Original Research Article

Growth Performance, Haematological and Blood Biochemical Characteristics of Broiler Chickens fed varied Levels of Dietary Shea Caterpillar (*Cirina Butyrospermi*) Larvae Meal

ABSTRACT

Aims: The increasing feed cost of poultry production makes a search for suitable alternatives essential. A five-week study was conducted to determine the outcome of dietary shea caterpillarlarvaemeal (SCM)on growth performance, haematological and blood biochemical characteristics of broiler chickens.

Study design:A Completely Randomized Design (CRD) was used for the experiment.

Place and Duration of Study: Department of Animal Science Education (Poultry Section of the Animal farm) of Akenten Appiah-Menka University of Skills Training and Entrepreneurship Development, Asante Mampong, Ghana. The study lasted for five weeks.

Methodology:

Ninety 4-week-old sexed Cobb 500 broiler chickens were assigned to five dietary treatments with three replicates. Each treatment had 18 birds with 6 birds per replicate in a male to female ratio of 4:2. Five dietary treatments were formulated to replace anchovy at 0%, 25%, 50%, 75% and 100% with shea caterpillar larvae meal and designated as $SCM^{0\%}$(The Control), $SCM^{25\%}$, $SCM^{50\%}$, $SCM^{75\%}$, and $SCM^{100\%}$ respectively.Data collected included proximate and amino acid analysis of shea caterpillar meal, growth performance, blood profile and cost benefit analysis. Data collected were subjected to analysis of variance with General Linear Model (GLM) procedure of Statistical Analysis System (SAS for windows, version 7).

Results:

The proximate and amino acids results showed that shea caterpillar meal contains 60.42 % crude protein, a crude fibre of 7.90 %, and 3306.76 kcal/kg of metabolizable energy as well as fifteen amino. There was a significant difference (P=0.05) among all the treatment means for daily feed and water intake, final body weight and total weight gain. For mean daily feed intake, $SCM^{0\%}$ was similar to $SCM^{25\%}$, but statistically different from $SCM^{50\%}$, $SCM^{75\%}$ and $SCM^{100\%}$. Birds fed dietary $SCM^{25\%}$ (5134g/bird) consumed more feed while the least was recorded from birds fed $SCM^{75\%}$ (4615g/bird).Similar trend was observed for total water intake.

Mean Final weight and total weight gain, birds fed $SCM^{0\%}$, $SCM^{25\%}$ and $SCM^{50\%}$ were similar, but statistically better than $SCM^{75\%}$ and $SCM^{100\%}$.It was noticed that final weight and total weight gain decreases as the inclusion levels of shea caterpillar meal increases.

The haematological and biochemical attributes were not significant except for red cell distribution width coefficient of variation and globulin respectively.

The red cell distribution width coefficient of variation values of birds on all the treatments was similar and more than twice the value obtained for the control treatment $SCM^{0\%}$. The globulin values of the birds fed the control, were similar to $SCM^{25\%}$and $SCM^{50\%}$but were significantly different from birds fed $SCM^{75\%}$and $SCM^{100\%}$.

Conclusion: It wasconcluded that the substitution of SCM for fish meal at a level not exceeding 50% had no detrimental effect but improved growth performance.

Keywords: Shea caterpillar (Cirina butyrospermi), proximate composition, growth performance, haematological, biochemical, broilers.

1. INTRODUCTION

The present human population is projected at 7.6 billion people and it is estimated that by the year 2050, the world population will be centred around 9.2 billion individuals which will probably put pressure on global food security [1].To ameliorate this challenge, poultry production primarily has the potential to efficiently accomplish the present and future food security in the world due to their short maturity period. Broiler production sub-sector serves as a source of employment, and income and offers not only superior protein food but also significant vitamins and minerals to reduce malnutrition among the vulnerable in developing countries and across the world at large [2].

Nevertheless, the poultry sector in Ghana is confronted with numerous challenges such as diseases, imported frozen chicken, high cost and scarcity of conventional sources of feed ingredients such as protein leading to adulteration in some cases[3]. More than 70% of the total cost of production of poultry in Ghana is due to feed costs alone [4].

A search for a suitable non-conventional feedstuff especially protein resources as alternative to fish meal is necessary and timely for saving the poultry industry from total collapse. One possible alternative source of animal protein ingredient is edible insects such as the shea caterpillar (*Cirina butyrospermi)* larvae. The shea caterpillar is an edible insect from the family Saturniidae and order Lepidoptera [5] and is locally called 'Taantuni' in Dagaare/Wale. The shea caterpillars arise seasonally on shea-nut trees around June each year [6] and feed exclusively on the leaves of the host tree. Shea caterpillar larva meal is rich in protein, iron, fat, minerals, and amino acids [7, 8] and serves as a major source of food in the human and fish diets [5, 9].

In spite of the numerous benefits of shea caterpillars, there is limited evidence on its utilization as a source of animal protein ingredient for poultry in Ghana where the shea plant is found. This study was therefore conducted to determine the feeding value of dietary shea caterpillar *(Cirina butyrospermi*) larva meal on growth performance, haematological and blood biochemical characteristics and cost savings of broiler chickens.

2.0 MATERIAL AND METHODS

2.1 Location of experiment and duration

The study was carried out at the Poultry Section of the Animal farm of the Department of Animal Science Education, of Akenten Appiah-Menka University of Skills Training and Entrepreneurship Development (AAMUSTED), Mampong, Ghana and lasted for five weeks. Asante Mampong is a town positioned in the North-Eastern part of the Ashanti region within longitudes 0^{o} 05″W and 1^{o} 30″W and latitudes 6^{o}55″ N and 7^{o}30″N. 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 [10].

2.2 Source and preparation of shea caterpillar larva meal

The already-dried shea caterpillar larvae were purchased from the Wa market in the Upper West Region of Ghana. The shea caterpillars were further sun-dried for three consecutive days and milled at the Poultry unit of the Animal Farm using a hammer mill with a 2mm sieve. The resulting product was further milled by a grinding miller into powder and kept in sacks at a clean, dried area until it was incorporated into the experimental diets. The texture and particle sizes of the milled shea caterpillars were similar to fish meal. The appearance (Plates 1)was pale yellow and the scent was like dried ground okra.

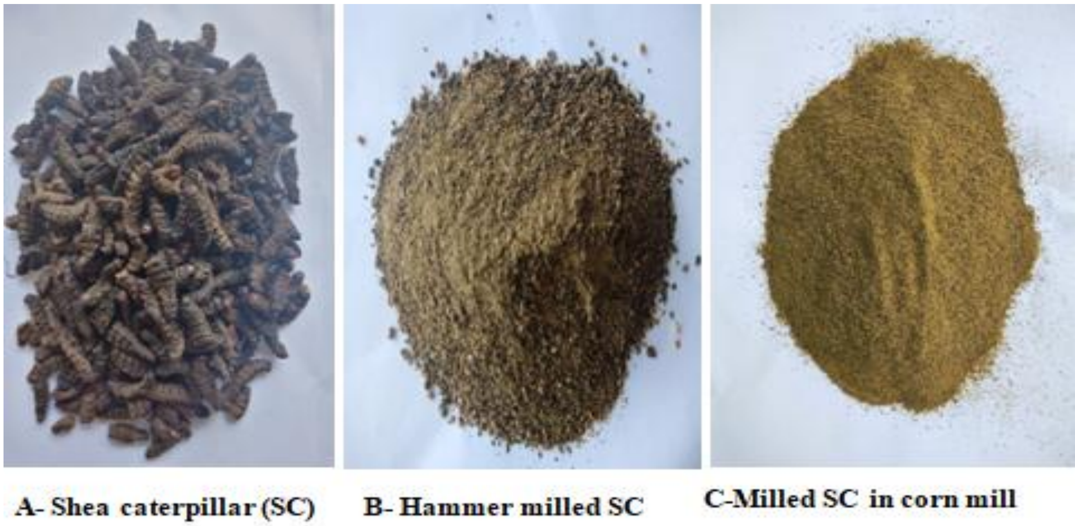

Plate 1: Dried shea caterpillar and milled particle sizes

2.3 Proximate and amino acid analysis of shea caterpillar larva meal

Samples of shea caterpillar larva meal and fish meal were subjected to proximate analysis according to procedure of Association of Official Analytical Chemists [11]. The amino acid composition of the shea caterpillar meal was analysed at Noguchi Memorial Institute for Medical Research, Accra, to determine both indispensable and dispensable amino acids using High-Performance Liquid Chromatography (HPLC) as described by [12].

2.4 Determination of coliform load in milled shea caterpillar

A sample of shea caterpillar was subjected to microbial analysis according to the procedure in[13]in the Microbiology Laboratory at AAMUSTED, Asante Mampong. The total coliforms of the feed ingredient (Shea Caterpillar meal) 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 millilitre (1ml) of each dilution was inoculated by pour plate method triplicate.
The plates were incubated in an inverted position at 37℃ for 24 hours.

2.4.1Total 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*.

2.5 Management of pre-experimental birds

Two hundred (200) one-day-old Cobb 500 broiler chicks were obtained from Darko farms located in Kumasi, Ghana, and brooded for 4 weeks in a deep litter system. The birds were fed a starter diet and water *ad libitum* during the brooding period and the recommended medication and routine activities were followed according to the guidelines of Veterinary Service Directorate [14]

2.6Experimental Birds and Design

Ninety (90) 4-week-oldCobb 500 birds were selected out of the initial stock based on weight and body condition. The selected birds were balanced by weight and allocated to five treatments and replicated three times in a completely randomized design. Each replicate had 4 males and 2 females. The birds were housed in 15 pens with dimensions of 1.8 m x 0.88m with a floor space of 0.32 m^2 per bird.

2.7Experimental Diets

The composition of the experimental diets is presented in Table 1. Shea caterpillar larva meal was used to partially and completely replace fish meal in five dietary treatments. Five dietary treatments were formulated to replace anchovy at 0%, 25%, 50%, 75% and 100% with shea caterpillar larvae meal and designated as $SCM^{0\%}$, $SCM^{25\%}$, $SCM^{50\%}$, $SCM^{75\%}$, and $SCM^{100\%}$ respectively.

Table 1: Composition of experimental diets

Feed ingredient	$SCM^{0\%}$	$SCM^{25\%}$	$SCM^{50\%}$	$SCM^{75\%}$	$SCM^{100\%}$
Maize grain	57.7	57.7	57.7	57.7	57.7
anchovy	**16**	**12**	**8**	**4**	**0**
Shea Caterpillar	**0**	**4**	**8**	**12**	**16**
Wheat bran	14	14	14	14	14
Soya bean meal	9	9	9	9	9
Oyster shell	1.5	1.5	1.5	1.5	1.5
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**
Calculated analysis					
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- MetabolizableEnergy; SCM- Shea Caterpillar Meal ,%-percentage

2.8Parameters measured

Data on proximate, amino acid, growth performance, haematological and biochemical characteristics and cost benefit on feed were recorded.

2.8.1 Proximate and amino acid analysis of shea caterpillar larva meal

Samples of shea caterpillar larva meal subjected to proximate analysis according to AOAC [11]. The amino acid composition of the shea caterpillar larvae meal and fish meal were analysed to determine the quantity of both essential and non-essential amino acids using High-Performance Liquid Chromatography (HPLC) as described by [12].

2.8.2Growth performance

Growth parameters determined were daily feed intake, total feed intake, initial weight, and final body weight. Average daily feed intake was determined by dividing daily feed intake by number of birds per replicate, total feed intake per bird was determined by summation of daily feed intake over the study period. Daily water intake was found by dividing amount of daily water intake by number of birds in a replicate and the values were added together to obtain total water intake. Electronic Kitchen scale (Zhongshan Jinli Electronic Weighing Equipment Co.,Ltd,China)was used to weigh experimental birds to determine initial live weight, weekly weight and final live weight. Total weight gain was calculated by the difference between initial live weights from weekly live weights and feed conversion ratio was calculated by dividing feed intake by weight gain and average feed conversion was then determined.

2.8.3Haematological parameters

Blood samples were collected from 15 birds selected at random, (one male bird per replicate) after the area was disinfected with cotton wool dampened with methylated spirit. A disposable sterilised 5ml syringe and needle were inserted into the right-wing vein (armpit) of each bird and 2mm of blood were drawn and discharged into sterilised vacutainer test tubes containing Ethylene Diamine Tetra Acetic Acid (EDTA) to prevent coagulation. A Rayto Automatic Haematology Analyser (Oscar Medicare Pvt. Ltd, India) was used to determine the haematological parameters such as Red Blood Cells, White Blood Cells, Platelets, Haemoglobin, Lymphocytes, Mean Corpuscular Haemoglobin, Mean Cell Volume, Mean Corpuscular Haemoglobin Concentration, Red Cell Distribution width standard deviation, and Red Cell distribution width coefficient of variation, as well as Platelets Distribution Width.

2.8.4 Biochemical attributes

Blood samples were collected from 15 birds selected at random from the five treatments involving a male bird per replicate. The blood samples were collected carefully from the right-wing vein of each bird after the area was disinfected with cotton wool moistened with methylated spirit using 5ml disposable sterilized syringes and dispensed gently into plain vacutainer tubes without EDTA and kept in a vacuum flask with ice cubes and analysed for the biochemical attributes using Mindray BA 88A semi-auto Chemistry Analyser(Shenzhen Mindray Bio-Medical Electronic Co.,Ltd,China). Total protein was assessed using the Biuret method whereas albumin was found using the Bromo Cresol Green method. Total cholesterol was determined using the CHOP-PAP method and globulin value was estimated by deducting albumin from total protein. Triglycerides, high-density lipoprotein, and low-density lipoprotein were also determined Keller [15]

2.8.5 Cost-benefit effectiveness

The cost of feed per bird was calculated by multiplying the per kilogram cost of feed by the total feed consumed per bird. The profit on feed alone was calculated by subtracting the cost of feed from the selling price of a bird.

2.9Statistical analysis

The data collected were subjected to analysis of variance using General Linear Model (GLM) procedure of Statistical Analysis System (SAS for windows, version 7(2008). Differences between means were separated using the Tukeys test at a 5% level. The statistical model used was defined as:

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

Where:

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

μ 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** β_5 the coefficients associated with the explanatory variables X_1, X_2, X_3, X_4, and X_5, respectively.

X_{1i} representsthe control treatment, Shea caterpillar larvae meal at 0% ($SCM^{0\%}$).

3. RESULTS AND DISCUSSION

3.1 Proximate analysis of shea caterpillar larva meal

The proximate analysis of the shea caterpillar larvae meal is presented in Table 2. The outcome showed that the caterpillar meal has a high crude protein content of 60.42% which fell within the normal range (20 - 80%) of protein content for edible insects of the order Lepidoptera [16]. The Crude protein of 60.42 % reported in this study is higher than the 55% CP [7] but less than 62%[17] and 63% [12]. Also, Amao *et al.,*[18] reported a superior value of 66.74% for Westwood (*Cirinaforda*) larvae meal. Similarly, [19] reported 50.30% CP content forsilkworm caterpillar meals which also disagreed with current findings. The disparity in crude protein content observed is attributed to the quality of shea leaves as feed, and the mode of processing the shea caterpillars. According to [7], 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 as well as different species of insects.

The ash content of 3.9% reported in this study was lower than the 4.8% [7] and 5.1% [17]. It was observed that some insect larvae meals are rich in ash content than shea caterpillar larvae meals. Ash content indicates the mineral potential in a feed[7]. 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[20].

The crude fibre content of 7.9% in this study was in agreement with the 7.5% reported for Westwood*(Cirinaforda)* larvae meal [18], but differed from 2.8%, 9.1% and 10.9% reported by [7], [21] and[19] respectively. Fibre in insects is chitin which cannot be absorbed or degraded into the blood and therefore affect the digestibility of proteins [18, 12]. The fibre content in this study was within the suggested limit of 7 % to improve the efficiency of digestion[22]. 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 [12]. The fat value of 10.4% was lower than the 12% [12] and 14.5% indicated by [17]. Also, the nitrogen-free extract content of 6.3% was more than the 3% obtained by [7] and less than the value of 12.6%[17].

Table 2. Proximate composition of shea caterpillar larva meal

Parameter	Shea caterpillar meal composition
Moisture content (%)	11.08
Ash content (%)	3.9
Crude protein (%)	60.42
Crude fat (%)	10.4
Crude fibre (%)	7.9
Nitrogen Free Extract (%)	6.3
Metabolizable energy (kcal/kg)	3306.76

3.2 Amino acid composition of shea caterpillar larva meal and fish meal

Table 3 shows the essential and non-essential amino acids composition of shea caterpillar larva meal. The shea caterpillar has fifteen different amino acids with a total amino acid content of 64.52mg/100g which disagreed with 59.52g/100g and 70.39g/100g amino acids reported by [7]and [17] respectively. The differences observed could be attributed to the stage of larvae development, the quality of the shea leaves consumed, the geographical location of shea trees, and the efficiency of the analysis procedures [12].

Similarly, in this study, fish meal used consisted of 15 amino acids with a total content of 37.071mg/100g, which differs from 42.27mg/100g reported by [9]. The disparities observed could be attributed to different types of fish used to prepare fish meal, method of processing, and drying.

The amino acid content of SCM was higher than the fish meal and therefore could be implied that the SCM was better in terms of the relatively high amino acid content of theshea caterpillar larva meal. However, the accurate feeding value is determined by the animal.

Table 3. Amino acid composition of shea caterpillar larva meal and fish meal

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
Total EAA	**29.34mg/100g**	**22.89mg/100g**
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	**35.09mg/100g**	**14.17mg/100g**
Total EAA+NEAA	**64.52mg/100g**	**37.01mg/100g**

*Essential Amino acid (EAA), ** Non- Essential Amino Acid (NEAA)

3.3 Microbial analysis of shea caterpillar meal

The microbial analysis showed that shea caterpillar meal contains coliform up to 200,000 CFU/g (expressed as 2.0 x 105) which was higher than estimated limits of 103 CFU/g, but it was safe for consumption. The coliform count in foodstuffs that need supplementary cooking and salty meat is 103 CFU/g Lim *et al.* (2012) as cited in [23].

The coliform levels which were high indicates that the shea caterpillar meal might have been contaminated and this could be attributed probably to unhygienic methods of processing, mode of drying, exposed ways of advertising for buyers at marketplaces, and poor storage facilities. According to Cornell University[24]coliforms have been used as an indicator of unhygienic conditions and the quality of food and water products. Therefore, decent sanitation and personal hygiene, particularly during home-based food processing and storage should be adhered to by all actors' in the caterpillar value chain since the caterpillars are usedas food or feed ingredient.

3.4 Effect of shea caterpillar larvae meal on growth performance

Mean daily feed intake, daily water intake, mean final weight and mean total weight gain differed (P=.05) among the dietary treatments except total feed intake, and feed conversion ratio (Table 4).
Mean daily feed intake of birds fed $SCM^{0\%}$was similar to $SCM^{25\%}$, but statistically different from $SCM^{50\%}$, $SCM^{75\%}$ and $SCM^{100\%}$. Treatments $SCM^{50\%}$and $SCM^{100\%}$ were similar in daily feed intake but differed from $SCM^{75\%}$.
Also, $SCM^{25\%}$ recorded superior mean daily water intake compared with the other treatment means. However, $SCM^{50\%}$ and $SCM^{75\%}$were similar but lower than$SCM^{0\%}$ and superior to $SCM^{100\%}$.
Mean final weight and total weight gain of $SCM^{0\%}$, $SCM^{25\%}$ and $SCM^{50\%}$ were similar (P=.05), but statistically better than birds fed $SCM^{75\%}$ and $SCM^{100\%}$ which were also alike (Table 4).
It was observed that the increasing level of the shea caterpillar larva meal resulted in decreased feed intake of the birds. The reduced feed intake was particularly observed for broilers on the dietary shea caterpillar meal above 50% replacement for anchovy and this was due to reduced palatability and fibre content of the SCM. Decreased feed intake has been reported to beassociated with high fibre content of feed[25],energy level, feed shape, health, and management practices affect the consumption of feed by table birds [26],the quality of the feed as well as how efficiently the birds utilize the feed [27]
The lower final body weight and total weight gain of broiler growers fed 75% and 100% replacement level of SCM-based diet is attributed to decreased feed intake. Additionally, chitin component of the shea caterpillar larvae could influence nutrient availability due to stronger bond with some nutrients and thus might have compromised nutrient utilisation for body growth. Campus[28]reported that grasshopper meal inclusion at 100% showed higher feed intake and weight gain which was contrary to the present study. In this study, at 100% inclusion of SCM, the feed intake was lowest and the growth rate was relatively slow.

Table 4: Effect of shea caterpillar larvae meal on growth performance of broiler chickens

	Treatments						
Parameters	$SCM^{0\%}$	$SCM^{25\%}$	$SCM^{50\%}$	$SCM^{75\%}$	$SCM^{100\%}$	SEM	P-v
Initial weight, g/bird	720.0	726.7	733.3	720.0	726.7	7.30	0.682
Mean daily feed intake, g/bird	142.14^{a}	146.68^{a}	$135.23b^{c}$	138.71^{b}	131.86^{c}	1.493	<.001
Total feed intake, g/bird	4975	5134	4733	4855	4615	176.9	0.329
Mean daily water intake, ml/bird	329.37^{b}	335.29^{a}	314.91^{c}	316.43^{c}	306.34^{d}	0.742	<.001
Total water intake, ml/bird	11,528	11,735	11,022	11,075	10,722	386.1	0.400
Final body weight, g/bird	2794^{a}	2746^{a}	2778^{a}	2393^{b}	2304^{b}	86.5	0.005
Mean total weight gain, g/bird	2074^{a}	2019^{a}	2045^{a}	1673^{b}	1577^{b}	92.1	0.008
Feed Conversion Ratio	2.50	2.67	2.47	2.94	3.00	0.145	0.080

^{abcd}means values bearing different superscripts in the same row are significantly (*P*=.05) different
g= Gram, P= Probability, SEM=Standard Errors of Means,V=Value

3.5Effect of dietary shea caterpillar larvae meal on haematological parameters of broilers

Haematological parametersof birds fed different inclusion rates of shea caterpillar meal have been presented in Table 5.There was no significant difference (P=.05) among all the haematological indices except red cell distribution width coefficient of variation (RDW-CV). The red cell distribution width coefficient of variation of birds of all the treatments was similar and higher than $SC^{0\%}$, the control. The RDW is used with parameters such as MCH, MCHC and MCV to describe a population of RBC. High RDW has been reported to be associated with nutritional deficiency (Particularly vitamin12 and iron) [29,30] and could indicate that the SCM may be deficient in these nutrients, thus requiring supplementation in the diet for better erythropoietin [7].
However, values obtained for WBC were above the reference range reported by[31]. The white blood cells help to fight infections, defend the body against micro-organisms and produce antibodies in immune response [32]and show enhanced

well-being of the birds [33] as a result of producing high WBC against potential infection threat or by stimulation of T-cells. The haematological result of this study agrees with the work done by [33]who reported that Black soldier fly meal in broiler diets did not show any significant effect on haematological characteristics of the blood except WBC, MCV and platelets. The result is also similar tothe report of [34] and[35] in a study using silkworm caterpillar meal.

Table 5: Effect of shea caterpillar meal on haematological parameters of broiler chickens

Parameters	Treatments					SEM	P-value
	SCM$^{0\%}$	SCM$^{25\%}$	SCM$^{50\%}$	SCM$^{75\%}$	SCM$^{100\%}$		
WBC (10^6/l)	64.70	62.90	58.70	58.5	67.9	6.15	0.787
LYM (10^6/l)	58.00	56.90	54.60	54.4	62.1	5.18	0.824
RBC (10^{12}/l)	1.780	1.97	1.91	1.79	1.957	0.13	0.741
HGB(g/dl)	7.20	7.97	7.90	7.07	7.30	0.38	0.374
MCHC(g/dl)	31.13	31.37	31.17	30.20	30.13	0.48	0.284
MCH (pg.)	40.60	40.53	40.53	39.50	37.73	1.22	0.441
MCV(fl)	130.20	129.2	130.10	131.0	124.9	2.66	0.539
RDW-CV	4.22^b	11.87^a	11.87^a	11.83^a	12.73^a	1.87	0.046
RDW-SD (fl)	67.30	64.40	64.70	65.40	66.1	3.01	0.961
HCT%	23.17	25.37	25.93	23.47	24.20	1.44	0.614
PLT (10^9/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

^{ab} means values bearing different superscripts in the same row are significantly (*P*=.05) different
SEM=Standard Error of Means=Probability,*White Blood Cell (WBC), Lymphocytes(LYM),Red Blood Cell (RBC), Haemoglobin (Hb), Mean Corpuscular Haemoglobin Concentration (MCHC),Mean Corpuscular Haemoglobin (MCH), Mean Corpuscular Volume (MCV), Red Cell Distribution Width Standard Deviation (RDW-SD), Red Cell Distribution Width Coefficient of Variation (RDW-CV), Haematocrit (HCT), Platelets (PLT), Mean Platelets Volume (MPV).platelets Distribution Width (PDW), Mean Platelets Volume (MPV).Percentage (%), L-litre*

3.6Effect of dietary shea caterpillar meal on biochemical parameters of broiler chickens

Table 6 shows the biochemical parameters of birds fed different inclusion rates of shea caterpillar meal. The results showed no significant differences (P=0.05) among all the treatment means except globulin. The globulin values of birds fed SCM0% were similar to SCM$^{25\%}$ and SCM$^{50\%}$but were significantly different from SCM$^{75\%}$ and SCM$^{100\%}$. However, the values for SCM$^{25\%}$, SCM$^{50\%}$, SCM$^{75\%}$ and SCM$^{100\%}$ were also similar. Globulin plays an important role in liver function, blood clotting, and fighting infection.
Birds fed the control diet (SCM$^{0\%}$) had a higher total protein value (33.3 g/l) than all the SCM treatments. Total protein content decreases as shea caterpillar meal inclusion levels increase. This indicates that the control diet may relatively be of good quality than the SCM probably due to stronger bonding with minerals. The values obtained were all higher than the normal reference range of 3.0g/l - 4.9g/l [36]. This showed that probably the various diets were rich in protein and that the shea caterpillar did not adversely affect the total protein content. This finding was in line with [37] who indicated that the inclusion of maggot meal in the diet of broiler chickens did not show a significant effect for all the biochemical parameters.

Table 6: Effect of shea caterpillar meal on blood biochemical indices of broiler chickens

Parameters	Treatments					SEM	P-v
	SCM$^{0\%}$	SCM$^{25\%}$	SCM$^{50\%}$	SCM$^{75\%}$	SCM$^{100\%}$		
Total Protein (g/l)	33.3	27.3	27.0	25.0	22.0	2.49	0.085
Albumin (g/l)	11.67	9.67	10.67	10.67	8.33	0.955	0.217
Globulin (g/l)	21.67^{a}	17.67^{ab}	16.33^{ab}	14.33^{b}	13.67^{b}	1.706	0.050
Cholesterol (mmol/L)	2.70	2.50	2.97	2.67	2.67	0.2082	0.637
Triglyceride(mmol/L)	0.53	0.70	1.23	0.97	0.80	0.1125	0.255
HDL (mmol/L)	1.17	1.07	1.50	1.07	1.10	0.1125	0.096
LDL (mmol/L)	1.30	1.10	1.17	1.17	1.20	0.1164	0.239

^{ab} means values bearing different superscripts in the same row are significantly (*P*=.05) different
SEM=Standard Error of Means, P=Probability,LDL=Low Density Lipoprotein, HDL=High Density Lipoprotein,

3.7Cost-benefit of incorporating shea caterpillar meal in broiler chicken diets

The shea caterpillar meal at varied inclusion level showed significant differences (Table 7). There was a significant difference among the treatment means in terms of cost of feed per bird, selling price of bird and profit on feed alone. Birds fed SCM$^{0\%}$ and SCM$^{25\%}$ had higher feed cost while SCM$^{100\%}$incurred the least, but similar to SCM$^{50\%}$and SCM$^{75\%}$. Birds fed the SCM$^{0\%}$, SCM$^{25\%}$ and SCM$^{50\%}$ had similar selling price which was significantly higher than those fed SCM$^{75\%}$ and SCM$^{100\%}$.The profit on feed of birds fed SCM$^{0\%}$, SCM$^{25\%}$ and SCM$^{50\%}$ was similar and significantly higher than birds fed SCM$^{75\%}$ and SCM$^{100\%}$.But profit on the birds fed SCM$^{25\%}$ and SCM$^{75\%}$ were not different.
The birds fed at 50% SCM, recorded a profit per bird of GH¢38.4 followed by GH¢37.3 for the control (SCM$^{0\%}$) and GH¢35.6 for 25% SCM and GH¢26 for 100% SCM which had the least profit recorded. The inclusion levels at 75% SCM or more reduced the profit margins making such inclusion levels less efficient in commercial poultry production. Hence the best inclusion rate to maximize profit by a farmer should not exceed 50% of the shea caterpillar meal at the finisher phase. 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 expensive compared to the SCM. Oyegoke*et al.*[38] reported that decreasing levels of Westwood (*Cirinaforda)* incorporation in the diets of broiler chickens has led to a reduction of costs of production and therefore, economically suitable to use in diets of broiler chickens. This agreed with the findings of this present study. Similarly,[19]also reported that the replacement of silkworm caterpillar meal with fish meal indicates that cost per kilogram gain reduced as silkworm caterpillar meal inclusion declined at the starter phase suggesting more profit.

Table 7. Cost-benefit effectiveness of using shea caterpillar larvae meal in broiler diets

Description	Treatments					SEM	P-v
	SCM$^{0\%}$	SCM$^{25\%}$	SCM$^{50\%}$	SCM$^{75\%}$	SCM$^{100\%}$		
Per kg feed cost	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	0.33
Cost of feed per bird (GH¢)	20.76^{ab}	20.97^{a}	18.83^{bc}	18.80^{bc}	17.34^{c}	0.650	0.03

Total Wt. Gain kg/bird	2.074^{a}	2.019^{a}	2.045^{a}	1.673^{b}	1.577^{b}	0.0921	0.01
Feed Cost per kg body Wt. Gain	10.07	10.44	9.36	11.26	11.03	0.610	0.17
Selling price of birdGH¢)	58.1^{a}	56.5^{a}	57.2^{a}	46.8^{b}	44.2^{b}	2.35	0.01
Profit on feed alone	37.3^{a}	35.5^{ab}	38.4^{a}	28.0^{bc}	26.2^{c}	2.50	0.01

^{abc}means values bearing different superscript in the same row are significantly (*P*=.05) different**.**
SEM-standard errors of means, Wt. =weight, Kg=kilogram. P=Probability,V=value. One (1) US Dollar=GH₵11.98

4. Conclusion

This study concludes that dietary shea caterpillar larvae meal has a considerable amount of nutrients especially crude protein value and amino acids which can be utilized as an organic feed resource for broiler chickens. Shea caterpillar larvae meal had no detrimental effect on the growth performance and blood profile of broilers.The mean cost of feed per kilogram and mean cost of feed per bird declined gradually with increasing shea caterpillar larvae meal and at a rate of 50% or lower improves profit. SCM at a 50% inclusion rate or below is recommended in broilers diet while further studies involving digestibility of SCM is suggested.

CONSENT

All authors declared that 'written informed' consent was obtained from the approved parties for publication of this article and accompanying images.

ETHICAL APPROVAL (WHEREEVER APPLICABLE)

All authors hereby declare that "Principles of laboratory animal care" (NIH publication No. 85-23, revised 1985) were followed, as well as specific national laws where applicable. All experiments have been examined and approved by the appropriate ethics committee"

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