77.0215 <sup>c</sup>	77.080 <sup>b</sup>	74.7968 <sup>d</sup>	0.01100	<0.001

<sup>abcd</sup> Means bearing the same superscript are not significantly different (P>0.05).

Wt. = weight, SEM=Standard Error of Means. P-Probability

There was a significant difference (P<0.05) among the treatment means regarding dressing percentage, liver weight, heart weight, neck weight, breast weight, wings weight, head weight and the rest were not significant. In terms of head weight, birds fed treatments T1 (control), T2 and T3 had higher head weights than birds on T4 and T5. The head weight of T2, T3, and T4 was similar.

Also, broilers fed dietary treatments T1, T2 and T3 had heavier weight than those fed T4 and T5 diets in terms of wings weight. However, birds on T2, T3, and T5 were also similar in terms of wing weight. Birds fed T1, T2 and T3 also had similar weight concerning breast weight, but different from T4 while those served T5 recorded the least. Similarly, the neck weight of birds fed dietary treatment T1, and T3 were higher than those birds fed on T2, T4, and T5. With regards to liver weight, birds' performance in T1, T2, and T5 were the best and T4 recorded the lowest. Birds fed the control diet (T1) had the best dressing percentage followed by T4 and the least was noticed in T5 (Table 4.14). In conclusion, birds fed dietary T1 (control) were heavier in terms of dressing percentage while the least was observed in birds fed T5. Dietary shea caterpillar meal influenced some of the carcass characteristics of broilers.

#### 4.6 Effect of Shea Caterpillar on Organoleptic Characteristics of Broiler Breast Meat

The effect of shea caterpillar on organoleptic characteristics of broiler breast meat is shown in Table 4.15.

**Table 4.15: Effect of SCM on Organoleptic Characteristics of Broiler Breast meat**

DESCRIPTION	TREATMENT					SEM	P-Value
	T1	T2	T3	T4	T5		
COLOUR	3.25	4.38	4.62	3.88	3.38	0.34	0.301
FLAVOUR	3.75	3.25	3.88	4.00	3.62	0.55	0.891
JUICINESS	3.88	3.75	3.00	3.75	4.00	0.48	0.616
TENDERNESS	3.62	3.50	4.25	3.75	3.50	0.56	0.868
TOUGHNESS	3.62	3.75	3.50	3.25	3.58	0.53	0.935

SEM=Standard Error of Means, P-Probability

There were no significant differences ( $P>0.05$ ) among all the treatment means of birds fed dietary treatments T1, T2, T3, T4, and T5 with respect to colour, flavour, juiciness, tenderness and toughness. Dietary shea caterpillar has no influence on the organoleptic characteristics of broiler breast meat (Table 4.15).

#### 4.7 Cost-Benefit Analysis of using Shea Caterpillar Meal in Broiler Chicken Diets

The Cost-benefit analysis of using shea caterpillar meal in broiler chicken diets is presented in Table 4.16.

**Table 4.16. Cost-Benefit Analysis of Using Shea Caterpillar Meal in Broilers Diets**

DESCRIPTION	TREATMENTS					SEM	P-Value
	T1	T2	T3	T4	T5		
Per kg feed cost (GH¢)	4.19	4.08	3.98	3.87	3.77	0.000	-
Total feed intake kg/bird	4.975	5.134	4.733	4.855	4.615	0.1769	0.329
Cost of feed per bird (GH¢)	20.76 <sup>ab</sup>	20.97 <sup>a</sup>	18.83 <sup>bc</sup>	18.80 <sup>bc</sup>	17.34 <sup>c</sup>	0.650	0.033
Total Wt. Gain kg/bird	2.074 <sup>a</sup>	2.019 <sup>a</sup>	2.045 <sup>a</sup>	1.673 <sup>b</sup>	1.577 <sup>b</sup>	0.0921	0.008
Feed Cost per kg body Wt. Gain	10.07	10.44	9.36	11.26	11.03	0.610	0.171
Selling price of bird (GH¢)	58.1 <sup>a</sup>	56.5 <sup>a</sup>	57.2 <sup>a</sup>	46.8 <sup>b</sup>	44.2 <sup>b</sup>	2.35	0.007
Profit on feed alone (GH¢)	37.3 <sup>a</sup>	35.5 <sup>ab</sup>	38.4 <sup>a</sup>	28.0 <sup>bc</sup>	26.2 <sup>c</sup>	2.50	0.007

<sup>abc</sup> Means bearing the same superscript are not significantly different ( $P>0.05$ )

SEM-Standard errors of means, Wt. -weight, Kg-kilogram-Value

There was a significant difference ( $P<0.05$ ) across all the treatment means in terms of cost of feed per bird, total weight gain kg/bird, selling price of bird and profit on feed alone throughout the experimental period except per kilogram feed cost and total feed intake. Feed cost was high for birds fed the control diet (T1) and those on T2 while the cost of feed for birds reared on T5 was low. The highest profit was from dietary T3 and those fed on dietary T1, the control diet and T2. Birds fed dietary treatment five yielded the lowest profit at the end of the period (Table 4.16).

#### 4.8 Determination of Coliform Load in Shea Caterpillar meal.

The outcome shows that the milled shea caterpillar contains coliform. It was observed through the analysis that the shea caterpillar contains 200,000 CFU/g (expressed in exponential form as  $2.0 \times 10^5$ ), which was high and therefore suggest that the meal was contaminated.

#### 4.10 Experiment Two

##### 4.10.1 Effect of shea caterpillar meal on feed intake of broilers (0 -9weeks)

The effect of varying levels of shea caterpillar meal on feed intake of broiler chicken (0 to 9 weeks) is showed in Table 4.17.

**Table 4.17: Effect of Sea Caterpillar Meal on Feed intake of Broiler chickens**

WEEKS	TREATMENTS					SEM	P-Value
	T1	T2	T3	T4	T5		
1	270.92 <sup>a</sup>	266.83 <sup>b</sup>	243.00 <sup>c</sup>	265.13 <sup>d</sup>	174.34 <sup>e</sup>	1.732	<001
2	338.66 <sup>a</sup>	285.40 <sup>c</sup>	301.74 <sup>b</sup>	265.13 <sup>d</sup>	206.70 <sup>e</sup>	1.640	<001
3	544.43 <sup>a</sup>	458.02 <sup>c</sup>	490.71 <sup>b</sup>	388.88 <sup>d</sup>	345.25 <sup>e</sup>	1.732	<001
4	784.70 <sup>a</sup>	625.38 <sup>d</sup>	676.91 <sup>b</sup>	632.04 <sup>c</sup>	577.99 <sup>e</sup>	1.732	<001
5	724	744	673	628	604	49.1	0.275
6	1075	1055	1044	914	1001	57.8	0.358
7	1210	1286	1146	1089	1197	61.2	0.292
8	1173	1261	1280	1080	1178	55.3	0.158
9	1191	1279	1305	1085	1146	107.4	0.593
T.F.I	7310.7	7260	7160.4	6293.7	6430.4	270	0.059

<sup>abcd</sup> Means bearing the same superscript are not significantly different ( $P>0.05$ )

T.FI-Total Feed Intake, SEM-Standard errors of means. *P*-Probability

There was a significant difference ( $P<0.05$ ) among all the treatment means from week one to four. During the first week, feed intake by chicks on dietary treatments one (control) was significantly different ( $P<0.05$ ) from all the four other treatment means. Treatment T2 was significantly different ( $P<0.05$ ) from T3, T4 and T5 respectively. The best performance of

birds was seen in T1 while the least was recorded in T5. In second and third week, T1 was significantly different ( $P < 0.05$ ) from T2, T3, T4 and T5. Birds in treatment T1 performed better (Table 4.17). In week four, birds fed treatment T1 performed better and the worst performance was observed in T5 (Table 4.17).

For the 5<sup>th</sup> week to the 9<sup>th</sup> week, there were no significant differences ( $P > 0.05$ ) in the means of the various treatments from. Numerically, feed consumption consistently increased among all the treatments means every week except in week 8 for T2, T4 and T5. With regards to total feed intake, there was no significant difference ( $P > 0.05$ ) among birds in all the treatments. The highest feed intake was recorded in T1 and the lowest in T4 (Table 4.17).

#### 4.10.2 Effect of shea caterpillar on water intake of broiler chickens in millilitres

The effect of shea caterpillar on water intake of broiler chickens in millilitres is shown in Table 4.18.

**Table 4.18: Effect of Shea Caterpillar on Water Intake of Broiler Chickens in Millilitres**

WEEKS	TREATMENT					SEM	P-Value
	T1	T2	T3	T4	T5		
1	341.30 <sup>a</sup>	267.92 <sup>d</sup>	330 <sup>b</sup>	293.48 <sup>c</sup>	297.05 <sup>c</sup>	1.74	<.001
2	699.13 <sup>a</sup>	564.58 <sup>c</sup>	607.92 <sup>b</sup>	413.81 <sup>d</sup>	361.67 <sup>e</sup>	1.80	<.001
3	1149.57 <sup>a</sup>	997.50 <sup>c</sup>	1052.50 <sup>b</sup>	668.69 <sup>d</sup>	562.08 <sup>d</sup>	1.73	<.001
4	1540.00 <sup>a</sup>	1137.92 <sup>c</sup>	1255.00 <sup>b</sup>	663.58 <sup>d</sup>	613.75 <sup>e</sup>	1.60	<.001
T. WATER	3730.50 <sup>a</sup>	2967.90 <sup>c</sup>	3245.40 <sup>b</sup>	2039.6 <sup>d</sup>	1843.6 <sup>e</sup>	6.82	<.001

<sup>abcd</sup> Means bearing the same superscript are not significantly different ( $P > 0.05$ )

SEM: Standard Errors of Means.

There was a significant difference ( $P < 0.05$ ) among all the treatment means from week one to week four. By the first week, the water intake of birds in dietary treatment T1 was significantly different from T2, T3, T4, and T5. Also, water intake in T3 was significantly

different from T2, T4, and T5. The level of water consumption on T4 and T5 were similar ( $P>0.05$ ) (Table 4.18). During the second week, water intake in T1 (control) was significantly different ( $P<0.05$ ) from T2 T3, T4, and T5. The intake in T3 was also significantly different from T2, T4, and T5. By the close of the third and fourth week, water consumption was higher in T1 followed by T3 and the least was in T5. Total water intake was significantly ( $P<0.05$ ) influenced among all dietary treatment means. Water intake was higher ( $P<0.05$ ) in T1 (3730.5ml) while birds in T5 consumed the least (1843.6ml) (Table 4.18).

#### 4.10.3 Effect of shea meal caterpillar on water intake of broilers in millilitres

Effect of shea meal caterpillar on water intake of broilers in millilitres is presented in Table 4.19.

**Table 4.19: Effect of Shea Caterpillar on Water intake of Broiler Chickens in Millilitres**

WEEKS	TREATMENT					SEM	P-Value
	T1	T2	T3	T4	T5		
5	1998 <sup>a</sup>	1892 <sup>ab</sup>	1764 <sup>b</sup>	1310 <sup>c</sup>	1433 <sup>c</sup>	99.9	<003
6	2295 <sup>a</sup>	2448 <sup>a</sup>	2335 <sup>a</sup>	1583 <sup>b</sup>	1743 <sup>b</sup>	103.8	<001
7	2677 <sup>b</sup>	2963 <sup>a</sup>	2398 <sup>c</sup>	1812 <sup>d</sup>	1819 <sup>d</sup>	74.5	<001
8	2837 <sup>a</sup>	2900 <sup>a</sup>	2967 <sup>a</sup>	1908 <sup>b</sup>	2158 <sup>b</sup>	165.4	<003
9	2790	3201	3214	2655	2704	380.8	0.438
T.W.I	12597 <sup>a</sup>	13404 <sup>a</sup>	12678 <sup>a</sup>	9268 <sup>b</sup>	9858 <sup>b</sup>	515.2	< 001
G.T.WI	16327 <sup>a</sup>	16372 <sup>a</sup>	15923 <sup>a</sup>	11308 <sup>b</sup>	11692 <sup>b</sup>	514.8	< 001

<sup>abcd</sup> Means bearing the same superscript are not significantly different ( $P>0.05$ ).

SEM-Standard Errors of Means, T=Total, G.T.W.I=Grand total water intake.

There was a significant difference ( $P<0.05$ ) among treatments in all the weeks except week nine. By the end of week five, the water intake of birds in T1 and T2 were similar ( $P>0.05$ ) but significantly different ( $P<0.05$ ) in T4 and T5. The performance of birds in T4 and T5

were similar (Table 4.19). By week six, water intake by birds in T1, T2, and T3 were similar ( $P>0.05$ ) but were significantly different ( $P<0.05$ ) from those in T4 and T5. During week seven, the level of water consumption in T2 was significantly different ( $P<0.05$ ) from the four other treatment means. The water intake of birds in T4 and T5 was similar. In the eighth week, the performance of birds was similar to the sixth week. In terms of total water intake, the consumption by birds on T1, T2 and T3 were similar ( $P>0.05$ ) but were significantly different ( $P<0.05$ ) from T4 and T5 (Table 4.19).

#### **4.10.4 Effect of shea caterpillar meal on weekly body weight of broilers (0 to 4 weeks)**

Effect of shea caterpillar meal on weekly body weight of broilers (0 to 4 weeks) is presented in Table 4.20.

**Table 4.20: Effect of Shea Caterpillar Meal on weekly Body Weight of Broilers**

PARAMETERS	TREATMENT					SEM	P-Value
	T1	T2	T3	T4	T5		
INITIAL.WT	41	41	41	41	41	0.00	-
WT1	171.50 <sup>a</sup>	160 <sup>b</sup>	142.70 <sup>c</sup>	137.50 <sup>c</sup>	124 <sup>d</sup>	1.73	<.001
WT2	459.50 <sup>a</sup>	429.80 <sup>b</sup>	325.70 <sup>c</sup>	270.00 <sup>d</sup>	227.50 <sup>e</sup>	1.73	<.001
WT3	640.20 <sup>a</sup>	599.50 <sup>b</sup>	522.50 <sup>c</sup>	456.90 <sup>d</sup>	391.20 <sup>e</sup>	1.73	<.001
WT4	950 <sup>a</sup>	933.30 <sup>b</sup>	733.30 <sup>c</sup>	695.20 <sup>d</sup>	490.50 <sup>e</sup>	1.73	<.001

<sup>abcde</sup> Means bearing the same superscript are not significantly different ( $P>0.05$ ).

SEM-Standard Errors of Means

There was a significant difference ( $P<0.05$ ) among the treatment means in the weekly body weight from week one to four. The initial live body weights of the day-old chicks were similar and there was no significant difference ( $P>0.05$ ) in the mean weight across the various treatment means at the start of the experiment. By week one of the experiment, the

live body weight (LBW) of birds in T1 was significantly different ( $P < 0.05$ ) from T2, T3, T4, and T5. Birds in T3, and T4 were significantly different ( $P < 0.05$ ) from birds in T2 and T5. Birds in the control performed better. In the second, third, and fourth week, the performance of birds in T1 was significantly different ( $P < 0.05$ ) from birds in T2, T3, T4, and T5. Birds in T2 performed better than those in T3, T4, and T5 while the performance of chicks in T3 was also better than T4 and T5. (Table 4.20).

#### 4.10.5 *Effect of shea caterpillar meal on weekly body weight of broiler chickens*

Effect of shea caterpillar meal on weekly body weight of broiler chickens is displayed in Table 4.21.

**Table 4.21: Effect of Shea Caterpillar Meal on Weekly Body Weight of Broiler Chickens**

PARAMETERS	TREATMENT					SEM	P-Value
	T1	T2	T3	T4	T5		
WT5	1380 <sup>a</sup>	1260 <sup>a</sup>	1187 <sup>b</sup>	860 <sup>d</sup>	680 <sup>e</sup>	24.9	<.001
WT6	1720 <sup>a</sup>	1640 <sup>ab</sup>	1158 <sup>b</sup>	1133 <sup>d</sup>	896 <sup>e</sup>	41.3	<.001
WT7	2067 <sup>a</sup>	2060 <sup>ab</sup>	1933 <sup>b</sup>	1440 <sup>c</sup>	1147 <sup>d</sup>	42.3	<.001
WT8	2413 <sup>a</sup>	2480 <sup>a</sup>	2413 <sup>a</sup>	1760 <sup>b</sup>	1467 <sup>c</sup>	80.2	<.001
WT9	2690 <sup>a</sup>	2841 <sup>a</sup>	2839 <sup>a</sup>	2083 <sup>b</sup>	1762 <sup>b</sup>	121.5	<.001

<sup>abcde</sup> Means bearing the same superscript are not significantly different ( $P > 0.05$ ).

SEM-Standard Errors of Means. WT. Weight-Probability

By week five of the feeding trials, the live body weight (LBW) of birds in treatment T1 and T2 were similar but significantly different ( $P > 0.05$ ) from T3, T4, and T5. Birds on T1 and T2 performed best. During weeks 6 and 7 chickens on dietary treatment T1 and T2 had similar body weights which were significantly different ( $P > 0.05$ ) from T3, T4, and T5. By the end of weeks 8 and 9, the body weight of birds in dietary treatment T1, T2, and T3 was

similar but was significantly different ( $P < 0.05$ ) from T4 and T5. The performance of birds in T1, T2, and T3 were the best (Table 4.21).

#### 4.10.6 Effect of shea caterpillar meal on body weight gain of broilers

Effect of shea caterpillar meal on body weight gain of broilers is presented in Table 4.22.

**Table 4.22: Effect of Shea Caterpillar Meal on Weight Gain of Broiler Chickens**

PARAMETERS (g)	TREATMENTS					SEM	P-Value
	T1	T2	T3	T4	T5		
WTG1	130.50 <sup>a</sup>	119.00 <sup>b</sup>	101.70 <sup>c</sup>	96.50 <sup>c</sup>	83.70 <sup>d</sup>	1.732	<.001
WTG2	288.00	269.80	183.00	132.50	102.80	0.000	
WTG3	180.70	129.70	196.70	186.96	163.70	0.000	
WTG4	309.80	373.80	210.80	238.30	99.30	0.000	

<sup>abc</sup> Means bearing the same superscript are not significantly different ( $P > 0.05$ )  
WTG-Weight gain, SEM-Standard Errors of Means, P-Probability

Mean body weight gain (BWG) for week one showed a significant difference ( $P < 0.05$ ) of birds in T1 from birds in dietary treatment T2, T3, T4, and T5. Birds fed dietary treatment T2 were significantly different ( $P < 0.05$ ) from those fed T3, T4 and T5. The performance of birds in T3 and T4 were similar (Table 4.22).

**Table 4.23: Effect of Shea Caterpillar Meal on Weight Gain of Broiler Chickens**

PARAMETERS(g)	TREATMENT					SEM	P-Value
	T1	T2	T3	T4	T5		
WTG5	430 <sup>a</sup>	327 <sup>b</sup>	453 <sup>a</sup>	165 <sup>c</sup>	190 <sup>c</sup>	25.30	<.001
WTG6	340.0 <sup>ab</sup>	380.0 <sup>a</sup>	393.3 <sup>a</sup>	273.3 <sup>bc</sup>	215.7 <sup>c</sup>	21.77	<.001
WTG7	347	420	353	307	251	37.90	0.092
WTG8	347	420	480	320	320	48.80	0.158
WTG9	277	361	425	323	295	61.10	0.484
TWTG	2649 <sup>a</sup>	2800 <sup>a</sup>	2798 <sup>a</sup>	2042 <sup>b</sup>	1721 <sup>c</sup>	171.80	<.001

<sup>abc</sup> Means bearing the same superscript are not significantly different ( $P > 0.05$ )  
SEM-Standard Errors of Means. TWTG-Total weight gain.

#### 4.10.7 Effect of shea caterpillar meal on weight gain of broiler chickens

There was a significant difference ( $P < 0.05$ ) among treatment means in weight gain of birds in the fifth and sixth weeks except for weeks seven to nine. By week five, the weight gain of birds fed dietary treatment T1 and T3 were similar ( $P > 0.05$ ) but significantly different ( $P < 0.05$ ) from T2, T4, and T5. The weight gain of birds in T2 also differed from birds fed T4 and T5. In week six, there was no significant difference ( $P < 0.05$ ) among birds fed dietary treatment T1, T2, and T3, but was significantly different ( $P > 0.05$ ) from T4 and T5. Birds in T1, T2, and T3 performed better. In terms of total weight gain, there was no significant difference ( $P > 0.05$ ) among the treatment means of birds fed T1, T2, and T3 but were significantly different ( $P < 0.05$ ) from those fed T4 and T5. The least weight gain was recorded from bird served T5 (Table 4.23).

#### 4.10.8 Feed conversion ratio of broilers fed shea caterpillar meal

Feed conversion ratio of broilers fed shea caterpillar meal is presented in Table 4.24.

**Table 4.24: Effect of Shea Caterpillar Meal on Feed Conversion Ratio of Broilers**

WEEKS	TREATMENT					SEM	P-Value
	T1	T2	T3	T4	T5		
1	2.08 <sup>c</sup>	2.24 <sup>b</sup>	2.39 <sup>a</sup>	2.24 <sup>b</sup>	2.08 <sup>c</sup>	0.029	<001
2	1.18 <sup>c</sup>	1.06 <sup>d</sup>	1.65 <sup>b</sup>	2.00 <sup>a</sup>	2.01 <sup>a</sup>	0.01	<001
3	3.01 <sup>b</sup>	3.53 <sup>a</sup>	2.49 <sup>c</sup>	2.08 <sup>c</sup>	2.11 <sup>d</sup>	0.01	<001
4	2.53 <sup>d</sup>	1.67 <sup>e</sup>	3.21 <sup>b</sup>	2.65 <sup>c</sup>	5.82 <sup>a</sup>	0.01	<001
5	1.69 <sup>c</sup>	2.28 <sup>bc</sup>	1.50 <sup>c</sup>	3.86 <sup>a</sup>	3.37 <sup>ab</sup>	0.35	0.003
6	3.16 <sup>b</sup>	2.78 <sup>b</sup>	2.70 <sup>b</sup>	3.34 <sup>b</sup>	4.75 <sup>a</sup>	0.35	0.012
7	3.68 <sup>b</sup>	3.08 <sup>b</sup>	3.27 <sup>b</sup>	3.57 <sup>b</sup>	4.91 <sup>a</sup>	0.32	0.043
8	3.44	3.06	2.75	3.43	3.84	0.39	0.394
9	4.43	3.95	3.13	3.79	3.90	0.67	0.761
AV.FCR	2.80 <sup>b</sup>	2.63 <sup>b</sup>	2.57 <sup>b</sup>	2.99 <sup>b</sup>	3.64 <sup>a</sup>	0.15	0.003

<sup>abcd</sup> Means bearing the same superscript are not significantly different ( $P < 0.05$ )

SEM-Standard Errors of Means, AV.FCR: Average Feed Conversion Ratio, P-Probability

There were significant differences ( $P < 0.05$ ) among all the treatment means in week one. The best performance was recorded in T1 and T5 while birds on T4 and T3 performed similarly and better than those fed T3 (Table 4.24). During week two, the performance of birds was significantly different ( $P > 0.05$ ) in all five treatments. The best performance was observed in T2 and T1 while the worst was seen in T4 and T5 (Table 4.24). In week three, birds on all the dietary treatments did show significant differences ( $P < 0.05$ ) among the treatment means. The performance of birds was best in T3 and T4 and the least was recorded in T2. During week four, there were significant differences ( $P < 0.05$ ) among chicks in all the dietary treatment means. Broilers on T2 had a better FCR followed by T4 and the least was seen in T5. In week five, birds on diets T1, T2, and T3 did not show significant differences ( $P > 0.05$ ) among the treatment means but were significantly different from ( $P > 0.05$ ) from T4 and T5. The average FCR for broilers raised on T1, T2, T3, and T4 dietary treatments showed no significant difference ( $P > 0.05$ ) among the treatment means but were significantly different ( $P < 0.05$ ) from T5. The worst average FCR was observed in dietary treatment T5 (Table 4.24).

#### **4.11 Effects of shea meal caterpillar on haematological parameters of broilers**

The Effects of shea caterpillar on haematological parameters of broiler chicken (0-9 weeks) are presented in Table 4.25.

**Table 4.25: Effect of shea Caterpillar Meal on Haematological Parameters of Broilers**

PARAMETERS	TREATMENTS					SEM	P-Value	NRR
	T1	T2	T3	T4	T5			
WBC(10 <sup>9</sup> /L)	91.7	82.0	91.1	84.8	70.7	7.28	0.311	1.2-3.0*
LYM(10 <sup>9</sup> /L)	82.7 <sup>a</sup>	72.6 <sup>a</sup>	81.5 <sup>a</sup>	59.3 <sup>a</sup>	21.0 <sup>b</sup>	9.16	0.004	45-70*
GRA.	1.7	1.8	2.0	2.3	10.1	3.61	0.445	
RBC(10 <sup>12</sup> /L)	2.313	2.167	2.377	2.293	2.237	0.1471	0.876	2.5-3.5*
HGB(g/DL)	8.97	8.40	9.30	8.40	8.63	0.495	0.659	9.27-13*
MCHC(g/dL)	29.40	28.33	28.23	28.03	28.13	0.536	0.419	26-35*
MCH (Pg)	39.00	38.73	37.77	36.60	38.27	1.847	0.719	33-47*
MCV(fl)	132.3	136.6	133.6	130.6	136.4	9.59	0.491	90-140*
RDW-CV	12.20	12.10	12.67	12.30	12.97	0.544	0.778	
RDW-SD(fl)	68.0	70.5	71.3	67	74.7	2.97	0.427	
HCT%/PVC	33.6	29.6	31.7	30.0	30.5	9.60	0.564	22.0-35 *
PLT (10 <sup>9</sup> /L)	32.7	27.7	64.3	27.0	22.7	16.05	0.408	
MPV (fl)	6.07	6.00	6.60	6.03	5.70	0.308	0.403	
PDW	11.10	11.07	10.50	11.53	11.60	0.667	0.778	
PCT	0.0197	0.0170	0.0454	0.0160	0.0133	0.01244	0.405	

<sup>ab</sup> Means in the same row bearing the same superscript are not significantly different (P>0.05)

NRR: Normal reference range \*: Jain. (1993) as cited in Aengwanich *et al.* (2004). SEM=Standard Error of Means. P-Probability.

*Red Blood Cell (RBC), White Blood Cell (WBC), Platelets (PLT), Platelets Distribution Width (PDW), Packed Cell Volume (PCV)/Haematocrit (HCT), Lymphocytes(LYM), Granulocyte (GRA), Red Cell Distribution Width Standard Deviation (RDW-SD), Red Cell Distribution Width Coefficient of Variation (RDW-CV), Mean Corpuscular Volume/Mean Cell Volume (MCV), Mean Corpuscular Haemoglobin (MCH), Haemoglobin (Hb) and Mean Corpuscular Haemoglobin Concentration (MCHC), PCT (Procalcitonin).*

There was no significant difference (P>0.05) among all the treatment means on the haematological indices except Lymphocyte (Table 4.25). The lymphocyte values of birds fed T1 (control) were similar to birds on T2, T3, and T4 but significantly higher than those fed T5. Lymphocyte values of birds fed T5 fell below the recommended reference range (Table 4.25). The WBC values were higher than the normal reference range. Red blood cell and HGB values obtained were also lower than the normal reference range. The MCV value of birds fed T3 and PVC value of birds fed T4 were within the normal reference range (Table 4.25).

#### 4.12 Effect of Shea Caterpillar on Carcass Characteristics of Broiler Chickens

The effect of shea caterpillar on carcass characteristics of broiler chickens is displayed in Table 4.26

**Table 4.26: Effect of Shea Caterpillar Meal on Carcass Characteristics of Broilers**

Parameters	TREATMENTS					SEM	P-Value
	T1	T2	T3	T4	T5		
Live weight	3251 <sup>a</sup>	3090 <sup>a</sup>	3126 <sup>a</sup>	2414 <sup>b</sup>	2209 <sup>b</sup>	202.0	0.014
Bled weight	3131 <sup>a</sup>	2968 <sup>a</sup>	3004 <sup>a</sup>	2321 <sup>b</sup>	2120 <sup>b</sup>	192.8	0.013
Defeathered weight	3048 <sup>a</sup>	2857 <sup>a</sup>	2900 <sup>a</sup>	2226 <sup>b</sup>	2018 <sup>b</sup>	187	0.010
Dressing percentage	82.57 <sup>a</sup>	79.98 <sup>ab</sup>	79.21 <sup>ab</sup>	76.58 <sup>b</sup>	75.69 <sup>b</sup>	1.185	0.014
Dressed carcass wt.	2683 <sup>a</sup>	2470 <sup>a</sup>	2478 <sup>a</sup>	1861 <sup>b</sup>	1678 <sup>b</sup>	173.7	0.008
Head weight	77.3 <sup>ab</sup>	81.7 <sup>a</sup>	81.7 <sup>a</sup>	60.7 <sup>b</sup>	59.3 <sup>b</sup>	5.83	0.042
Wings weight	250.7 <sup>a</sup>	225.7 <sup>ab</sup>	240.3 <sup>a</sup>	186.0 <sup>bc</sup>	159.3 <sup>c</sup>	15.49	0.009
Breast weight	797 <sup>ab</sup>	908 <sup>a</sup>	716 <sup>bc</sup>	620 <sup>c</sup>	569 <sup>c</sup>	51.9	0.006
Neck weight	129.7	90.0	104.3	98.3	95.7	19.57	0.656
Drum stick	182.3 <sup>a</sup>	148.3 <sup>b</sup>	180.7 <sup>a</sup>	113.7 <sup>c</sup>	101.3 <sup>c</sup>	9.88	0.001
Feet weight	126.0 <sup>a</sup>	113.3 <sup>a</sup>	118.3 <sup>a</sup>	81.0 <sup>b</sup>	73.0 <sup>b</sup>	9.06	0.006
Full gizzard	67.3	50.3	56.3	64.0	52.0	5.01	0.142
Empty gizzard	50.3 <sup>a</sup>	38.0 <sup>b</sup>	43.0 <sup>ab</sup>	46.0 <sup>ab</sup>	37.0 <sup>b</sup>	2.92	0.045
Heart weight	14.0 <sup>a</sup>	11.0 <sup>b</sup>	13.67 <sup>ab</sup>	10.33 <sup>b</sup>	10.33 <sup>b</sup>	0.931	0.039
Liver weight	50.3	51.3	45.0	45.3	37.3	4.15	0.206
Proventriculus weight	13.67	11.67	12.33	10.67	10.67	1.116	0.342
Abdominal fat	17.7	4.0	21.3	30.3	31.7	8.34	0.206
Intestine weight	144	147	151.7	128.7	113	13.95	0.039

<sup>abc</sup> Means bearing different superscripts in the same row differ significantly ( $P < 0.05$ )

SEM-Standard Errors of Means-Probability

There was a significant difference ( $P < 0.05$ ) within treatment means in terms of live weight, bled weight, de-feathered weight, dressing percentage, dressed carcass weight, head weight, wings weight, breast weight, drumstick weight, feet weight, and heart weight (Table 4.25).

Birds fed T1, T2 and T3, had the highest live weight, bled weight, and De-feathered weight which was significantly different ( $P < 0.05$ ) from birds served T4 and T5. Also, dietary treatments T1 (control), T2, and T3 were similar and significantly different ( $P < 0.05$ ) from T4 and T5 in terms of the dressed carcass. The birds fed T4 and T5 were similar in terms of

a dressed carcass. With regards to dressing percentage, birds fed T1, T2, and T3 had similar performance but were significantly different ( $P>0.05$ ) from dietary treatment T5. The best dressing percentage of birds was noted in the control. Birds fed dietary T1, T2 and T3 were equivalent but were significantly different ( $P<0.05$ ) from T4 and T5 (Table 4.24).

In addition, the wings weight of birds fed T1 was similar to birds served T2 and T3 but was significantly different ( $P<0.05$ ) from T5. The performance of birds in T2 and T4 was similar. The similarity was also noticed in birds in dietary treatment T4 and T5 in terms of the weight of wings. With regards to breast weight, dietary T1 was similar to T2 but significantly different ( $P<0.05$ ) from T3, T4, and T5. The best breast weight recorded was from dietary treatment T2 (Table 4.26).

Lastly, dietary T1 and T3 were similar but were different ( $P<0.05$ ) from T2, T4, and T5 with regards to drumstick weight. However, birds fed T3 performed better than those in T4, and T5. The feet weight of birds fed diets T1, T2 and T3 were similar while birds served T4 and T5 were similar. Heart weight for birds in dietary treatment T1 and T3 were the best and similar but varied significantly ( $P<0.05$ ) from T2, T4, and T5 (Table 4.25).

#### **4.13 Cost-Benefit Analysis of Using Shea Caterpillar Meal in Broiler Chicken Diets**

The cost-benefit analysis of using shea caterpillar meals in broiler chicken diets is presented in Tables 4.27 and 4.28.

**Table 4.27: Cost-benefit Analysis of using Shea Caterpillar Meal in Broilers Diets**

DESCRIPTION	TREATMENTS					SEM	P-Value
	T1	T2	T3	T4	T5		
Per kg. feed cost (GH¢)	4.38	4.27	4.15	4.04	3.93	0.000	
Total feed intake kg/bird	1.9387 <sup>a</sup>	1.6356 <sup>c</sup>	1.7124 <sup>b</sup>	1.4987 <sup>d</sup>	1.3043 <sup>e</sup>	0.00682	<.001
Cost of feed per bird (GH¢)	8.490 <sup>a</sup>	6.980 <sup>c</sup>	7.110 <sup>b</sup>	6.053 <sup>d</sup>	5.120 <sup>e</sup>	0.0283	<.001
Total Wt. Gain kg/bird	0.90900 <sup>a</sup>	0.89230 <sup>b</sup>	0.69230 <sup>c</sup>	0.65420 <sup>d</sup>	0.44940 <sup>e</sup>	0.001733	<.001
Feed Cost/ kg body Wt. Gain	9.3467 <sup>c</sup>	7.8200 <sup>e</sup>	10.2700 <sup>b</sup>	9.2533 <sup>d</sup>	11.3933 <sup>a</sup>	0.01673	<.001
Selling price of bird (GH¢)	25.453 <sup>a</sup>	24.983 <sup>b</sup>	19.383 <sup>c</sup>	18.317 <sup>d</sup>	12.583 <sup>e</sup>	0.0491	<.001
Profit on feed alone (GH¢)	16.9633 <sup>b</sup>	18.1033 <sup>a</sup>	12.2733 <sup>c</sup>	12.2633 <sup>c</sup>	7.4700 <sup>d</sup>	0.02106	<.001

<sup>ab</sup> Means in the same row bearing different superscript are significantly different (P<0.05)  
SEM=Standard Error of Means, P-Probability.

In general, there were significant differences (P<0.05) among all treatment means except for per kilogram feed cost. The per kilogram cost of feed dropped marginally as more SCM was added to replace fish meal. The cost of feed per bird was high in T1 and T3 and low in T5. Feed cost per kilogram body weight gain in treatment T5 was the highest and the lowest was in T2. The profit on feed was high from birds fed T2 and T1 (control) and the lowest profit from birds fed T5. The profit margin declined as the inclusion rate of fish meal reduced in the starter phase (Table 4.27). The best profit margin was observed from birds fed T2.

**Table 4.28: Cost-benefit Analysis of using Shea Caterpillar Meal in Broilers Diets**

DESCRIPTION	TREATMENTS					SEM	P-Value
	T1	T2	T3	T4	T5		
Per kg feed cost (GH¢)	4.17	4.08	3.98	3.87	3.77	0.000	
Total feed intake kg/bird	5.37	5.62	5.45	4.80	5.13	0.269	0.292
Cost of feed per bird (GH¢)	22.42	22.93	21.68	18.58	19.34	1.055	0.067
Total Wt. Gain kg/bird	1.740 <sup>ab</sup>	1.907 <sup>a</sup>	2.105 <sup>a</sup>	1.388 <sup>bc</sup>	1.271 <sup>c</sup>	0.1224	0.003
Feed Cost per kg body Wt. Gain	12.99 <sup>ab</sup>	11.85 <sup>b</sup>	10.30 <sup>b</sup>	13.38 <sup>ab</sup>	15.22 <sup>a</sup>	1.050	0.035
Selling price of bird (GH¢)	48.7 <sup>ab</sup>	53.4 <sup>a</sup>	58.9 <sup>a</sup>	38.9 <sup>bc</sup>	35.6 <sup>c</sup>	3.43	0.003
Profit on feed alone (GH¢)	26.3 <sup>b</sup>	30.8 <sup>ab</sup>	37.2 <sup>a</sup>	20.3 <sup>b</sup>	16.3 <sup>b</sup>	4.52	0.007

<sup>abc</sup> Means in the same row bearing the same superscript are not significantly different  
SEM-standard errors of means, P-Probability

There was a significant difference ( $P < 0.05$ ) among all the treatment means except the cost of feed per bird and total feed intake kg/bird. As usual, the cost of a kilogram of feed declined slightly as fish meal was replaced by more SCM (Table 4.28). When the birds were fed at inclusion levels of 50% SCM (T3), the profit per bird was GH¢37.2 followed by GH¢30.8 (T2) and at 100% (T5) inclusion levels the lowest profit of GH¢16.3 was obtained (Table 4.28). It is therefore significant to conclude that dietary SCM inclusion level of 50% or below yielded more profit.

## CHAPTER FIVE

### 5.0 DISCUSSION

#### 5.1 Proximate composition of *shea caterpillar* and fish meal

##### 5.1.1 Proximate Composition of *Shea Caterpillar*

The high protein content of (60.42 %) of shea caterpillar in this study falls within the normal range (14 - 68 %) of protein content for edible insects of the order Lepidoptera (Xiaoming *et al.*, 2010). The Crude protein of 60.42 % reported in this study was higher than the 55 % CP indicated by Yapo *et al.* (2017) but slightly lower than 62 % and 63 % stated by Anvo *et al.* (2016a) and Anankware (2017) respectively. Also, Amao *et al.*, (2010) reported superior value of 66.74 % for Westwood larvae meal. Similarly, Ijaiya and Eko (2009a) reported 50.30 % CP content for Silkworm caterpillar meal which also disagreed with current findings. Adeniji (2007) also reported crude protein value of 37.2 % for housefly maggot meal which was the lowest. The changes in crude protein content may be due to the quality of shea leaves as feed, and the mode of processing the shea caterpillars. According to Yapo *et al.*, (2017) the differences in the proximate composition of insects may perhaps be attributed to the host plant since the amount of protein differs within similar species and by different species of insects.

The moisture content of 11.08 % in the present study disagreed with the 7.9 % reported by Yapo *et al.* (2017) and 8.12 % by Amao *et al.*, (2010). The difference in moisture content might be due to the drying method used, it could either be sun drying or oven drying since shea caterpillars are normally harvested in the rainy season. Low moisture content may improve longer storage periods.

The ash content of 3.9% reported in this study was lower than the 4.8% reported by Yapo *et al.* (2017) and 5.1% by (Anvo *et al.*, 2016a). Likewise, Ijaiya and Eko (2009a) reported 12.03 % ash content for silkworm caterpillar meal while 7.15% was stated by Adeniji (2007) for housefly maggot meal which also disagreed with current findings. It was observed that some insects' meal are rich in ash content than shea caterpillar meal. Ash content indicates the mineral potential in a feed Yapo *et al.* (2017). The difference in ash content could be attributed to the quality of shea leaves consumed and the developmental stages of the caterpillar larvae. The high ash content could also be due to the hard body of the insect owing to the high chitin content (Raksakantong *et al.*, 2010). Also, it could be attributed to the geographical location of the shea trees, soil condition, and maturity stage of the caterpillars (Anankware, 2017).

The analysis also revealed that the shea caterpillar has 10.4 per cent of fat. This value was higher than 9.50 % fat stated for Westwood by Amao *et al.*, (2010), but lower than the 12 % fat reported by Anankware (2017) and 14.5 % by Anvo *et al.*, (2016a) for the same insect. Also, Adeniji (2007) reported 35.5 % fat for housefly maggot meal and Ijaiya and Eko (2009a) testified by 16.43 % for silkworm caterpillar meal.

The core purpose of fats is to supply energy to the animal body. Fats are reserved source of energy to the animal body. Also, it helps in the absorption of calcium and phosphorus in the body. Certain fat soluble vitamin such as vitamin, A, D, E, and K are absorbed in the blood in presence of fat (Chahal *et al.*, 2008). According to Yapo *et al.*, (2017), the difference in the fat content may be attributed to the nutritional qualities of host plant since the amount of

protein differs within similar species. It may also be attributed to different types insects used.

The crude fibre content of 7.9 % in this study was in agreed with 7.5 % reported for Westwood larvae meal by Amao *et al.*, (2010), but higher than 2.8 % fibre content reported by Yapo *et al.* (2017). Also, Adeniji (2007) stated 9.05 % fibre for maggot meal and Ijaiya and Eko (2009a) affirmed 10.90 % fibre content for silkworm caterpillar meal which were superior to the value observed in this study. Anankware (2017) reported 56 % neutral detergent fibre in shea caterpillar. Studies have revealed that insects contain variable and a significant amount of fibre which are measured as acid detergent fibre (ADF) and neutral detergent fibre (NDF) (Anankware, 2017). It has been observed by several writers that, the fibre in insects is actually chitin which cannot be absorbed or degraded into the blood. This can affect the digestibility of proteins hence, the measurements of chitin are important when insects are used in animal nutrition (Anankware, 2017). The amount of fibre that birds need to improve the efficiency of digestion should not exceed 7 % (Koney, 2004). The fibre content in this study was within the recommended limit of 7 %. The difference in fibre content may perhaps be attributed to the extra fibrous feed of shea caterpillar larvae and the presence of bristles and setae on the caterpillar (Anankware, 2017). Also, the difference could be assigned to different types of insects involved. The higher crude fibre content could be ascribed to chitin, which is carbohydrate polymer usually found in invertebrate exoskeleton of insects Goodman, (1989) as cited by Amao *et al.*, (2010).

In this study, the Nitrogen free extract content is 6.3 % which was more than the 3% obtained by Yapo *et al.* (2017) and less than the value of 12.6 % by Anvo *et al.* (2016a) for

the same caterpillars. It also disagreed with 10.34 % for Silkworm caterpillar meal reported by (Ijaiya and Eko, 2009a) and 11.1 % stated by (Adeniji, 2007) for housefly maggot meal. Carbohydrates are a major source of energy and form the bulk of poultry feed (Koney, 2004). Carbohydrates are a major source of energy and form the bulk of about 70% to 75% of poultry feed (Koney, 2004). The quantity of carbohydrates in any feed for birds should form the highest percentage of the diet and should be easily digestible. Carbohydrates also are vital components of production, temperature control, and proper functioning of the different parts of the animal body (Chahal *et al.*, 2008).

The analysis revealed that the shea caterpillar has 3306.76 kcal/kg of metabolizable energy which was lower than 4920 kcal/kg reported by Yapo *et al.* (2017) and 4320 kcal/kg by Anvo *et al.* (2016a). Similarly, Adeniji (2007) stated a much higher value of 5,249Kcal/kg for housefly maggot meal. The difference in energy observed could be due to nutritional content of the leaves of the host plants, different type of insects and the geographical locations of the shea trees. The amount of energy in feed depends on the protein, carbohydrates, and lipids contents in the feed (Yapo *et al.*, 2017). According to Adeniji (2007) increase in metabolizable energy may be due to the fat content of insects since fat has a lot of energy which are released when the fat is oxidized. It was observed that the fat content of the insects were higher than the shea caterpillars.

The energy value in this study compared with the fish meal suggests that the shea caterpillar can offer more energy when incorporated in broiler chickens diets and this has reflected in the feeds compounded for this study based on the proximate analysis carried out.

### **5.1.2 Proximate Composition of Fish meal**

The study showed that fish meal contained moisture content of 11.95%.. This value marginally agreed with 10.0% stated by Preston, (2011), but disagreed with 20.0 %, 9.9% and 7.4% reported by Amao *et al.*, (2010), Rostagno *et al.*, (2011) and Hosain *et al.*, (2016) respectively. The variations in moisture content could be due to freshness of fish, types of ovens used for drying and duration of heating (Kharag (2019)). The crude protein content of 54.51 % reported in this study was in close agreement with 53.0% reported by Batal and Dale, (2010), and 54.6% by Rostagno *et al.*, (2011). However, the CP value differs from 63.11 %, 66.0%, 49.9 %, 69.5% and 70.0 % reported by Amao *et al.*, (2010), Preston, (2011), Hosain *et al.*, (2016),Anvo *et al.* (2017) and Kharag, (2019) respectively. According to Miles and Jacqueline, (2006) crude protein content of fish meal can differ from 57 to 77%, depending on the species of fish used. It was observed that the crude protein content in this study and similar others fell below the range reported by Miles and (Jacqueline, 2006). The differences observed in the crude protein value of fish meal could be credited to different fish species, types of diets of fish, and different parts of fish used to prepare the fish meal.

The ash content of 16.91 % stated in the current study was higher than 6.45 % reported by Amao *et al.*, (2010) and 13.67 % by Anvo *et al.*, (2017), but lower than 22.7% reported by Rostagno *et al.*, (2011), 20.0 % by Preston, (2011) and 21.8 % by Hosain *et al.*, (2016). The ash value showed the mineral content particularly calcium, phosphorus and magnesium in the fish meal. According to Chahal *et al.*, (2008) calcium is necessary for skeletal formation, usual blood clotting, rhythmic action of heart, and activation of enzyme like lipase. The phosphorus plays a significant role in the formation of bones and teeth along with calcium.

Phosphorus preserved the normal level of blood calcium and its proper action and plays active part for the development of phospholipid in cells, nucleic acid and phosphoprotein (Chahal *et al.*, 2008). Mineral like magnesium plays essential role in activating various enzymes such as acyltransferases, phosphate transferases and decarboxylases. Magnesium is also an activator of phosphates and takes an active part in the carbohydrate metabolism. Similarly, it plays a vital role in calcium and phosphorus metabolism for the formation of bone and teeth (Chahal *et al.*, 2008). The change in ash content could be attributed to the quality and parts of fish used and the different types of fish meals sold in the market.

The crude fat content of 6.28 % reported in this study disagreed with the outcome of 7 %, 9.0 %, 12.02 % and 10.7 % discovered by Rostagno *et al.* (2011), Preston (2012), Hosain *et al.* (2016) and Anvo *et al.* (2017) respectively. The fat in fish meal serve as a source of energy to the body and also supports in the absorption of calcium and phosphorus in the body. The differences might varied type of fish meal in the market and quality of fish used.

Also, the nitrogen-free extract obtained was 10.35 % which agreed with 10.44 % by Amao *et al.* (2010). However, this value was better and differed from 4.9% reported by Hosain *et al.* (2016) and 4.82 % by Anvo *et al.* (2017). The nitrogen-free extract (carbohydrates) in any feed for birds form the highest percentage of the diet and should be easily digestible. Carbohydrates also are vital components of production, temperature control, and proper functioning of the different parts of the animal body (Chahal *et al.*, 2008). The metabolizable energy content recorded in this study was 2892.82 kcal/kg which was greater and varied from 2449.3 kcal/kg reported by Hosain *et al.* (2016). The energy content of 2892.82 kcal/kg obtained fell within the metabolizable energy range of 2500 to 3200 kcal

ME/kg reported for fish meal by Miles and Jacqueline (2006). Differences in metabolizable energy may be due to the varied fat content of fish meal since fat has a lot of energy which are released when the fat is oxidized (Adeniji, 2007).

The differences observed in the proximate composition of fish meal in this study could be attributed to different fish species, types of diets of fish, and different processing methods. According to Hosain *et al.* (2016) nutrients composition of fish meal varies and depends on fish type, fish freshness before treating and method of preparation or processing. Kharag (2019) observed that differences in proximate composition might be due to type of fresh fish, processing, duration of heating, type of dryer used, temperatures, and storage period.

Shea caterpillar can be considered as a suitable protein source of feed for human beings and poultry based on the results of proximate composition of these insects. The high CP level and amino acid profile make it a suitable animal protein source for broiler chicken.

The fish meal obtained from the Pioneer Food Company had crude protein content of 54 % which clearly showed a disparity on their labelled as 60 % crude protein. The value reported in this study fell below the recommended range of 57 to 77 % (Miles and Jacqueline, 2006). It can be implied that the fish meal might have been prepared using low quality raw materials.

## **5.2 Composition of Broilers Starter and Finisher Diets for Experiments One and Two**

The results of the nutritional facts of the broiler chickens starter diets showed that ash value in the various diets reduced when fish meal inclusion level varies from 25 % to 75 %.The

control diets (T1) with solely fish meal had more ash content and this may attributed to the ash content of fish meal based on the proximate outcome of the fish meal. It was also observed that as the quantity of fish meal decreased, the amount of crude protein in the diets also decreased by an average of 1% in dietary treatments two, three and four. Although shea caterpillar meal was rich in crude protein, it did not reflect in the various diets.

Similarly, it was noticed that as the quantity of fish meal was reduced at various percentages, there was a corresponding increased of crude fibre content in T2, T3, T4 and T5 that contained varied amount of shea caterpillar meal. This trend could be attributed to the rich fibre content of shea caterpillar meal.

Also, a related trend was observed in the nitrogen-free extract and metabolizable energy level when the amount of fish meal declined, the nitrogen-free extract and metabolizable energy levels of dietary treatments two, three and four increased indicating the effect of shea caterpillar in the various diets. The increase in metabolizable energy with increasing shea caterpillar level may be attributed to the high fat contained in the shea caterpillar. According to Adeniji (2007) fat contains a lot of energy which are released when the fat is oxidized.

On the other hand, the finisher diets showed a similar pattern to the starter diets. As the amount of fish meal declined from 25 % to 75 %, the ash content in treatments T2, T3, and T4 reduced by an average of 1.5%. The difference observed could be due to the high ash content in fish meal. Also, as the quantity of fish meals declined and shea caterpillar meal increased, the fat content in T2 (SC25 %), T3 (SC50 %), and T4 (SC75 %) improved. Equally, when shea caterpillar meal inclusion levels was increased from 25 % to 100 %, the

fibre content and the metabolizable energy level increased in the various diets due to the effect of shea caterpillar meal.

Differences were observed among the various treatment diets as percentages of fish meal was replaced by shea caterpillar meal partially or completely. The differences in the nutritional attributes of the various diets could be assigned to different sources of protein, manual compounding of feed, crude fibre, fat and energy content of shea caterpillar as well as the different diets of shea caterpillar and fish.

### **5.3 Amino acid Composition of Shea Caterpillar and Fish meal**

The shea caterpillar meal has both essential and non-essential amino acids. This study reported that the shea caterpillar contained fifteen amino acids with a total amino acid content of 64.52mg/100g which was lower than 59.52g/100g and 70.39g/100g obtained from 17 amino acids discovered by Yapo *et al.* (2017) and Anvo *et al.* (2016b) respectively. Anankware (2017) also reported that shea caterpillar has 9 amino acids with a total amino acid content of 332.4 ( $\mu\text{g/g}$ ) which was less than the content of the amino acid in the present study. The differences observed could be attributed to the stage of larvae development, quality of the shea leaves consumed, geographical location of shea trees, and efficiency of the analysis procedures Anankware (2017).

Similarly, in this study, fish meal contained 15 amino acids with a total content of 37.071mg/100g, which was less than 42.27mg/100g protein obtained from nine essential amino acids reported by Anvo *et al.* (2017). The disparities observed could be attributed to different types of fish used to prepare fish meal, method of processing, and drying. According to Miles and Jacqueline (2006) amino acid quality of the fish meal is what brands this ingredient as attractive as a protein supplement. It was further added that, the protein in

a fish meal is an exceptional source of indispensable amino acids like lysine, methionine and tryptophan. In this study, the total essential amino acid was 22.9mg/100g, and lysine, methionine and tryptophan alone constituted 9.852mg/100g which was 43% of the total contribution of the 8 essential amino acids.

The amino acids are constituents of structural and defensive tissues, such as skin, feathers, bone matrix, ligaments, soft tissues, organs, and muscles. Also, amino acids and small peptides may serve a variety of metabolic functions and as precursors of various essential non-protein body constituents (NRC, 1994). The iron in shea caterpillar (Yapo *et al.*, 2017) support the formation of red blood cells which enables the birds to perform different metabolic activities.

## **5.4 Experiment One**

### ***5.4.1. Effect of shea caterpillar meal on feed and water intake of broilers (4 - 9 weeks)***

Feed intake did not follow the increasing levels of shea caterpillar meal in the experimental diets and the higher inclusion level of shea caterpillar meal did not favour the weekly feed intake of the birds. The reduced feed intake of broilers on diets containing 50% shea caterpillar meal and above may be due to palatability, unfamiliar nature of the shea caterpillar meal in the diets, fibre since the caterpillars contained fibre and energy level of the diets. Over the five weeks, birds on dietary treatment two (SC25%) consumed the highest feed of 5,134g/bird with less SCM while the least amount of feed was consumed by birds in T5 (4615g/bird) which was solely SCM. The differences could be due to fibre and energy content of the diet. Esonu *et al.* (2001) and Onu *et al.* (2011) reported that a decrease in feed intake is associated with the palatability of feed arising from high fibre content. According to Ferket and Gernat (2006), energy level, feed shape, health, and management

practices affect the consumption of feed by table birds. This was in line with studies by Adeniji (2007) who reported that the replacement of housefly maggot meal for groundnut cake in the diets of broilers did not show a significant difference in feed intake, feed to gain ratio, and nutrient retention with increasing levels of maggot meal in the diets of the broilers. Ijaiya and Eko. (2009) also reported that replacement of silkworm caterpillar meal (SCM) with fish meal shows no significant difference in terms of feed intake, body weight gain, feed conversion ratio, and nutrient digestibility of the birds. Similarly, Mohammed *et al.* (2017) confirm that replacing black soldier fly larvae meal at low levels in broiler finisher diets improved growth performance, feed intake, live weight gains, and feed competences to that of the control diets. Biasato *et al.* (2017) also revealed that the inclusion of dietary Yellow Mealworm (*Tenebrio molitor*) meals in female broiler chickens' diets improved body weight and feed intake. However, Campus (2009) reported that Grasshopper meal was replaced with a fish meal at 100 % and the results showed higher feed intake and weight gain which was contrary to the current study. In this study at 100 % (T5) inclusion of SCM, the feed intake was the lowest and the growth rate was low. The difference may be due to the different species of insects, feed composition, and smell of the caterpillar meal used.

On the other hand, water intake also followed a similar trend as observed in feed consumption in the first three weeks of the study. The highest water intake was recorded in T2 while the lowest was observed in treatment T5. Mostly, there is a high relationship between feed intake and water intake. Hence, birds on dietary treatment T2 recorded the highest water and feed intake while birds on T5 had the lowest water and feed intake. The differences in water consumption may be attributed to changes in temperature, rate of growth, and less feed consumed due to feeding composition. Intake of water by table birds is

influenced by environmental temperature, rate of growth, feed composition, and kidney water resorption (Ferket and Gernat 2006).

#### ***5.4.2 Effect of shea caterpillar meal on body weight of broiler chicks (4 - 9 weeks)***

The initial live body weights of the 28-day-old chicks were similar ( $P>0.05$ ) across all the treatment means at the start of the experiment. However, the improvement in the performance of birds fed the control diet (T1), T2 and T3 inclusion of SCM compared to the other dietary treatments may be attributed to palatability and low quantity of SCM in the diets which enhance consumption and thus increase in weight of broiler chickens.

The decreasing trend in growth observed in weekly live body weight as the inclusion of SCM increased differs from the findings by Biasato *et al.* (2017) who reported that increasing levels of dietary Yellow Mealworm (*Tenebrio molitor*) meal in broiler chickens diets improve body weight and feed intake. The higher inclusion of SCM above 50% did not enhance the performance of birds in the current study. The difference could be due to different species of insects used and the inability of birds to utilize the protein in the feed consumed.

#### ***5.4.3 Effect of shea caterpillar meal on body weight gain of broilers (4 - 9 weeks)***

Body weight gain values were similar among Treatments T1, T2, and T3 but were all significantly different from the body weight gain of birds fed diets that contained 75% and 100% shea caterpillar. Body weight gain showed a similar pattern to feed consumption. The decline in weight gain or poorer growth rate of broiler chicks fed 75% and 100% inclusion level of SCM-based diet may be attributed to palatability and decreased feed intake. The lower body weight has been linked to the fact that weight gain in broilers is directly related

to feed intake, quality of the feed as well as how efficiently the birds utilize the feed (Egbunike *et al.*, 2009). The lower weight gain of birds fed 75% and 100% SCM inclusion diet compared to birds fed 0%, 25%, and 50% inclusion diets could also be partly attributed to the higher crude fibre content of shea caterpillar in the diet since the high crude fibre is known to affect feed intake and thus weight gain in poultry (Onu, 2010) as a result of poor digestibility. It is also agreed that simple stomach animals cannot utilise high crude fibre meals efficiently (Gadzirayi *et al.*, 2012).

#### ***5.4.4 Effect of shea caterpillar meal on feed conversion ratio of broiler chickens***

There were no significant differences among all the treatment means in weeks one to four. However, in week five, the FCR of birds on diets T1, T2, T3, and T4 were similar among the treatment means. The average FCR for chicks on all the dietary treatments showed no significant difference among the treatment means. This was in line with Ijaiya and Eko, (2009) who stated that replacement of silkworm caterpillar meal with fish meal showed no significant difference in terms of feed conversion ratio and nutrient digestibility of the birds. Also, Adeniji (2007) reported that the replacement of housefly maggot meal for groundnut cake in the diets of broilers did not show a significant difference in feed to gain ratio with increasing levels of maggot meal in the diets of the broilers.

The high FCR of the birds fed above 75% inclusion level of shea caterpillar meal may be due to the inability of the chicks to effectively digest, absorb, and utilize the nutrients in the feed Mohammed *et al.* (2017). The low FCR may be attributed to the reduction in feed intake and improvement in nutrient absorption and utilization resulting in better weight gain.

## **5.5 Effect of Shea Caterpillar Meal on Haematological Parameters of Broiler Chickens**

The values of the haematological indices were not significantly influenced among all the dietary treatments. However, some differences were observed in the red cell distribution width coefficient of variation (RDW-CV). The red cell distribution width coefficient of variation of birds on all the treatments was higher than the control. The red cell distribution width coefficient of variation is an indicator of variation in RBC size within a blood sample. The RDW is used along with parameters such as MCV, MCH, and MCHC to describe a population of RBC. The outcome of this study was in agreement with the work done by Opoku *et al.* (2018) who reported that the replacement of black soldier fly larvae meal in broiler diets did not show any significant effect on haematological characteristics of the blood. These results were similar to Biasato *et al.* (2017). Moreover, substituting a fish meal with different levels of silkworm (*Anaphe infracta*) caterpillar meal on haematological characteristics showed no significant differences between the treatment means in terms of blood parameters (Ijaiya and Eko, 2009).

However, Mohammed *et al.* (2017) reported that there was a significant difference in the levels of packed cell volume, haemoglobin, and red blood cells of fowls fed the black soldier fly larvae meal than those fed the control diet which contradicts the results of the current study. The differences observed might be due to different species of insects used and different management conditions. According to Mohammed *et al.* (2017) factors like, breed of animals, management, age, genotype, diseases, medication, and nutrition may influence the blood parameters of farm animals.

Red blood cells transport oxygen from the lungs to tissues and carbon dioxide from tissues to lungs in the body of animals (Isaac *et al.*, 2013). Red blood cell values obtained in this study were not significantly different among all the dietary treatments. The RBC values of the fell within the normal reference ranges (1.5-3.5) reported by Aengwanich *et al.* (2004). Hence, a low red blood cell count denotes a reduction in the level of oxygen transport to the tissues and the level of carbon dioxide returned to the lungs (Isaac *et al.*, 2013).

White blood cells for birds on all the treatments were similar. White blood cells help to fight infections, defend the body against attack by organisms and produce as well as dispense antibodies in immune response (Etim *et al.*, 2014). The WBC values of birds on all the treatments were higher than normal reference values (1.2-3.0) as reported Aengwanich *et al.* (2004) and (4.07-4.32) by Etim *et al.* (2014). The difference in WBC may be attributed to infection among experimental birds. Therefore, animals with high numbers of WBC counts are capable of generating antibodies in the process of phagocytosis and have a high ability to fight diseases (Etim *et al.*, 2014).

Haemoglobin has the physiological role of conveying oxygen to tissues of the animal for oxidation of consumed food to release energy for other body functions as well as conveyance of carbon dioxide out of the body of animals (Isaac *et al.*, 2013).

In this study, the haemoglobin values across all the treatments' mean fell below the normal reference values (11.60-13.68) as reported by Etim *et al.* (2014). This means that the efficiency of carrying oxygen to all parts of the animal body may be affected due to the low values recorded. The low haemoglobin values were not due to the influence of the shea caterpillar because birds fed the control diet also fell below the reference range.

Packed Cell Volume is the percentage of red blood cells in the blood (Etim *et al.*, 2014). Isaac *et al.* (2013) reported that packed cell volume is associated with the transport of oxygen and absorbed nutrients. The PCV values obtained in the current study fell within the reference values of 22.0-35.0 % as stated by Aengwanich *et al.* (2004) and Etim *et al.*, (2014). The PCV levels showed the nutritional status of fowls (Aikhuomobhogbe and Orheruata, 2006).

Mean corpuscular haemoglobin and mean corpuscular haemoglobin concentration show blood level conditions in animals. Hence a low value is an indication of anaemia (Aster, 2004). In the present study, MCH and MCHC were similar across all the treatment means and values obtained fell within the normal reference values of 33.0-47 and 26-35 as reported by Aengwanich *et al.* (2004). This indicated that the birds were well nourished (Amevor, 2017).

### **5.6 Effect of Shea Caterpillar Meal on Biochemical Parameters of Broilers**

The results of the biochemical indices such as total protein, albumin, globulin, cholesterol, triglyceride, high-density lipoprotein, and low-density lipoprotein showed no significant differences among all the treatment means. Numerically, birds fed on T1 (control) had a higher total protein value (33.3g/l) than all the other treatments. The least value (22.0g/l) was recorded in T5. This indicates that the control diet may be relatively of good quality. The total protein values obtained in this study were higher than the normal reference range of 3.0g/l - 4.9g/l (Cynthia, 2011). It indicates that probable the various diets were rich in protein and that the shea caterpillar did not adversely affect total protein. These finding was in line with Akpodiete and Okagbare (2002) who indicated that the inclusion of maggot

meal in the broilers diet did not show a significant effect for all the biochemical indices considered but for cholesterol.

Albumin values were similar. These values were higher than the normal reference values of 2.6-3.58g/dl stated by Cynthia (2011). The differences could be due to good nutrition and enough protein obtained from the experimental diets.

The globulin values of birds fed T1 (control) were not significantly different from T2 and T3 but was significantly different from T4 and T5. Globulin plays an important role in liver function, blood clotting, and fighting infection.

Cholesterol and triglyceride values of birds in all the treatments were similar. Birds fed dietary T3 had the highest value of 2.967 mmol/L and birds on T2 recorded the least value of 2.500mmol/L. Akpodiete and Okagbare (2002) reported that cholesterol value was significantly influenced by the use of maggot meal leading to a reduction in cholesterol with increased inclusion in table birds' diet. This reduction in cholesterol levels is of nutritional and health importance, as it is suggestive of a cure for coronary diseases.

High-density lipoprotein and low-density lipoprotein did not show any significant differences among all the treatment means. However, the values reported in this study were below the normal reference values of (1.5-1.9 mmol/l) and (1.3-2.6) respectively Aengwanich *et al.* (2004) except for birds fed T3 for HDL and those on T1 for LDL.

### **5.7 Effect of Shea Caterpillar Meal on Carcass Characteristics of Broiler Chickens**

The outcome of the carcass characteristics showed significant difference among some of the treatment means. This was in line with a study conducted by Ballitoc & Sun (2013), who reported that replacing varied levels of yellow mealworms (*Tenebrio molitor*) in fowl feed

improved the performance and carcass quality of poultry meat without any adverse effect in birds. They added that moderate addition of yellow mealworm produces heavier gizzard and a high percentage of fat content within the meat. Similar results were obtained by Hwangbo *et al.* (2009) who stated that maggot supplementation in the diet of broiler chickens significantly increased dressing percentage, breast muscle, and thigh muscle. Anankware (2017) also confirmed that the inclusion of black soldier fly larvae at lower percentages for starter and finisher diets improves feed intake, wings, and drumstick weight. However, Balolong *et al.* (2020) revealed that the inclusion of black soldier fly larvae as protein feed in the broiler chicken diet did not show any significant difference between treatments in the carcass parameters of broilers.

#### **5.8 Composition of Fresh and Dried Broiler Chicken Thigh, Drum stick, and Breast Meat**

The proximate analysis of the fresh carcass showed that there was a significant difference across all the treatment means in terms of ash, crude protein, crude fat, nitrogen-free extract, and metabolizable energy. The proximate values indicated that the varying levels of shea caterpillar affected the nutritional facts of the carcass. In terms of moisture, as the quantity of shea caterpillar decreased, the moisture content increased in the treatment means without a particular trend. Also, as the amount of fish meal reduced, there was a consistent increase of crude protein content in dietary treatments T2, T3, T4, and T5 except for birds fed the control diet. It was observed that as the quantity of fish meal reduced, there was an increased in crude fat content in all the treatments which were higher than the control. With regards to NFE, as the amount of fish meal decreased, there was a decreased in NFE in the carcass of birds fed the experimental diet except the control. Metabolizable energy levels in the carcass

of all treatments decreased as shea caterpillar meal inclusion reduced without a particular trend, but all the treatment means were higher than the control indicating the effect of SCM in the diets.

On the other hand, the proximates of the dried carcass showed a similar trend just to the fresh meat. Apart from NFE which was higher and significant in T1 (the control), all the other proximate contents were significantly different and increased as a varied percentage of shea caterpillar reduced. The differences in proximate contents did not show any particular direction. It was observed that values of the proximate content were higher in the dried carcass than in the fresh.

The variations observed in the nutritional components of fresh and dried broiler carcasses might be due to different protein ingredients (fish meal and shea caterpillar meal), the nutritional composition of each diet, and the manual mixing of the feed. The decline of energy content in the various treatments may be attributed to the varied energy contents of the feed served.

### **5.9 Effect of Shea Caterpillar on Organoleptic Characteristics of Broilers**

It was observed that the addition of shea caterpillar meal in broiler chickens' diets had no significant effects on the organoleptic properties of the birds. The performance of birds across all the treatment means was similar. This was similar to the study of Gunya *et al.* (2018) who reported that the inclusion of earthworms positively influenced sensory scores of broiler breast meat. But added that chicken flavour scores reduced with the increasing inclusion rates of earthworm meal. Hwangbo *et al.* (2009) also reported that the effect of maggot supplementation in the chicken diet did not show significant differences in meat colour and crude protein contents. Okubanjo *et al.* (2014) reported that organoleptic

evaluation of broiler fowls fed with maggot meal did not alter the taste, tenderness, juiciness, colour, and flavour of the meat. Kim *et al.* (2021) posited that there were satisfactory results for the meat quality without harmful effects on broilers fed Black soldier fly larvae meal.

#### **5.10 Cost-Benefit of Incorporating Shea Caterpillar Meal in Broiler Chickens' Diets**

When the birds were fed at an inclusion level of 50% SCM, the profit per bird was GH¢38.4 followed by GH¢37.3 for the control and GH¢35.6 for 25% SCM and at 100% inclusion levels the lowest profit of GH¢26 was recorded. The inclusion levels above 75% SCM reduced the profit margins making such inclusion levels inefficient in commercial poultry production. Hence the best inclusion rate to maximize profit by a farmer should not exceed 50 percent of the shea caterpillar. The reduction in the cost of the feed per bird on the shea caterpillar meal-based diets could be attributed to the price difference between a fish meal and a shea caterpillar meal. Since the prevailing price of fish meal was higher than SCM. Oyegoke *et al.* (2013), reported that decreasing levels of *Cirina forda* incorporation in the diets of broiler chickens may lead to reducing costs of production and therefore, economically advisable to use in diets of broiler chickens. This agreed with the findings of this present study.

#### **5.11 Determination of Coliform Load in Shea Caterpillar Meal**

Foodborne diseases which are triggered largely by pathogenic microbes found in polluted foodstuffs are a major global problem, specifically in developing nations Ramashia *et al.*

(2020), like Ghana causing death to susceptible persons. Due to foodborne diseases, microbial analysis is usually done on food to quality assured it before consumption.

In this study, the microbial analysis shows that the shea caterpillar meal contains coliform with population of 200,000 CFU/g (expressed in exponential form as  $2.0 \times 10^5$ ). According to Lim *et al.* (2012), the ideal coliform count in foodstuffs that require further cooking and salted meat is  $10^3$  CFU/g but not insects.

In this study, the coliform levels were high which indicates that the shea caterpillar meal might have been contaminated. This contamination could be attributed probably to unhygienic methods of processing, the nature of the equipment used, drying, exposed ways of advertising for buyers at marketplaces, and poor storage facilities. According to Cornell University (2007), coliforms have been used as an indicator of unhygienic conditions and the quality of food and water products.

## **5.13 Experiment Two**

### ***5.13.1 Effect of shea caterpillar meal on growth performance of broiler chickens***

The effect of shea caterpillar meal on growth performance of broiler chickens fed different levels of shea caterpillar meal for a nine-week experimental period.

### ***5.13.2 Effect of shea caterpillar meal on feed intake of broiler chicks (0- 9 weeks)***

Chicks fed the control diet (T1) consumed significantly higher feed as compared with birds fed the other treatment diets. The total feed consumption of the broiler chicks decreased as the inclusion rates of SCM in the diets increased during the starter phase. However, feed consumption in the finisher phase did show any significant difference across all the

treatments. The results showed that birds served dietary T1 recorded higher total feed intake values followed by those on treatments T2 and T3. This could be attributed to the acceptability, palatability, appearance, and shape of the feed (Onu *et al.*, 2011) as it is known that animals are particular about these attributes of feed. Esonu *et al.* (2001) and Onu *et al.* (2011) reported that reduction in feed intake is related to the palatability of feed arising from high fibre content. According to Ferket and Gernat (2006), energy level, feed shape, health, and management practices affect the consumption of feed by table birds.

This was in line with studies by Adeniji (2007) who reported that broilers fed housefly maggot meal did not show a significant difference in intake of feed and weight gain with increasing levels of maggot meal in the diets of the broilers. Similarly, Ijaiya and Eko (2009a) also stated that the replacement of silkworm caterpillar meal with fish meal showed no significant difference in terms of feed intake, body weight gain, feed conversion ratio, and nutrient digestibility of the birds.

However, Biasato *et al.* (2017) also revealed that the inclusion of dietary Yellow Mealworm meal in broiler chickens' diets improved body weight and feed intake which was contrary to the present study, especially at the finisher phase.

### ***5.13.3 Effect of shea caterpillar meal on water intake of broilers (0 to 9 weeks)***

The observed overall similar water intake between the birds fed T1, T2, and T3 as compared with those fed T4 and T5 could be due to the differences in feed intake and body weight gain values recorded by the birds. According to Ferket and Gernat (2006), the amount of water required by poultry depends on the animal's size, environmental temperature, relative humidity, feed composition and intake, and rate of growth of birds. Hence, with higher feed

intake, fowls are likely to consume a relatively higher amount of water to facilitate digestion and metabolic needs.

#### ***5.13.4 Effect of shea caterpillar meal on weekly body weight of broilers (0 - 9 weeks)***

The higher inclusion rate of shea caterpillar did enhance body weight of broilers. The declining trend in growth rate observed in the weekly body weight as the inclusion of SCM increased differs from the finding by Biasato *et al.* (2017) who reported that increasing levels of dietary Yellow Mealworm meal in broilers diets improved body weight and feed intake. The higher inclusion of SCM above 50% did not enhance the performance of birds. The difference could be due to different sources of protein used and the inability of birds to consume more feed.

#### ***5.13.5 Effect of Shea Caterpillar meal on Body weight Gain of Broilers (0 - 9 weeks)***

Generally, at the starter phase, the WG of the birds fed shea caterpillar meal and the control diet did not follow any particular trend, but birds fed T2 performed better. It was observed that at 75 and 100 percent inclusion levels of SCM, the birds recorded lower weights in numerical value. The lower growth rate of broiler chicks fed 75 % inclusion level of SCM-based diet may be attributed to the lower feed intake and fibre content of diets containing SCM since studies have shown that monogastric cannot utilize diets with high fibre content (Gadzirayi *et al.*, 2012).

Alternatively, during the finisher phase for weeks 5 and 6, the results showed significant differences among the means of the various dietary treatments. Performance of birds in T1 and T3 were similar for week 5. The weight gain reflected feed intake. The better the feed intake, the more weight gain. High weight gain of birds has resulted from increased feed

intake. This could be an indication that finisher broilers tolerated the SCM better than the starter phase when the broiler chicks were young.

The declined weight gain observed in some birds served the dietary treatments at 75% and 100% inclusion levels of the SCM diets could be a result of the low feed intake, fibre content of the shea caterpillar meal, and anti-nutritional factors. Barnes *et al.* (1985) stated that consumption of feed containing anti-nutritional factors sometimes interfere with the digestion and utilization of dietary protein and carbohydrates as well as inhibit the availability of some mineral and nutrients and therefore, affect feed conversion ratio and growth rate.

The findings of this disagreed with studies by Adeniji (2007) who reported that broilers fed housefly maggot meal did not show a significant difference in weight gain with increasing levels of maggot meal in the diets of the broilers. Similarly, Ijaiya (2009) also stated that the replacement of silkworm caterpillar meal with fish meal showed no significant difference in terms of body weight gain and feed conversion ratio of the birds. This could be attributed to different insects used in the diets.

#### ***5.13.6 Effect of Shea Caterpillar Meal on Feed Conversion Ratio of Broilers***

The overall average feed conversion ratio for birds in all treatments was similar except for birds fed T5. The values of the average FCR in this study were higher than the normal reference range as observed in the control (T1) and other treatment diets. This might be due to chickens' inability to put on more weight compared with their feed intake. Also it could be attributed to feed wastage by birds. This study was in contrast to Adeniji. (2007) who reported that the inclusion of housefly maggot in broiler diets showed no significant difference in feed conversion ratio with increasing levels of maggot meal in the diets of the

broilers. Similarly, Ijaiya and Eko. (2009) stated that substitution of silkworm caterpillar meal with fish meal showed no significant difference in terms of feed conversion ratio. Also, a related study showed that feeding broiler chicks with Yellow Mealworm (*Tenebrio molitor*) larvae meal as an alternative to fish meal enhanced feed intake, body weight gain, but did not enhance feed conversion ratio (Campus, 2009; Biasato *et al.* 2017). The variations could be assigned to different types of insects. Good FCR could be an indicator of protein quality in a diet. However, the high average FCR across all the treatment means may be as a result of the chicks' inability to effectively digest, absorb, and utilize the nutrients in the feed (Mohammed *et al.*, 2017).

#### **5.14 Effect of Shea Caterpillar Meal on Haematological Characteristics of Broilers**

There was a significant difference among the treatment means in terms of lymphocytes levels.

The lymphocytes values for T1, T2 and T3 were higher than the normal reference range while the value for T5 was below the normal range (Aengwanich *et al.*, 2004). Lymphocytes are type of white blood cells. They play an essential role in the immune system, which helps to fight diseases and infections. Lymphocytes levels may vary depending on diet, age, sex and breed of animal (Boostani *et al.*, 2010). The high lymphocytes levels may improve the immune system of birds in T1, T2 and T3 to help fight possible infections (Boostani *et al.*, 2010; Anankware, 2017). The low lymphocytes level observed in birds fed dietary treatment five may indicate higher risk of infection or disease. It was noticed that the lymphocytes values reduces with an increasing levels of shea caterpillar meal in the treatment diets.

The WBC values of birds on all the treatments were higher than normal reference values of (4.07-4.32) as reported by Etim (2014). The high WBC may be attributed to improvement in the immune system among the birds Christensen *et al.* (2002) to help fight potential

infections (Anankware, 2017). According to Togun *et al.* (2007), when haematological values are within the standard range described for an animal, it suggests that diets did not have any negative influence on haematological parameters performance of birds.

The outcome of this study was in agreement with the work done by Opoku *et al.* (2018) who reported that the replacement of Black soldier fly larvae meal in broiler diets did not lead to any significant effect on haematological features. Similarly, substituting a fish meals with silkworm caterpillar meals showed no significant difference in terms of blood parameters (Ijaiya and Eko, 2009).

On the contrary, Mohammed *et al.* (2017) reported that there was a significant difference in the levels of packed cell volume, haemoglobin, and red blood cells of fowls fed the black soldier fly larvae meal than those fed the control diet. The differences observed might be due to different species of insects used and different management conditions. Factors like the breed of animals, management, age, genotype, diseases, medication, and nutrition may influence the blood parameters of farm animals (Mohammed *et al.*, 2017).

#### **5.15 Effect of Shea Caterpillar Meal on Carcass Characteristics of Broiler Chickens**

The inclusion of shea caterpillar meal showed significant difference among some of the treatments means in terms of carcass parameters. This was in line with a study by Ballitoc and Sun (2013), who reported that replacing varied levels of yellow mealworms in broiler diets improved the performance and carcass quality of birds, especially gizzards. Similarly, Hwangbo *et al.* (2009) stated that supplementation of maggot in the diet of broilers significantly increased dressing percentage, breast as well as thigh muscle. Anankware

(2017) also confirmed that the addition of black soldier fly larvae at 12 and 13 % for starter and finisher diets respectively improves wings and drumstick weight.

However, Opoku *et al.*, (2018) reported that substituting a fish meal or soya bean meal in broiler diets with black soldier fly larvae meal did not indicate any significant difference in carcass characteristics. Similarly, Balolong *et al.* (2020) reported that increasing levels of black soldier fly larvae as protein feed did not show a significant difference between treatments in the carcass attributes. These findings disagreed with the current study. The disparities may be attributed to different sources of protein used in the diets and varied sources of feed by the insects.

#### **5.16 Cost-Benefit of incorporating Shea Caterpillar Meal in Broilers Diets**

The cost of total feed intake per bird was reduced by an average of GH¢2.18 per kilogram when the highest amount of SCM (100%) was incorporated in the broiler chicken diets. This was mainly due to the decrease in a fish meal whose price was higher than SCM on a per kilogram basis. Feed cost per kilogram of body weight gain was high at an inclusion rate above 50% of SCM compared to the control. The difference might be attributed to the inferior total weight gain of birds fed with higher levels of SCM even though the cost of feed was low. When the birds were fed at an inclusion level of 25% SCM, the profit per bird was GH¢18.1033 and at 100% inclusion levels, the lowest profit of GH¢7.470 was obtained. Thus, inclusion levels above 25% SCM reduce the profit margins making such inclusion levels not economical in the starter phase of production.

At the finisher phase, the per kilogram cost of feed reduced marginally as the amount of fish meal was replaced by more shea caterpillar meal. The cost of total feed intake per bird was

reduced by about GH¢3.1 per kg when SCM was completely incorporated into the broiler chicken diets. This was generally due to price differences. The price of fish meals was higher than SCM on a per kilogram basis. Feed cost per kilogram of body weight gain was high at an inclusion rate above 50% of SCM compared to the control. The difference might be attributed to the unimpressive total weight gain of birds fed with higher levels of SCM even though the cost of feed was low. When the birds were fed at an inclusion level of 50% SCM, the profit per bird was GH¢37.3 followed by GH¢30.8 for T2 and at 100% (T5) inclusion levels the lowest profit of GH¢16.3 was noted.

Thus, inclusion levels between 25% and 50% SCM increased profit, and levels above 50% SCM reduced the profit margins making such inclusion levels unprofitable in commercial broiler production. The results obtained were similar to the finding by Dutta *et al.* (2012) who reported that the inclusion of silkworm pupae meal in birds' diet was the cheapest and has the potential to replace the overpriced fish meal as a protein source. Similarly, substituting a fish meal with silkworm caterpillar meal enhanced economic gains in the starter phase and resulted in a decline in feed cost per kilogram at the finisher phase suggesting higher returns (Ijaiya and Eko, 2009a; Ijaiya and Eko, 2009b). Also, Oyegoke *et al.* (2013) reported that the inclusion of Westwood in the diets of broilers resulted in a reduction in the cost of production and therefore, economically advisable to use in formulating diets of broiler chickens.

## CHAPTER SIX

### 6.0 CONCLUSIONS AND RECOMMENDATIONS

#### 6.1 Conclusions

It can be concluded from this study that:

1. Nutritionally, the shea caterpillar contains 60.42 % crude protein as well as 3306.76 kcal/kg of metabolizable energy while fish meal had 54.51 % crude protein and 2892.82kcal/kg of metabolizable energy. Shea caterpillar meal is rich in crude protein and amino acid than fish meal.
2. The partial inclusion of dietary shea caterpillar meal up to 25 % positively influenced the growth performance of broiler chickens the starter phase and 50 % at the finisher phase.
3. The inclusion of shea caterpillar meal in the diets of broilers had no adverse effect on the haematological and biochemical characteristics.
4. The inclusion of shea caterpillar meal in the diets of broilers had no harmful effect on the carcass and organoleptic attributes of broiler chickens, however, harvesting, drying and processing methods needs to be done well to prevent coliform contamination of the shea caterpillar.
5. The cost-benefit analysis on feed showed that the inclusion of SCM in the diets of broiler chickens up to 50 % increased the profitability of broiler production.

## **6.2 Recommendations**

Based on the conclusions of this study, it is recommended that:

1. Inclusion levels of SCM not exceeding 25 % can be used in broiler feed at the starter phase and 50 % at the finisher phase for small scale farmers.
2. A similar experiment should be conducted to determine the effect of SCM in other monogastric animals especially layers and guinea fowls.
3. Determination of mineral composition and evaluation of the anti-nutritional factors of shea caterpillar meal is recommended.
4. The Ministry of Science, Technology, and Innovation through its agencies and Universities should consider the breeding of shea caterpillars to empower rural folks with the requisite skills to sustainably farm shea caterpillars, harvest and improve upon the local collection and processing of these insects to earn a living.

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## APPENDICES

### Appendix 3.1: Vaccination and Medication scheduled for Experiment One

Days/ weeks	Type of medication	Mode	Dosage
Day,1	Glucose plus water	Oral	
Day, 2	Glucose plus water	Oral	
Day, 7	1 <sup>st</sup> Gumboro (intermediate )	Oral	12mil/10liters
Day,14	1 <sup>st</sup> Newcastle (Hb1) H-Hitchner	Oral	12g/10liters
Day,21	2 <sup>ND</sup> Gumboro (intermediate plus strain)	Oral	12g/10liters
Day,28	2 <sup>nd</sup> Newcastle (Lasota)	Oral	12g/10liters
Day,30	Provitamin (Vita-X)	Oral	15mil/10liters
Day 31	Provitamin (Vita-X)	Oral	15mil/10liters
Day 32	Provitamin (Vita-X)	Oral	15mil/10liters
Day,51	Antibiotics(Antibact 3x)	Oral	10g/10liters
Day,52	Antibiotics(Antibact 3x)	Oral	10g/10liters
Day,53	Antibiotics(Antibact 3x)	Oral	10g/10liters

**Appendix 2: Medication and vaccination schedule for Experiment Two**

DAYS/WEEK	TYPE OF MEDICATION	MODE	DOSAGE
Day 1,2	Glucose Plus Water	Oral	
Day 4,5,6,7	Ciprofloxaxine	Oral	5mil/10liters
Week one	1st Gumboro	Oral	12mil/10liters
Day 11,12,12,14	Amprolin-300sw (Coccidiostat)	Oral	15g/10liters
Week two	1st.Newcastle(Hb1)	Oral	12mil/10liters
Day 18,19,20,21	Amprolin-300sw (Coccidiostat)	Oral	20g/10liters
Week three	2 <sup>nd</sup> Gumboro	Oral	12mil/10liters
Day 25,25,27,28	Ciprofloxaxine (Antibiotic)	Oral	15mil/10liters
Week four	2 <sup>nd</sup> Newcastle(Lasota)	Oral	12mil/10liters
Day 36,37,	Toltracox (Coccidiostat)	Oral	20mil/10liters
Day 43,44,	Toltracox (Coccidiostat)	Oral	20mil/10liters
Day 45,46,47	Amino-Vitasol	Oral	18g/10liters
Day 58,59	Sulphuridine	Oral	60g/10liters

### Appendix 3 Sensory Evaluation Hedonic Scale

#### SENSORY EVALUATION 5-POINT HEDONIC SCALE

This 5-point hedonic scale is purely for academic purposes and respondents should fill it out carefully and appropriately.

Level: .....

Age: (less than 25)..... (25-30)..... (31-35)..... (36-40) .....

(Above 41).....

Course of study: .....

**Kindly study the meaning of the following terms and respond separately on each treatment using the five-point hedonic scale below.**

**Tenderness:** This is a quality of meat measuring how easy it is chewed or cut. Tender meat is softer, easier to chew, and more palatable.

**Colour/appearance:** Appearance is the first characteristic perceived by the human senses and plays an important role in the identification and final selection of food. This is the visual perception of food comprised of colour, shape, size, and dullness.

**Juiciness:** Depends on the amount of water retained in cooked meat products. Juiciness increased flavour, and helps soften meat making it easier to chew and stimulating saliva production in the mouth.

**Flavour/aroma:** It is a sensory phenomenon that is used to denote the sensations of odour, taste, and mouthfeel.

**Toughness:** Means something that is difficult to chew.

**COLOUR**

- 1= very unacceptable [ ]
- 2 = unacceptable [ ]
- 3= Moderate [ ]
- 4 = slightly acceptable [ ]
- 5 = very desirable [ ]

**FLAVOUR**

- 1= very unacceptable [ ]
- 2 = unacceptable [ ]
- 3= Moderate [ ]
- 4 = slightly acceptable [ ]
- 5 = very desirable [ ]

**TENDERNESS**

- 1= very unacceptable [ ]
- 2 = unacceptable [ ]
- 3= Moderate [ ]
- 4 = slightly acceptable [ ]
- 5 = very desirable [ ]

**JUICINESS**

- 1= very unacceptable [ ]
- 2 = unacceptable [ ]
- 3= Moderate [ ]
- 4 = slightly acceptable [ ]
- 5 = very desirable [ ]

**TOUGHNESS**

- 1= very unacceptable [ ]
- 2 = unacceptable [ ]
- 3= Moderate [ ]
- 4 = slightly acceptable [ ]
- 5 = very desirable [ ]