

International Journal of Advanced Biochemistry Research



ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2025): 5.29
IJABR 2025; 9(12): 1256-1260
www.biochemjournal.com
Received: 21-10-2025
Accepted: 25-11-2025

Dr. Neev J Patel
Department of Animal
Nutrition, College of
Veterinary Science & Animal
Husbandry, Kamdhenu
University, Navsari, Gujarat,
India

Dr. Ajay P Raval
Department of Animal
Nutrition, College of
Veterinary Science & Animal
Husbandry, Kamdhenu
University, Bhuj, Gujarat,
India

Dr. Yogesh D Padheriya
Department of Livestock Farm
Complex, College of Veterinary
Science & Animal Husbandry,
Kamdhenu University,
Navsari, Gujarat, India

Dr. VK Singh
Department of Veterinary
Physiology and Biochemistry,
College of Veterinary Science &
Animal Husbandry,
Kamdhenu University,
Navsari, Gujarat, India

Dr. JK Movaliya
Department of Animal
Nutrition, College of
Veterinary Science & Animal
Husbandry, Kamdhenu
University, Navsari, Gujarat,
India

Dr. PH Katara
Department of Animal
Nutrition, College of
Veterinary Science & Animal
Husbandry, Kamdhenu
University, Navsari, Gujarat,
India

Corresponding Author:

Dr. Neev J Patel
Department of Animal
Nutrition, College of
Veterinary Science & Animal
Husbandry, Kamdhenu
University, Navsari, Gujarat,
India

Effects of *Hermetia illucens* (HI) larvae meal as a partial to complete substitution soybean meal on hematological and blood biochemical parameters in broiler chickens

Neev J Patel, Ajay P Raval, Yogesh D Padheriya, VK Singh, JK Movaliya and PH Katara

DOI: <https://www.doi.org/10.33545/26174693.2025.v9.i12p.6775>

Abstract

The study aimed to investigate the black soldier fly (*Hermetia illucens*; HI) larvae meal inclusion blood on hematological and biochemical parameters in broiler chicken. A total one hundred and sixty a day-old broiler chicks (Vencobb-400 strain) were randomly divided into five groups based on their body weight with 4 replicates (8 chicks/replica) in each for a period of 6 weeks (d 1 to d 42). The five dietary treatments were as CON having basal diet only, while in HI25, HI50, HI75 and HI100 were incorporated with 25, 50, 75 and 100% of *Hermetia illucens* (HI) larvae meal as a partial to complete substitution for soybean meal in the basal diet, respectively. All the major hematological parameters were in normal range and reflected that inclusion of HI larvae meal does not affected the health status of birds. Serum glucose, uric acid, creatinine and triglycerides remained statistically ($p > 0.05$) similar amongst treatment groups. While serum total protein, albumin, globulin quadratically ($p < 0.05$) increased with highest in HI25 and lowest in HI75. Total cholesterol linearly increased ($p < 0.01$) with increasing level of HI larvae meal in the diet. Further, ALT activity quadratically increased with increasing HI larvae meal substitution in the diet although AST activity linearly increased with increase in HI larvae meal in the diet. Total antioxidant capacity (umol/L), superoxide dismutase (ng/mL) and glutathione peroxidase (umol/L) linearly ($p < 0.01$) increased with increasing level of HI larvae meal in the diet. Thus, *Hermetia illucens* larvae meal as a partial substitute of soybean meal up to 25% inclusion have no adverse effects on blood-biochemical parameters and antioxidant status in broiler diet.

Keywords: Black soldier fly larvae, Broiler, *Hermetia illucens*

Introduction

The demand for animal origin protein sources has tremendously increased during last few decades due to growing global human population and limited amount of agricultural land (Barragan-Fonseca *et al.* 2017) [3]. Poultry has the potential to fulfill the demand of protein source because of its high feed conversion efficiency (Ndotono *et al.* 2022) [22]. Poultry production in India has taken a quantum leap in the last few decades and emerged from conventional farming practices to intensive production system. However, feed contributes to about 60-70% of production costs and dietary protein is an important and costly nutrient required for optimum broiler production. Soybean meal (plant origin) are most commonly used ingredients as protein source which is becoming costlier for poultry farmers to afford due to shortage of land for cultivation, human consumption and global cost fluctuation (Ndotono *et al.* 2022) [22].

Insects seems to be a prominent candidate to meet the global challenge of finding new alternative protein sources as it having high protein content, lower space requirement for raising and emission of green house gases (GHGs), high feed conversion efficiency, converting low value organic byproducts into high value proteins (Van Huis and Oonincx, 2017) [30]. In addition, insects can be reared on wide range on organic waste like Fruits and vegetable waste and organic manure (Marono *et al.* 2017) [19]. Various insects have been tested as animal feeds, amongst the most promising species being the black soldier fly (*Hermetia illucens*), yellow mealworm (*Tenebrio molitor*) and common house fly (*Musca domestica*)

(Ndotono *et al.* 2022) ^[22]. Black soldier fly (*Hermetia illucens*) larvae meal inclusion in broilers (Dabbou *et al.* 2018; Schiavone *et al.* 2019) ^[11, 27], ducks (Gariglio *et al.* 2019) ^[15], quails (Cullere *et al.* 2016) ^[10] and partridges (Secci *et al.* 2018) ^[28] ration has been studied earlier by researchers but limited up to partial replacement. As insect meal normally contains chitin as an antinutritional factor, studies regarding complete substitution of HILM with soybean meal in broiler health status are limited. Considering above points, present experiment was carried out to study the effects of substituting conventional protein sources with *Hermetia illucens* larvae meal (HILM) on blood-biochemical parameters in broiler chicken.

Material and method Ethical approval

Present experiment was approved by Institutional Animal Ethics Committee (IAEC) on having approval no. 137/VCN/ANN/2023 dt.26/12/2023.

Experimental diet, design and housing

A total of one hundred and sixty (n=160) day old broiler chick of Vencobb-400 strain day-old broiler chicks (Vencobb-400 strain) were reared from day 01 to day 42 and assigned to five dietary treatments with 32 birds having 4 replicates (8 chicks/replica) in each group. The maize-soybean based diet was used as control without inclusion of partially defatted HI larvae meal while HI25, HI50, HI75 and HI100 were incorporated with 25, 50, 75 and 100% of HI larvae meal as a partial replacement of soybean meal in

the basal diet, respectively. HI larvae meal was reared on fruits and vegetable wastes and substituted at different levels with protein source (soybean meal) of basal diet. Iso-nitrogenous and iso-caloric diets were formulated for 3 phases of pre-starter (0-7 day), starter (7-21 day) and finisher (21-42 day) as per BIS (2007) (Table 1). The entire replica under each group was having facility of individual feeding and watering. *Ad libitum* feed was offered in weighed quantity once in a day at morning 08.00 hrs. *Ad libitum* drinking water was also provided to experimental birds throughout study period. Feed offered, left over and faecal samples were collected and analysed as per procedure of AOAC (2005) ^[2]. All the birds were reared on deep litter housing system having rice husk as a bedding material. Formalin and postassium (KMnO₄) solutions were used to fumigate poultry shed two days prior to arrival of chicks. Each experimental pen was separated using a wire net for partitioning. Each pen was provided with a 60-watt bulb for brooding and brooding temperature was maintained at 34 °C up to first 7 days of age. From 2nd week onwards all the birds were kept under a normal environmental temperature. All the experimental birds were vaccinated for infectious bursal disease and new castle disease.

Chemical composition of feedstuffs

The analyzed chemical composition of HI larvae meal in current study had 94.35% DM, 48.87% CP, 11.88% EE, 17.16% Ash, 5.2% calcium, 0.84% phosphorus and 6.90% chitin.

Table 1: Ingredient composition of experimental feed containing varying levels of HI larvae meal

Ingredients	Pre starter					Starter					Finisher				
	CON	HI ₂₅	HI ₅₀	HI ₇₅	HI ₁₀₀	CON	HI ₂₅	HI ₅₀	HI ₇₅	HI ₁₀₀	CON	HI ₂₅	HI ₅₀	HI ₇₅	HI ₁₀₀
Corn	58.00	58.30	58.90	58.75	58.00	59.00	60.00	60.50	61.86	61.16	63.50	65.40	66.00	66.50	66.50
Soybean Mea	32.50	24.38	16.25	8.13	0.00	32.00	24.00	16.00	8.00	0.00	24.00	18.00	12.00	6.00	0.00
Corn glutenm	4.00	4.00	4.00	4.70	4.75	2.25	2.25	2.10	2.50	2.80	4.95	3.95	3.95	4.36	4.86
Soybean oil	1.50	1.00	0.60	0.00	0.00	2.75	1.75	1.25	0.25	0.00	3.50	2.50	1.90	1.00	0.50
BSFLM	0.00	8.12	16.25	24.38	32.50	0.00	8.00	16.00	24.00	32.00	0.00	6.00	12.00	18.00	24.00
Calcium carbonate	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
DCP	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.10	2.10	2.10	2.10	2.10
Sodium chloride	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27
L-Lysine	0.13	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.12	0.12	0.11	0.11	0.11	0.11	0.11
DL-Methioni	0.16	0.16	0.16	0.16	0.16	0.17	0.17	0.17	0.17	0.17	0.19	0.19	0.19	0.19	0.19
Choline chloride	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Trace mine mixture	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
Toxin binder	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
Total	100.04	99.84	100.04	100.00	99.29	100.04	100.04	99.89	100.65	100.00	100.10	100.00	100.00	100.01	100.01
CP	23.12	23.18	23.26	23.66	23.64	22.03	22.15	22.15	22.51	22.64	20.00	19.66	19.74	20.02	20.02
ME(Kcal/	3035.00	3049.62	3083.00	3099.36	3095.00	3102.00	3095.00	3110.10	3129.38	3143.08	3205.70	3180.40	3183.40	3171.28	3171.28
EE	3.80	4.64	5.59	6.35	7.61	4.87	5.28	6.11	6.55	7.57	5.64	5.74	6.18	6.36	6.36
CF	4.24	4.73	5.23	5.72	6.18	4.19	4.69	5.17	5.70	6.16	3.85	4.24	4.61	4.99	4.99
CA	1.03	1.02	1.01	1.00	0.98	1.03	1.02	1.01	1.00	0.99	1.04	1.03	1.02	1.01	1.01
P	0.79	0.74	0.70	0.65	0.60	0.79	0.74	0.69	0.65	0.60	0.78	0.75	0.71	0.68	0.68

*Mineral-vitamin premix: Vitamin A (retinyl acetate)-12,500 IU; Vitamin D₃ (cholecalciferol)- 3000IU; Vitamin E (DL- α -tocopheryl acetate)-60 IU; Vitamin K (menadione sodium bisulfite)-1.02 mg; Riboflavin- 2.0mg; Pantothenate-8.0mg; Niacin-6mg; Folic acid-0.5 mg; Biotin-0.10 mg; Thiamine-1mg; Vitamin B₁₂-20 mg; Mn-120 mg; Zn-80 mg; Fe-52 mg; Cu-15 mg; I-1.5 mg; Se- 0.4m

Hematology and blood biochemical parameters

Blood was collected at the end of experiment (42 day) from total eight birds per group having 2 birds per replicate. Blood was collected from wing vein in early morning with sterilized needles in two different vials for hematological and biochemical analysis. One tube containing EDTA was used for estimation of hematological assay. Approximately 02 ml of whole blood in EDTA vial was used for hematological

parameters such as hemoglobin (Hb), hematocrit value/packed cell volume (PCV) and total erythrocyte count (TEC) and total leucocyte count (TLC) was done by manually in department of pathology.

Second tube without anticoagulant was used and allowed the blood to clot for 1 hour at room temperature and then centrifuged at 2000 rpm for 15 minutes to obtain serum (Remi R-8M bench top centrifuge). Clear, non-hemolysed

serum collected in tubes was stored at -40°C for various biochemical analysis. Blood biochemical parameters like total protein, glucose, total cholesterol, triglycerides and uric acid were analysed from serum using commercially available analytical kits in spectrophotometer (Model No. 4001/1 Gensys 20), Thermo Fisher Scientific, USA).

Statistical analysis

All the data generated from hematological and biochemical parameters were analysed using IBM SPSS version (20.0) software. One way -Anova (Analysis of variance)

was used and orthogonal polynomial contrast having linear and quadratic effects were tested. Significance was declared at 5% level ($p < 0.05$) and difference amongst means were tested using post-hoc Tukey's HSD test.

Results

Hematological and blood-biochemical parameters

The concentration of Hb, RBCs, WBCs, MCV, PCV, MCH and MCHC lymphocytes and monocytes did not show any significant ($p > 0.05$) changes amongst the treatment groups. (Table 2).

Table 2: Hematological parameters with inclusion of different level HI larvae meal in broiler chickens

Parameters	CON	HI ₂₅	HI ₅₀	HI ₇₅	HI ₁₀₀	SEM	P-Value (C)	P-Value (L)	P-Value (Q)
Hb (g/dL)	9.67	9.26	9.45	9.21	9.74	0.11	0.226	0.182	0.246
RBCs ($\times 10^6/\mu\text{L}$)	2.63	2.67	2.81	2.85	2.80	0.06	0.710	0.219	0.562
PCV (%)	29.50	29.00	29.05	28.44	28.64	0.25	0.722	0.212	0.731
MCV (fl)	113.45	110.40	104.70	100.06	104.97	2.10	0.295	0.071	0.334
MCH (pg)	37.27	39.21	34.14	32.64	36.08	0.96	0.217	0.184	0.406
MCHC (g/dL)	32.87	35.47	32.53	32.52	34.07	0.43	0.120	0.866	0.800
TLCs ($\times 10^3/\mu\text{L}$)	12.41	12.43	12.44	12.94	12.88	0.12	0.461	0.106	0.765
Lymphocytes (%)	68.25	69.37	68.87	70.50	69.62	0.50	0.702	0.289	0.662
Monocytes (%)	4.75	4.87	4.12	4.62	5.00	0.30	0.918	0.911	0.508

Hb: Haemoglobin; RBC: Red blood cell; PCV; Packed cell volume; MCV: Mean corpuscular volume; MCH: Mean corpuscular haemoglobin; MCHC: Mean corpuscular haemoglobin concentration; TLC: Total leucocyte counts C: Combined; L: Linear and Q: quadratic effects.

Serum glucose (mg/dL), creatinine (mg/dL), uric acid (mg/dL) and triglycerides (mg/dL) remained non-significant ($p > 0.05$) between treatment groups (Table 2). Further, serum total protein (g/dL), albumin (g/dL) and globulin (g/dL) quadratically increase in HILM treatment groups with highest values in HI₂₅ and lowest in HI₇₅ groups. Albumin to globulin ratio showed quadratic ($P < 0.05$) effect with HI larvae meal inclusion with highest value in HI₁₀₀ and lowest in CON. Serum total cholesterol

(mg/dl) increased linearly ($p < 0.001$) with increasing levels of HILM in the diet. Serum ALT (U/L) found quadratic increase in treatment groups with highest in HI₂₅ followed by HI₇₅, HI₅₀, HI₁₀₀ and lowest CON. AST (U/L) increased linearly ($p < 0.001$) with increasing levels of HILM in the broiler diet. Total antioxidant capacity (umol/L), superoxide dismutase (ng/mL) and glutathione peroxidase (umol/L) increased linearly with increased level of HI larvae meal inclusion in broilers ration.

Table 2: Blood-biochemical parameters with inclusion of different level HI larvae meal in broiler chicken

Parameters	CON	HI ₂₅	HI ₅₀	HI ₇₅	HI ₁₀₀	SEM	P-Value (C)	P-Value (L)	P-Value (Q)
Glucose (mg/dl)	218.02	220.31	204.63	225.30	214.21	4.87	0.751	0.941	0.820
Total Protein (g/dl)	3.72 ^{ab}	3.81 ^a	3.61 ^{ab}	3.09 ^c	3.26 ^{bc}	0.99	0.000	0.001	0.021
Albumin (g/dl)	1.41 ^{ab}	1.47 ^a	1.46 ^a	1.35 ^c	1.37 ^{bc}	0.04	0.005	0.476	0.020
Globulin (g/dl)	2.31 ^a	2.34 ^a	2.15 ^{ab}	1.74 ^b	1.72 ^b	0.08	0.002	0.152	0.001
Albumin: Globulin	0.61 ^b	0.63 ^b	0.67 ^{ab}	0.77 ^a	0.79 ^a	0.03	0.248	0.989	0.031
Uric Acid (mg/dl)	5.71	5.62	5.24	5.28	5.69	0.17	0.247	0.600	0.092
Creatinine (mg/dl)	0.40	0.43	0.39	0.43	0.46	0.08	0.210	0.129	0.240
Total Cholesterol (mg/dl)	90.48 ^b	95.33 ^b	100.53 ^{ab}	106.14 ^{ab}	128.68 ^a	3.99	0.017	0.001	0.239
Triglyceride (mg/dl)	110.48	105.81	101.42	116.93	108.42	5.37	0.930	0.716	0.415
ALT (U/L)	3.08 ^b	4.65 ^a	3.98 ^{ab}	4.25 ^a	3.72 ^{ab}	0.23	0.002	0.823	0.137
AST (U/L)	175.25 ^d	190.37 ^{cd}	230.62 ^b	216.37 ^{bc}	259.50 ^a	34.98	0.000	0.000	0.952
TAC (umol/L)	0.98 ^b	1.15 ^a	1.21 ^a	1.16 ^a	1.22 ^a	0.02	0.006	0.002	0.074
SOD (ng/mL)	1.03 ^b	1.18 ^{ab}	1.31 ^{ab}	1.65 ^a	1.41 ^{ab}	0.07	0.097	0.021	0.346
GSH-Px (umol/L)	0.77 ^b	0.85 ^a	0.86 ^a	0.87 ^a	0.84 ^a	0.01	0.026	0.031	0.011

^{abc}Means with different superscript in a row differ significantly TAC: Total antioxidant capacity; SOD:

Superoxide dismutase; GSH-PX: Glutathione peroxidase C: Combined; L: Linear and Q: quadratic effects.

Discussion

All the hematological and blood biochemical parameters obtained in present study were in normal range and results revealed that HI larvae meal inclusion did not affected overall health status of experimental birds (Dabbou *et al.* 2018; Kim *et al.* 2022) [11, 18]. The Hb, RBCs, WBCs, MCV, PCV, MCH and MCHC, lymphocytes and monocytes values did not show any significant ($p > 0.05$) changes amongst the treatment groups. Hemoglobin (g/dl) level remained similar

($p > 0.05$) amongst treatment group. Normally, Hb level is dependant on numbers of erythrocytes and oxygen levels in the blood (Irawan *et al.*, 2020) [16]. Higher value of hemoglobin indicates a better nutrient supply in the body system of the broiler chickens (Alabi *et al.*, 2013) [1]. No change in overall hematological parameters was found by many researchers like, Kim *et al.* (2021) [17]; Dabbou *et al.* (2018) [11] Bellezza *et al.* (2021) [5], Bongiorno *et al.* (2022) [6], Tykałowski *et al.* (2023) [29] in broiler chickens indicates

no overall adverse effect of HILM inclusion of hematological parameters.

Serum glucose (mg/dL), uric acid (mg/dL) and triglycerides (mg/dL) level remained statistically ($P>0.05$) similar amongst treatment groups. Similar findings were observed by various authors (Dabbou *et al.*, 2018; Marono *et al.* 2017; Kim *et al.* 2022) ^[11, 19, 18]. Serum total protein (g/dL), albumin (g/dL), globulin (g/dL) quadratically increase in HILM treatment groups with highest values in HI25 and lowest in HI75 groups. Similar findings were observed by Chen *et al.* (2022) ^[8] who found quadratic increase in total protein (g/dL), albumin (g/dL), globulin (g/dL) in HILM substituted groups at higher levels. In contrast, Marono *et al.* (2017) ^[19], Schiavone *et al.* (2018) ^[26], Dabbou *et al.* (2021) ^[12], Kim *et al.* (2021) ^[17], Bongiorno *et al.* (2022) ^[6], Mat *et al.* (2022) ^[20], and Tyakalowski *et al.* found non-significant serum total protein between treatment groups. Further, according to Gariglio *et al.* (2019) ^[15] similar total protein levels between groups indicative of a similar dietary protein bioavailability in the birds. Serum total protein, albumin and globulins are important measures and useful to assess body condition of poultry (Piotrowska *et al.*, 2011) ^[24] as plasma protein plays a key role in body homeostasis maintenance. Albumin serves as the important source of amino acids for protein synthesis (Filipovic *et al.*, 2007) ^[14]. Present findings regarding globulin provided an overall increase of circulating immunoglobulins and showed stronger disease resistance response in larvae-feeding birds up to 25% HILM inclusion (Marono *et al.*, 2017) ^[19]. It was also reflected with lower mortality in HILM substituted group ($n=1$) as compared to CON ($n=1$). However, Gariglio *et al.* (2019) ^[15] found negative effects of higher level of HILM inclusion in Muscovy ducks as it may compromise auto immunity of the birds due over production of globulin. Serum uric acid (mg/dL) and serum creatinine (mg/dL) remained statistically non-significant between treatment groups. Supporting to our findings, Marono *et al.* (2017) ^[19], Dabbou *et al.* (2021) ^[12], Kim *et al.* (2021) ^[17], Bellezza *et al.* (2021) ^[5], Mat *et al.* (2022) ^[20] and Bongiorno *et al.* (2022) ^[6] found similar uric acid and creatinine levels in HILM substituted birds. In contrast, Tyakalowski *et al.* (2023) found increased uric acid levels with increasing level of HI larvae meal. Uric acid is major nitrogenous end product which represents protein catabolism in broilers (Tyakalowski *et al.*, 2023). Creatinine is a byproduct of phosphocreatine breakdown in skeletal muscle and an important indicator of protein metabolism in birds (Piotrowska *et al.*, 2011) ^[24]. Further, serum creatinine levels are associated with muscle mass, age, physical activity and diet (Rajman *et al.*, 2006) ^[25]. Non-significant uric acid and creatinine are indicative that insect meal at higher inclusion levels does not affect kidney functions. Serum total cholesterol (mg/dL) increased linearly ($p<0.01$) with increasing levels of HILM in the diet while triglycerides (mg/dL) remained unaffected ($p>0.05$) between treatment groups. Present study was supported by Mbhele *et al.*, (2019) ^[21], Dabbou *et al.* (2018) ^[11], Dabbou *et al.* (2021) ^[12], Bellezza *et al.* (2021) ^[5] and Mat *et al.* (2022) ^[20]. In present study, the diet was isocaloric in nature and HILM used was partially defatted so, the dietary lipids might have contributed to circulating lipid. In contrast, Gariglio *et al.* (2019) ^[15] and Kim *et al.* (2021) ^[17] found linear decrease in total cholesterol and triglycerides level with increasing level of HI larvae meal inclusion in broilers due to chelating effect of chitin in the HI larvae meal (El-Gobary *et al.*, 2016) ^[13]. Commercial chitin has also reported to decrease the lipid absorption by binding to lipids which lowers plasma cholesterol (Bovera *et al.*, 2018 and Marono *et al.*, 2017) ^[7, 19]. Chitosan, a chitin derivative, has a high anion-

exchange capacity and consequently has a bile acid binding capacity which may disturb the enterohepatic circulation and enhance fecal triglycerides (Bedford and Gong, 2018) ^[4]. Serum ALT (U/L) found quadratic increase in treatment groups with highest in HI25 followed by HI75, HI50, HI100 and lowest CON. AST (U/L) increased linearly ($p<0.001$) with increasing levels of HILM in the broiler diet. Similar findings were observed by Chen *et al.* (2022) ^[8] significant increase in AST activity with partial to complete substitution of HI larvae oil in broilers. In contrast, Tyakalowski *et al.* found increasing level (up to 100%) of HI larvae meal significantly reduced AST level in broilers and found no effect on ALT activity. Increased ALT and AST activity are generally associated with liver damage. Improvement in overall antioxidant status of broiler birds substituted with HI larvae meal was observed by another scientist like Chen *et al.* 2022; Chu *et al.* 2020 and Dabbou *et al.* 2021 ^[9, 8, 12]. Total antioxidant capacity increased linearly ($p<0.002$) with increased level of HI larvae inclusion in broilers. Dabbou *et al.* (2018) ^[11] also supported present findings and found that total antioxidant capacity increased with HILM in treatment groups. Kim *et al.* (2021) ^[17] also found that black soldier fly oil had improved the total antioxidant capacity of broiler chickens by increasing plasma TAC levels. Superoxide dismutase also found linear increase ($p<0.021$) with increasing level of HI larvae meal in diet. The present findings are supported by Chu *et al.* (2020) ^[9] and Chen *et al.* (2022) ^[8] when full-fatted HI larvae and HI larval oil was included in the broiler diet, respectively. Glutathione peroxidase found linear ($p<0.031$) increase with increasing level of HI larvae meal in the broiler diet. Similar findings were supported by Dabbou *et al.* (2018) ^[11] and Chu *et al.* (2020) ^[9], when partially defatted and full fatted larvae meal in the broilers. Black soldier fly contains a proportion of medium chain fatty acids like lauric acid (not measured here) and antioxidant peptide providing important antioxidant ability and antibacterial activity (Chu *et al.* 2020) ^[9]. Lauric acid also helps to enhance intestinal immune ability due to its antioxidant and prebiotic properties (Park *et al.* 2014; Zhu *et al.* 2020; Chen *et al.* 2022) ^[23, 31, 8]. Further, free radical scavenging effect of a chitin plays a vital role in providing antioxidant capacity by preserving cellular structural integrity and biological functions (Gariglio *et al.* 2019) ^[15]. BSF insect meal provides dietary tocopherols, which further contributes to increase glutathione peroxidase activity in insect meal groups (Secci *et al.* 2018) ^[28].

Conclusion

HI larvae meal as a partial to complete substitution of soybean meal in broiler chicken diet did not affect overall hematological and blood-biochemical parameters with improvement in overall antioxidant status of broiler birds. Further, research with higher substitution rate at different agroclimatic conditions will provide better insight about insect meal feeding in tropical conditions in poultry industry.

References

1. Alabi JO, Arigbede M, Ng'ambi J, Norris D, Shiawoya E, Onyekachi S. Effects of urea-treated fibrous diets on nutrient intake, digestibility, performance and haematological parameters of Yankasa rams. Tropical Animal Health and Production. 2013;45(6):1349-1355.

2. AOAC. Official methods of analysis. 18th ed. Washington (DC): Association of Official Analytical Chemists; 2005.
3. Barragan-Fonseca KB, Dicke M, van Loon JJ. Nutritional value of the black soldier fly (*Hermetia illucens* L.) and its suitability as animal feed: a review. *Journal of Insects as Food and Feed*. 2017;3(2):105-120.
4. Bedford A, Gong J. Implications of butyrate and its derivatives for gut health and animal production. *Animal Nutrition*. 2018;4(2):151-159.
5. Bellezza Oddon S, Biasato I, Imarisio A, Pipan M, Dekleva D, Colombino E, *et al.* Black soldier fly and yellow mealworm live larvae for broiler chickens: effects on bird performance and health status. *Journal of Animal Physiology and Animal Nutrition*. 2021;105(1):10-18.
6. Bongiorno V, Gariglio M, Zambotto V, Cappone EE, Biasato I, Renna M, *et al.* Black soldier fly larvae used for environmental enrichment purposes: effects on growth, slaughter performance, and blood chemistry of chickens. *Frontiers in Veterinary Science*. 2022;9:1-13.
7. Bovera F, Loponte R, Pero ME, Cutrignelli MI, Calabrò S, Musco N, *et al.* Laying performance, blood profiles, nutrient digestibility and inner organ traits of hens fed an insect meal from *Hermetia illucens* larvae. *Research in Veterinary Science*. 2018;120:86-93.
8. Chen X, Jin J, Hou F, Song B, Li Z, Zhao Y. Effects of black soldier fly larvae oil on growth performance, immunity, antioxidant capacity and intestinal function of broilers. *Journal of Applied Poultry Research*. 2022;31(4):1-16.
9. Chu X, Li M, Wang G, Wang K, Shang R, Wang Z, *et al.* Evaluation of low inclusion of full-fatted *Hermetia illucens* larvae meal for layer chickens. *Frontiers in Veterinary Science*. 2020;7:585843.
10. Cullere M, Tasoniero G, Giaccone V, Miotti-Scapin R, Claeys E, De Smet S, *et al.* Black soldier fly as dietary protein source for broiler quails. *Animal*. 2016;10(12):1923-1930.
11. Dabbou S, Gai F, Biasato I, Capucchio MT, Biasibetti E, Dezzutto D, *et al.* Black soldier fly defatted meal as a dietary protein source for broiler chickens. *Journal of Animal Science and Biotechnology*. 2018;9(1):49.
12. Dabbou S, Lauwaerts A, Ferrocino I, Biasato I, Sirri F, Zampiga M, *et al.* Modified black soldier fly larva fat in broiler diet. *Animals*. 2021;11(6):1837.
13. El-Gobary G, El-Zoghby AF, El-Sheikh N, Hamdy AS. Effect of chito-oligosaccharide as feed additive on egg production of laying hens. *Egyptian Journal of Chemistry and Environmental Health*. 2016;2(2):183-194.
14. Filipovic N, Stojevic Z, Milinkovic-Tur S, Ljubic BB, Zdelar-Tuk M. Changes in blood serum proteins of chickens during fattening. *Veterinarski Arhiv*. 2007;77(4):319-326.
15. Gariglio M, Dabbou S, Crispo M, Biasato I, Gai F, Gasco L, *et al.* Effects of dietary inclusion of partially defatted black soldier fly meal on blood chemistry and tissue histology of Muscovy ducks. *Animals*. 2019;9(6):307.
16. Irawan AC, Astuti DA, Wibawan IW, Hermana W. Supplementation of black soldier fly (*Hermetia illucens*) on productivity and blood hematology. *Jurnal Ilmu-Ilmu Peternakan*. 2020;30(1):50-68.
17. Kim B, Bang HT, Jeong JY, Kim M, Kim KH, Chun JL, *et al.* Effects of dietary supplementation of black soldier fly larvae oil on broiler health. *Journal of Poultry Science*. 2021;58(4):222-229.
18. Kim B, Kim HR, Baek YC, Ryu CH, Ji SY, Jeong JY, *et al.* Evaluation of microwave-dried black soldier fly larvae meal in broiler diets. *Journal of Insects as Food and Feed*. 2022;8(9):977-988.
19. Marono S, Loponte R, Lombardi P, Vassalotti G, Pero ME, Russo F, *et al.* Productive performance and blood profiles of laying hens fed *Hermetia illucens* larvae meal. *Poultry Science*. 2017;96(6):1783-1790.
20. Mat K, Kari ZA, Rusli ND, Rahman MM, Harun HC, Al-Amsyar SM, *et al.* Effects of black soldier fly larvae meal on broiler production. *Saudi Journal of Biological Sciences*. 2022;29(2):809-815.
21. Mbhele FG, Mnisi CM, Mlambo V. Nutritional evaluation of insect meal as protein source for jumbo quails. *Sustainability*. 2019;11(23):6592.
22. Ndotono EW, Khamis FM, Bargul JL, Tanga CM. Gut microbial communities of broilers fed black soldier fly larvae-based diets. *Microorganisms*. 2022;10(7):1351.
23. Park K, Choi J, Nam S, Kim S, Kwak K, Lee S, *et al.* Antioxidant activities of black soldier fly (*Hermetia illucens*). *Journal of Sericultural and Entomological Science*. 2014;52(2):142-146.
24. Piotrowska A, Burlikowska K, Szymeczko R. Changes in blood chemistry of broiler chickens during fattening. *Folia Biologica (Krakow)*. 2011;59(3-4):183-187.
25. Rajman M, Juráni M, Lamosova D, Macajova M, Sedlackova M, Kostal L, *et al.* Effects of feed restriction on plasma biochemistry in chickens. *Comparative Biochemistry and Physiology Part A*. 2006;145(3):363-371.
26. Schiavone A, Dabbou S, De Marco M, Cullere M, Biasato I, Biasibetti E, *et al.* Black soldier fly larva fat as alternative fat source in broiler diets. *Animal*. 2018;12(10):2032-2039.
27. Schiavone A, Dabbou S, Petracci M, Zampiga M, Sirri F, Biasato I, *et al.* Black soldier fly defatted meal and broiler meat quality. *Animal*. 2019;13(10):2397-2405.
28. Secci G, Moniello G, Gasco L, Bovera F, Parisi G. Barbary partridge meat quality affected by insect meals. *Food Research International*. 2018;112:291-298.
29. Tykałowski B, Koncicki A, Kowalczyk J, Śmiałek M, Bakuła T, Murawska D, *et al.* Impact of full-fat *Hermetia illucens* larvae meal on broiler health. *Journal of Veterinary Research*. 2023;67(2):197-206.
30. Van Huis A, Oonincx DG. Environmental sustainability of insects as food and feed. *Agronomy for Sustainable Development*. 2017;37(5):43.
31. Zhu D, Huang X, Tu F, Wang C, Yang F. Antioxidant peptides from black soldier fly larvae. *Journal of Food Biochemistry*. 2020;44(5):e13186.