GROWTH PERFORMANCE AND BLOOD PROFILE OF BROILER CHICKENS FED DIETS CONTAINING GRADED LEVELS OF BLACK SOLDIER FLY LARVAE (HERMETIA ILLUCENS) MEAL AS PARTIAL REPLACEMENT FOR SOYBEAN

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ABSTRACT

Black Soldier fly larvae (Hermetia illucens) has been investigated as one of the promising and sustainable protein sources in poultry nutrition, this is because of its great potential and chemical composition suitable for use in different animal species. In broiler production, the cost of feed covers about 75% of the total production cost and as such, protein is considered the most expensive feed ingredients in broiler diets. Hence, the need to investigate the effect of black soldier fly larvae (BSFL) meal in the diets of broiler chickens in order to cut down the cost of production as low as possible. This research was therefore conducted to evaluate the growth performance, hematological indices and serum biochemistry of broiler chickens fed diets containing different inclusion levels of toasted Black soldier fly larvae (Hermetia illucens). A total number of 200 day old Cobb 500 broiler chicks purchased from Zartech Company in Jos were used for this study. The birds were randomly allotted to five dietary treatments. Forty (40) birds were randomly assigned to each of the dietary treatments having eight (8) birds per replicate in a completely randomized design. Toasted defatted black soldier larva meal (TDBSFLM) was included at graded levels 0, 2.5, 5, 7.5 and 10% each and were designated as T1, T2, T3, T4 and T5 respectively. Experimental diets and water were administered ad libitum at both starter and finisher's phases. All routine management practices were observed such as brooding, vaccination, administration of drugs and proper hygiene throughout the study. The results showed significant ($p<0.05$) difference in all the parameters measured across all the treatments at starter phase. While at finisher phase, all parameters measured were significantly ($p<0.05$) affected by dietary treatment except total feed intake and daily feed intake. A linear increase was observed in the final weight (FW) and total weight gain of birds when BSFLM was increased at the starter phase. These were significantly ($p<0.05$) higher in birds on graded levels of BSFLM than those in the control group (T1). Feed conversion ratio was lower and significantly better in birds fed diets T5 (2.37) containing 10% BSFLM compared to those in other treatment group. However, at finisher phase, significant ($p<0.05$) effects of treatments was observed in most of the parameters measured except total weight gain and daily feed intake. No significant ($p<0.05$) effects of treatments was observed in most of the heamatological parameters measured except basophils and monocytes. Diets containing graded levels of BSFLM has no significant ($p>0.05$) influence on all the serum biochemical indices of birds across the treatments except albumin. It was therefore concluded that toasted defatted black soldier fly larvae meal (TDBSFLM) up to 10% could be incorporated into broiler diets without any adverse effects on the growth performance and health status of the birds.

Keywords: *Black soldier fly larvae, broiler chicken, inclusion levels, growth performance, blood profile.*

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INTRODUCTION

In broiler production, the cost of feed covers about 75% of the total production cost and as such, protein is considered the most expensive feed ingredients in broiler diets. An attempt in alleviating the price of protein for poultry diet will substantially cause a significant financial relief on both the consumers and the producers. (Dar and OductiGowda, 2013, Yueng and Yee, 2002). Currently, the available protein ingridients from both animal and plant source are not sufficient to meet up the future demands (Capper, 2013). This is due to stiff competition between human and animals for these conventional protein such as soybeans, groundnut cake, fish meal etc

Reports by Fashina-Bombata & Balogun (1997) who compare the production cost of larvae and that of fish meal showed that the cost of larvae meal production was 20% lesser than same quantity of fish meal production. Similar report by Ajani et al.(2004) showed that there was 18% and 20% cost reduction when 50% and 100% fish meal was replaced with larvae meal in Tilapia respectively. Since, black Soldier fly larvae (BSFL) has been investigated as one of the promising and sustainable protein sources in poultry production (De marco et al., 2015), because of its great potential in term of its chemical composition suitable for use in different animal species. (Newton et al., 2005b), therefore there is a need to investigate the effects of BSFL on broiler chickens diet in order to keep all protein prices as low as possible. This research was aimed at evaluating the growth performance, hematological indices and serum biochemistry of broiler chickens fed diets containing graded levels of toasted Black soldier fly larvae (Hermetia illucens) meal.

MATERIALS AND METHODS

Description of study area

The research was conducted at the Poultry Unit of Teaching and Research Farm, Department of Animal Science Taraba State University Jalingo. The study area Jalingo is located in the north eastern parts of Nigeria. It lies between latitude 8^0 54 to 9^0 01^0 N and longitude 11^0 22^1 to 11^0 30^1 E. the annual temperature ranges from 39 to 42 ^{o}C, average precipitation of 8.30mm in August and average relative humidity of 62.9% (NOAA, 2023).

Source of Black soldier fly larvae

A total of one hundred (130 kg) dried BSFL were purchased from Afrimash Nigeria Limited in Lagos.

Processing of Black soldier fly larvae

Toasted defatted larvae

The toasting of BSFLM was done using frying pan while fire wood was used as a source of energy during the processing. A batch of one hundred (100 kg) larvae was toasted locally using a modification of Amaefule and Nwagbara (2004) in processing the BSFLM.

The larvae was firmly and constantly stirred using a long metal spoon, the toasting continued until greasy oil-like is seen on the spoon. The toasting stopped and the larvae were immediately crush to expose the fat and abdominal content.

A manual pressing machine was used to extract the free oil using a pressure of 250 bar at 50^o C for 30 minutes at National Research Institute for Chemical Technology (NARICT) Zaria. The toasted BSFLM was then milled and incorporated in the diets.

Chemical analysis of Black soldier fly larvae meal

Black soldier fly larvae meal as test ingredient were grinded into smaller particles. Samples were analyzed at the National Animal Production Research Institute (NAPRI) Laboratory Zaria, Kaduna State for Proximate, composition as described by the AOAC (1990).

Design and Managements of experimental birds

A total of 200 day old Cobb 500 broiler chicks purchased from Zartech Company in Jos were used for this study. The birds were randomly allotted to five dietary treatments. Fourty (40) birds were randomly assigned to each of the dietary treatments which had eight (8) birds per replicate in a completely randomized design. Five (5) experimental diets were formulated, milled toasted BSFL were incorporated into the dietary treatments at inclusion levels of 0, 2.5, 5.0, 7.5 and 10%. The diets were designated as T1 (control), T2, T3, T4 and T5 respectively.

Experimental diets

T1 - Control (0% Toasted/Defatted BSFLM inclusion (TDBSFLM0%)
T2 – Toasted/Defatted BSFLM inclusion (TDBSFLM 2.5%)
T3 - Toasted/Defatted BSFLM inclusion (TDBSFLM 5%)
T4 - Toasted/Defatted BSFLM inclusion (TDBSFLM 7.5%)
T5 - Toasted/Defatted BSFLM inclusion (TDBSFLM 10%

Table 1: Composition of broiler starter diets containing graded levels of the toasted defatted black soldier fly larvae meal (0-4 weeks).

	Treatments				
	T1 (Control) (0%)	T2 (TDBSFLM) (2.5%)	T3 (TDBSFLM) (5%)	T4 (TDBSFLM) (7.5%)	T5 (TDBSFLM) (10%)
Ingredients (%)					
Maize	47.2	47.2	47.2	47.2	47.2
Maize offal	10.00	10.00	10.00	10.00	10.00
Soybean meal	41.00	38.5	36.00	33.5	31.00
Toasted defatted BSFL	0.00	2.5	0.00	0.00	0.00
Toasted defatted BSFL	0.00	0.00	5.00	0.00	0.00
Toasted defatted BSFL	0.00	0.00	0.00	7.5	0.00
Toasted defatted BSFL	0.00	0.00	0.00	0.00	10.00
L-lysine HCL	0.1	0.1	0.1	0.1	0.1
DL-methionine	0.2	0.2	0.2	0.2	0.2
Vit/min premix	0.25	0.25	0.25	0.25	0.25
Bone meal	0.5	0.5	0.5	0.5	0.5
Salt	0.5	0.5	0.5	0.5	0.5
Total	**100**	**100**	**100**	**100**	**100**
Calculated Analysis					
Metabolizable energy (Kcal/kg)	2925.52	2937.28	2949.03	2960.79	2972.54
Crude protein	23.19	23.33	23.48	23.62	23.76
Crude fibre	4.67	4.78	4.89	5.00	5.12
Fat	3.40	3.50	3.61	3.71	3.81
Calcium	0.40	0.39	0.39	0.38	0.38
Phosphorus	0.32	0.31	0.31	0.30	0.29
Lysine	1.38	1.31	1.24	1.16	1.09
Methionine	0.51	0.50	0.48	0.47	0.45

Biomix chick premix per kg of diet: Vit. A 10,000 IU; Vit. D_3 32,000 IU; Vit. E 23,000mg; Vit. K 2,000mg; Vit, $B_1$1, 800mg; Vit B_5 500mg; Pantothenic acid 7,500mg; Vit. B_{12} 150mg; Folic acid 750mg; Biotin 100mg; Choline Chloride 300,000mg; Cobalt 3,000mg; Iodine 1,000mg; Iron 20,000mg; Manganase 40,000mg; Selenium 200mg; Zinc 30,000mg; Antioxidant 1250.

Table 2: Composition of broiler finisher diets containing graded levels of the Toasted defatted black soldier fly larvae meal (5-8 weeks).

	Treatments				
	T1 (Control) (0%)	T2 (TDBSFLM) (2.5%)	T3 (TDBSFLM) (5%)	T4 (TDBSFLM) (7.5%)	T5 (TDBSFLM) (10%)
Ingredients (%)					
Maize	68.30	67.50	67.00	67.00	67.00
Maize offal	0.50	1.80	2.00	2.00	2.00
Soya bean meal	29.20	26.20	23.70	21.20	18.70
Toasted defatted BSFL	0.00	2.50	0.00	0.00	0.00
Toasted defatted BSFL	0.00	0.00	5.00	0.00	0.00
Toasted defatted BSFL	0.00	0.00	0.00	7.50	0.00
Toasted defatted BSFL	0.00	0.00	0.00	0.00	10.00
L-lysine HCL	0.10	0.10	0.10	0.10	0.10
DL-methionine	0.20	0.20	0.20	0.20	0.20
Vit/min premix	0.25	0.25	0.25	0.25	0.25
Bone meal	1.00	1.00	1.00	1.00	1.00
Salt	0.50	0.50	0.50	0.50	0.50
Total	**100**	**100**	**100**	**100**	**100**
Calculated Analysis					
Metabolizable energy (Kcal/kg)	3100.73	3104.71	3104.41	3116.17	3127.92
Crude protein (%)	19.04	19.01	19.13	19.27	19.41
Crude fibre (%)	3.57	3.79	3.91	4.02	4.13
Fat (%)	3.62	3.71	3.80	3.91	4.01
Calcium (%)	0.41	0.40	0.50	0.49	0.78
Phosphorus (%)	0.44	0.39	0.38	0.37	0.48
Lysine (%)	1.08	0.99	0.92	0.85	0.49
Methionine (%)	0.37	0.45	0.44	0.42	0.37

Biomix chick premix per kg of diet: Vit. A 10,000 IU; Vit. D_3 32,000 IU; Vit. E 23,000mg; Vit. K 2,000mg; Vit, $B_1$1, 800mg; Vit B_5 500mg; Pantothenic acid 7,500mg; Vit. B_{12} 150mg; Folic acid 750mg; Biotin 100mg; Choline Chloride 300,000mg; Cobalt 3,000mg; Iodine 1,000mg; Iron 20,000mg; Manganese 40,000mg; Selenium 200mg; Zinc 30,000mg; Antioxidant 1250.

Data collected

Data were collected weekly on the following parameters such as total feed intake (TFI), total weight gain, feed conversion ratio and mortality. Performance of the birds was determined weekly using BWG (g) = (final body weight, g – initial body weight, g), FCR = (total feed intake, g) /final body weight

Hematological and serum biochemical indices of broiler chickens fed diets containing graded levels toasted Black soldier fly larvae.

The selected birds used for blood parameters were fasted overnight before the sample was collected in the morning as reported by Bush (1975). This is to avoid temporary elevation of blood metabolites due to feeding.
At slaughtering point, Ethylene Diamine tetra-acetic acid (EDTA) sample bottle were used to collect blood samples from jugular vein from one bird in each replicate for all the treatment used. This is on the basis of the average final body weight of the chickens at day 56.
For hematological and serum biochemistry parameters, three (3) milliliter of blood sample were collected from identified birds into the EDTA sample bottles. Sample for serology were centrifuged at 3000 rpm for 15 min. The Serum were then used to determine the concentration
of total protein, albumin, triglycerides and uric acid by spectrophotometry using diagnosis standard kits (Wiesbaden, 1940). For hematological parameters, a blood smear was prepared for each bird using a non-coagulated blood. The smear were stained using Giemsa stains and May-Grunwald to determine the hematological parameters.

Statistical analysis:
All data obtained were subjected to analysis of variance using the general linear model procedure of Statistical Analysis System (SAS). Significant differences among treatment means were separated using Tukey, T-test and Duncan multiple range test in SAS (Duncan, 1955).

RESULTS AND DISCUSSIONS

Results

Effect of diets containing different inclusion levels of toasted black soldier fly larvae meal on growth performance of starter broiler chicks (0-4 weeks).

The growth performance of broiler chickens fed different inclusion levels of toasted black soldier larvae meal at starter phase is presented in Table 3. There was significant ($p<0.05$) effects of treatment in all the parameters measured such as final weight (FW), total weight gain (TWG), total feed intake (TFI), daily feed intake (DFI) and feed conversion ratio (FCR). The FW, TWG of birds in T4 and T5 showed higher ($p<0.05$) performance values (1957.85, 1906.85g), (69.92, 68.10g) (808.00, 804.05 g) and (768.00, 762.05g) respectively compared to other treatments ($p<0.05$) at the starter phase.
T4 and T5 had significantly ($p<0.05$) higher TFI (1957.85 and 1906.85) and DFI (69.92 and 68.10) which is comparable to birds in T3 (1849.40 and 66.05), and significantly ($p<0.05$) lower compared to birds fed diet T1 and T2 respectively.
More so, Birds fed T5 demonstrated significantly ($p<0.05$) lower FCR (2.37) compared to other treatments. No mortality was observed in T3, T4 and T5. However, a significantly ($p<0.05$) lower mortality of 0.75 and 0.50% was recorded in T1 and T2 respectively.

Table 3: Effect of diets containing different inclusion levels of toasted Black soldier fly larvae meal on growth performance of broilers starter chicks (0-4 weeks)

	Treatments					
	T1 (TDBSFL0)	T2 (TDBSFL2.5%)	T3 (TDBSFL5%)	T4 (TDBSFL7.5%)	T5 (TDBSFL10%)	SEM
Parameters						
Initial weight (g)	40.00	40.00	37.50	40.00	42.00	1.37
Final weight (g)	545.00^{c}	714.25^{ab}	685.00^{b}	808.00^{a}	804.05^{a}	67.26
Total Weight gain (g)	505.00^{c}	674.25^{ab}	647.50^{b}	768.00^{a}	762.05^{a}	67.26
Total Feed intake (g)	1771.40^{b}	1790.20^{b}	1849.40^{ab}	1957.85^{a}	1906.85^{ab}	94.29
Daily Feed intake (g)	63.26^{b}	63.93^{b}	66.05^{ab}	69.92^{a}	68.10^{ab}	3.36
Feed conversion Ratio	3.25^{a}	2.25^{bc}	2.69^{b}	2.42^{bc}	2.37^{c}	0.06
Mortality (%)	0.75^{a}	0.50ab	0.00^{b}	0.00^{b}	0.00^{b}	0.34

abc Means within the same row bearing the same letter are not significantly different ($p<0.05$), SEM = Standard Error of Means

T1= TDBSFLM 0 - Control with No Inclusion
T2=TDBSFLM 2.5% - Toasted Defatted Black soldier larva meal,
T3=TDBSFLM 5% - Toasted Defatted Black soldier larva meal,
T4=TDBSFLM 7.5%- Toasted Defatted Black soldier larva meal,
5=TDBSFLM 10%- Toasted Defatted Black soldier larva meal,

Effect of diets containing different inclusion levels of toasted Black soldier fly larvae meal on growth performance of finisher broiler birds at (5-8 week)

The performance of broiler chickens fed different inclusion level of Black soldier fly larvae meal (BSFLM) at the finishers phase is presented in Table 4. In all the parameters measured, the values of final weight (FW) (2006.5, 2146.0, 2430.1, 2523.3,2811.1g), total weight gain (TWG) (1461.5,1431.7,1745.1,1715.3,2007.1g), total feed intake (TFI) (3791.91, 3895.68, 3731.3,3890.17,3967.38g), and daily feed intake (DFI) significantly ($P<0.05$) increased with increasing the inclusion levels from 0 to 10% across all the treatments. Similarly, an improved FCR ($p<0.05$) had been observed in bird fed T4 (1.54) and T5 (1.41) compared to other treatments at the finisher's stage. All the growth performance parameters such as the IW, FW, TWG, TFI and DFI significantly increased linearly as the inclusion level increases from 0 to 10%.

Table 4: Effect of diets containing different inclusion level of toasted Black soldier fly larvae meal on growth performance of finisher broiler birds (week 5-8)

	Treatments					SEM
	T1 (TDBSFL0)	T2 (TDBSFL2 .5%)	T3 (TDBSFL5%)	T4 (TDBSFL7.5%)	T5 (TDBSFL10%)	
Parameters						
Initial weight (g)	545.00^{c}	714.25^{ab}	685.00^{b}	808.00^{a}	804.05^{a}	67.26
Final weight (g)	2006.5^{b}	2146.0^{b}	2430.1a^{b}	2523.3^{ab}	2811.1^{a}	246.22
Total Weight gain (g)	1461.5^{b}	1431.7^{b}	1745.1^{ab}	1715.3^{ab}	2007.1^{a}	201.72
Total Feed intake (g)	3791.91	3895.68	3731.30	3890.17	3967.38	137.73
Daily Feed intake (g)	135.46	139.13	133.26	138.93	141.69	4.91
Feed conversion Ratio	1.88^{a}	1.81^{b}	1.53^{bc}	1.54^{c}	1.41^{c}	0.03
Mortality (%)	0.00	0.00	0.00	0.00	0.00	0.00

Means within the same row bearing the same letter are not significantly different ($p<0.05$),
SEM = Standard Error of Means

T1= TDBSFLM 0 - Control with No Inclusion
T2=TDBSFLM 2.5% - Toasted Defatted Black soldier larva meal,
T3=TDBSFLM 5% - Toasted Defatted Black soldier larva meal,
T4=TDBSFLM 7.5%- Toasted Defatted Black soldier larva meal,
5=TDBSFLM 10%- Toasted Defatted Black soldier larva meal

Hematological indices of broiler chickens fed diet containing different inclusion levels of toasted black soldier fly larvae meal (0-8 weeks)

Hematological indices of broiler chickens fed diets containing different inclusion levels of BSFLM are described in Table 5. No significant effects ($p>0.05$) related to inclusion levels were observed in all the hematological parameters measured except for monocytes (MONO). Most of the values of the hematological parameters measured were comparable except for white blood cells (WBC), lymphocytes (LYMP), and neutrophils (NEU). Birds fed T5 showed higher value of WBC (138.38g/l) and NEU (41.63%) compared to other treatments, whereas T1 showed the lowest value of WBC (26.85g/l) and NEU (5.15%). The highest LYMP was observed on birds fed T1 (86.25%) and the lowest value was recorded in birds fed diet T5 (34.58%). The results for mean corpuscular hemoglobin (MCH), mean corpuscular volume (MCV) and mean corpuscular hemoglobin concentration (MCHC) of birds differed non-significantly ($P>0.05$) across all the treatments.

Table 5: Hematological indices of broiler chickens fed diets containing different inclusion levels of toasted black soldier fly larvae meal (0-8 weeks)

	Treatments					SEM
	T1 (TDBSFL0)	T2 (TDBSFL2 .5%)	T3 (TDBSFL5%)	T4 (TDBSFL7.5%)	T5 (BSFL10%)	
Parameters						
Packed cell volume (%)	26.50	27.00	26.00	27.75	25.50	2.97
White blood cell (g/L)	26.85	120.65	59.73	50.00	138.38	57.93
Platelets (g/L)	17.25	15.75	15.75	15.75	17.50	6.68
Red blood cell (L)	2.57	2.72	2.37	2.75	2.55	0.31
Hemoglobin (g/dL)	8.10	8.47	7.50	8.5	8.12	1.10
Lymphocytes (%)	86.25	63.05	49.43	34.58	45.18	33.88
Monocytes (%)	8.60^{ab}	13.00^{a}	5.02^{b}	5.55^{b}	13.20	4.46
Neutrophils (%)	5.15	23.95	20.55	9.88	41.63	23.98
MCH (pg)	31.60	31.32	30.97	30.92	31.65	0.97
MCV (fL)	84.25	84.57	84.42	82.80	80.95	3.13
MCHC (g/dl)	37.52	37.02	36.70	37.42	39.17	1.13

abc = Means within the same row bearing the same letter are not significantly different ($p<0.05$), SEM = Standard Error of Mean.

MCH = Mean Corpuscular Hemoglobin, MCV= Mean Corpuscular Volume
MCHC= Mean Corpuscular Hemoglobin Concentration

T1= TDBSFLM 0 - Control with No Inclusion, T2=TDBSFLM 2.5% - Toasted Defatted Black soldier larva meal,
T3=TDBSFLM 5% - Toasted Defatted Black soldier larva meal,, T4=TDBSFLM 7.5%- Toasted Defatted Black soldier larva meal,, 5=TDBSFLM 10%- Toasted Defatted Black soldier larva meal,

4.2.4: Effect of diets containing varying inclusion levels of toasted Black soldier fly larvae meal on serum biochemical indices of broiler chickens (0-8 weeks)

The effect of diets containing varying inclusion levels of TBSFLM on the serum biochemical indices showed no significant ($p>0.05$) difference in all the parameters measured except for albumin as presented in Table 6. The values of albumin in T1 (15.30 g/l), T2 (16.32g/l), T3 (17.82g/l), and T4 (15.32 g/l) are slightly comparable whereas birds fed diet T5 (14.95 g/l) has significantly ($P<0.05$) lower albumin compared to other treatments groups. Birds fed T4 showed higher value of creatinine and ALAT (30.09 mmol/L and 11.25 IU/L) respectively. The value of serum biochemical parameters in this study were found to be relatively comparable. The value of urea in T1 (0.92 mmol/L) was higher than those of other treatments while the lowest urea value (0.74mmol/L) recorded was in birds fed diet T5.

Table 6: Effect of diets containing graded levels of toasted Black soldier fly larvae on serum biochemical indices of broiler chickens (0-8 weeks).

	Treatments					
	T1 (TDBSFL0)	T2 (TDBSFL2 .5%)	T3 (TDBSFL5%)	T4 (TDBSFL7.5%)	T5 (TDBSFL10%)	SEM
Parameters						
Albumin (g/L)	15.30^{ab}	16.32^{ab}	17.82^{a}	15.32^{ab}	14.95^{b}	1.21
Creatinine (mmol/L)	25.22	20.79	25.65	30.09	25.21	4.46
Urea. (mmol/L)	0.92	0.83	0.83	0.84	0.74	0.19
Cholesterol. (mmol/L)	3.38	3.17	3.60	2.95	3.63	0.96
Total protein (g/L)	38.75	34.37	39.65	31.77	30.32	5.41
Globulin (g/L)	23.10	18.06	22.55	16.45	15.77	4.71
ASAT (IU/L)	21.50	40.25	33.25	25.50	42.25	21.92
ALAT (IU/L)	8.25	8.00	7.75	11.25	7.75	3.02

abc = Means within the same row bearing the same letter are not significantly different ($p<0.05$), SEM = Standard Error of Means, ASAT= Aspartate aminotransferase, ALAT= Alanine aminotransferase

Reference Value = Bowes et al., 1989 and Arzour-Lakehal and Boudebza 2021)

T1= TDBSFLM 0 - Control with No Inclusion, T2=TDBSFLM 2.5% - Toasted Defatted Black soldier larva meal,
T3=TDBSFLM 5% - Toasted Defatted Black soldier larva meal,, T4=TDBSFLM 7.5%- Toasted Defatted Black soldier larva meal, T5=TDBSFLM 10%- Toasted Defatted Black soldier larva meal,

Discussion

Effect of diets containing different inclusion levels of toasted black soldier fly larvae on growth performance of broiler chickens (0-8 weeks).

The inclusion of BSFLM in broiler diet and the concomitant increase in body weight gain at both starter and finisher phases agreed with the work of Anankware (2018), who reported that increasing the level of BSFLM resulted in increased live body weight of the birds than those fed non-BSFLM diet. The result of the body weight, total feed intake and feed conversion ratio obtained in this study was higher than the result of Hwangbo (2009) and Sandi (2022). Improved body weight and weight gain was achieved as a result of the amino acid profile of BSFLM (Sandi, 2022).

It is reported that the body weight of birds fed up to 8% inclusion of BSFLM were higher than those below 5% inclusion level (Moula et al., 2018). Similarly, Moula and Detilleux (2019), revealed that inclusion of BSFL up to 10% improves the growth performance of broiler birds with no adverse effects on the FI and FCR.

In contrast, the report of Biasato et al. (2020) on toasted defatted BSFL proved that inclusion of BSFLM above 15% has negative effects on broiler performance and also reduce the microbial complexity and also the potentials of beneficial bacterial. Furthermore, other studies revealed that inclusion of BSFL from 20-30% significantly lowered the body weight of broiler chickens at week 6 (Moula et al., 2018).

In this present study, zero morbidity and mortality was observed at the finisher's stage. It is suggested that the antioxidant of the BSFLM due to the presence of chitin appears to have a beneficial effects by improving the

immune response of chickens (Sanchez et al., 2017, Oliveira et al., 2008). It was proved that the chitin found in BSFLM exhibits a prebiotics properties as well as bacteriostatic effects on bacterial (Ngo and Kim, 2014).

Hematological indices of broiler chickens fed diet containing different inclusion levels of toasted black soldier fly larvae (0-8 weeks)

The results obtained from this studies showed that varying inclusion levels of BSFLM had no significant effects on the hematological indices ($p>0.05$). This indicated that feeding different inclusion level of BSFLM had no negative effect on the health status of the birds. The result obtained in the current studies showed that all the hematological parameters fell within the within the normal physiological range for broiler chicken (Lumeij, 1997). The normal physiological ranges of hematological indices of broiler chickens are RBC: 2.02- 3.5 $x10^6$ µl, PCV: 22-35%, HGB: 7-13g/dl, MCV (FL): 90-140, MCH (pg): 20-69 and MCHC (g/dl): 20.77-64 (Bounous and Stedman, 2000, Kokore et al., 2021). More so, no group in the current study displayed any sign of toxicity.

A significant effects has been observed in Monocytes. Monocytes plays a role in fighting a foreign material found in the blood. The higher value of monocytes observed in birds fed varying inclusion level of BSFLM indicates zero or less morbidity compared to those with no BSFLM inclusion (Szabo et al., 2005). The RBC transport oxygen from the lungs to the tissue and help in the removal of co_2 from the tissue to the lungs through the hemoglobin (Kaminski et al., 2014).

This studies revealed that inclusion levels of BSFLM did not affect the RBC in all the treatments. The value of PCV was not affected throughout the study. However, PCV is used to envisage sexual maturity in animal and that can be affected by sex and age of the animal (Elagib and Ahmed, 2011). In the current study, the value of WBC in all the treatments was above the normal hematological range. This may be due to the stress which might have elevated the level of WBC when handling the birds during slaughter or when transporting the blood sample to the laboratory. Other authors suggested that the increased level of BSFLM in the treatments diets which may result in increased mineral such as vitamin A. Vitamin A are known to stimulate the immune response which may help to inhibit the growth of some infection such as coccidiosis (Diaz-Gomez et al., 2015). The higher value of WBC in the current study was similar to the findings of Addass et al. (2012).

The lower value of urea observed in T5 indicates a better utilization of protein. It is best explain as the higher the body weight gain the lower the feed conversion ratio. (Attivi et al., 2020).

Liver enzymes ALT (Alanine transaminase) and aspartate transaminase (AST) are key indicators of normal liver function (Ambrosy et al., 2015). Increase in the concentration of this enzymes is an indication of a tissue damaged or liver cell disease. Normal range for the ASAT and ALAT are 23-90 IU/L and 10.17-38.5 IU/L respectively. However, the result for both ASAT and ALAT in the current study fell within the normal physiological range of broiler chickens.

Effect of diets containing graded levels of toasted black soldier fly larvae on serum biochemical indices of broiler chickens (0-8 weeks).

Total protein is an indicator of both physiological and pathological wellbeing of an animal. However, this can be influenced by the quality and quantity of feeds consumed by the animal (Yaman et al., 2000). Albumin as plasma protein is known to synthesis protein during a somatic cell growth (Yaman et al., 2000). In this study no significant effect of treatment was observed in all the biochemical parameters measured except the albumin. Albumin and globulin make up total protein. The value of globulin is obtained as the difference between TP and ALB. The values of ALB and TP ranges as 1.17-2.74g/gl, and 3.0-4.9mg/dl respectively (Meluzzi et al., 1992). A consistent trend was observed for ALB, Urea, TP and GLB when the inclusion level increases.

The slight increase in the concentration of the albumin in T3 could be due to the high nutrient presents in BSFLM which might have improved the nutrients intake of the birds (Al-Qazzaz et al., 2016). The mean value of the urea in this study were lower than that reported by Nwosu and Igugo (2018). However, they were within the normal physiological range. This indicates normal functions of urea cycle and renal functions of birds during the study period.

Creatinine is a waste product obtained when nitrogen undergone metabolism in the muscles. Creatinine measures the function of kidney and high level of creatinine indicates diseased kidney (Peter, 2002). The value for the creatinine obtained in this study showed that all birds across the treatment group had healthy and functional kidneys.

CONCLUSION

From the findings of this study, it was concluded that toasted defatted black soldier fly larva meal (TDBSFLM) up to 10% could be incorporated into broiler diet without any adverse effects on growth performance and the health status of the animals.

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