Evaluation of Westwood Larva (*Cirina forda*) Meal as feed for Broiler Production

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Abstract

One hundred and ninety eight (198) day old broiler chicks of Arbor Acre strain were used to determine the performance, nutrients digestibility, serum enzymes and organoleptic properties of broiler chickens fed graded levels of Westwood larva meal (WLM) as a replacement for local fishmeal (*Schilbe mystus*) and imported fishmeal. Six experimental diets were fed in a completely randomized design. Diet without fishmeal served as Negative Control (NC). Diet containing 100% imported fishmeal (IF) was the Positive Control (PC). Westwood larva meal replaced imported fishmeal as well as *Schilbe mystus* fishmeal (SMF) at 50% and 100% in the other four diets. Data were collected on performance, serum enzymes and organoleptic properties. Data were analyzed using one-way analysis of variance. The WLM, IF and SMF respectively contained 42.7%, 60.9% and 54.6% crude protein. Westwood Larva meal showed high lysine (7.05%) and low methionine (0.91%) content. The final body weight (FBW) and average daily gain (ADG) of broiler chicken fed 50% WLM as replacement for SMF were significantly higher than those fed 100% SMF. Feeding 100% WLM to broiler chicken caused elevated level of serum alanine aminotransferase (ALT). Highest ether extract, crude fibre and nitrogen-free extract digestibility were noticed in broilers fed 100% SMF, 100% WLM and NC, respectively. Thigh meat of broilers fed diet 100% WLM (T6) had the best colour, flavour, juiciness and acceptability than those fed other diets.

It is concluded that WLM could optimally replace SMF and IF in broilers diet at 50% to support maximum growth rate.

Key words: Insect larva meal, fishmeal, broiler, growth performance, serum enzymes, meat

Introduction

The availability and cost of feed are of critical importance to livestock and aquaculture development (FAO, 2007). Livestock feed contributes 60–80% of total production cost with the protein ingredient accounting for about 70% of the total feed cost (Hasan, 2007; Lucas and Southgate, 2012; Abu et al., 2015). The major protein ingredients used in livestock production are fishmeal and soybean meal, utilising 10% (Van Huis, 2013) and over 85% (Riaz,

2005) of the total world fish and soybean production, respectively. Fishmeal is a high-quality animal protein source that is getting expensive due to increased demand resulting from the expansion in the livestock industry (Amao et al., 2010). The exorbitant prices and adulteration of imported fishmeal in recent years have necessitated the need for a local substitute, which is less expensive and can support optimal performance of broiler chickens. Available options of low prices and good nutritional profile include local fish species, edible insects, and animal by-products.

Records of 14 edible insects have been established in Southwestern Nigeria and the list includes *Cirina forda* (Banjo et al., 2006) which is also known as Westwood larva. This insect is also called Pallid emperor moth and belongs to the class "*Insecta*", order "*Lepidoptera*" and family "*Saturnidae*". Westwood larva can be harvested in the wild from the shea butter tree (*Vittelleria paradoxa*) an economically important tree that belongs to the family *Sapotacea* (Amao et al., 2010). It has been shown that the larva of *Cirina forda* has the potential to supply substantial amounts of proteins, minerals, and polyunsaturated fatty acids in the diets which are usually deficient in animal protein (Akinnawo and Ketiku, 2000). *Cirinia forda* is rich in crude protein ranging between 46.5 and 79.6% (Malaisse and Parent, 1980), and has been used as a supplementary diet in place of the commonly used fishmeal in various compounded diets for aquacultural and poultry organisms like *Clarias gariepinus* and even domestic fowls (Akintola and Oyegoke, 2002; Oyegoke et al., 2006). Currently, there are significant knowledge gaps in the field of edible insect production and use in livestock feed, particularly in Nigeria where insects are considered as a traditional food for man. This experiment therefore assessed the performance, nutrient digestibility, organoleptic assessment and serum enzymes analysis of broiler chicken fed graded levels of Westwood larva meal as a replacement for local fishmeal (*Schilbe mystus*) and imported fishmeal.

Materials and methods

Site of the Experiment

The experiment was conducted at Broiler Unit, Teaching and Research Farm of Ladoke Akintola University of Technology, Ogbomoso, Oyo State, Nigeria.

Source and Preparation of Westwood Larva Meal

Westwood larva (*Cirina forda*) harvested from the wild were purchased at a fish market Idi Ape in Ilorin, Kwara state Nigeria. The Westwood larva was briefly stored to defecate (empty gut content) and parboiled to render them lifeless and toughen the larva. The Westwood larva was later sundried to a constant weight and then ground using a hammer mill to get a Westwood larva meal.

Experimental Animals and Management

One hundred and ninety-eight (198) day-old broiler chicks of Arbor Acre strain were used for the experiment. The birds were randomly divided into six (6) dietary treatment groups, in which there were three replicates of eleven (11) birds each making thirty three (33) birds per treatment. The six experimental diets (Table 1) were formulated for the study. Westwood larva meal was used as a replacement for imported fishmeal (TripleNine® fishmeal) and local fishmeal (*Schilbe mystus*) at 50% and 100% (w/w). Diet in T1 did not contain fishmeal (served as Negative control), diet in T2 contained 100% Imported Fishmeal (IF) which served as Positive control. Diet in T3 contained 100% *Schible mystus* fishmeal and diet in T4 contained 50% IF and 50% WLM. Diet in T5 contained 50% SMF and 50% WLM. Finally, diet in T6 contained 100% WLM. The ingredient compositions of broiler starter and finisher diets are presented in Tables 1 and 2 respectively. The experiment lasted for six weeks (42 days) with two growth phases. Starter and finisher phases were each three weeks. The chicks were brooded with an artificial supply of heat for two weeks. Throughout the experiment, water and feed were supplied on *ad libitum* basis. Normal routine management, vaccination, and medication were observed. The number of mortality was recorded throughout the experiment.

Chemical Analysis

The proximate analysis and amino acid profile determination of Westwood larva meal was done using the methods of AOAC (2000).

Data Collection

At the beginning of the experiment, the live weight of the chicks was taken, denoted as Initial Live Weight (ILW) and subsequently, body weights of experimental broilers were taken weekly till the end of the experiment. Final Live Weight (FLW) was the live weight of the birds taken at the end of each growth phase. Weight gain is a difference between the initial live weight and final live weight in each growth phase.

Weight Gain (WG) = Final Live weight – Initial Live weight.

The feed supplied to the birds was weighed at the beginning of the week and leftover of the feed taken at the end of each week to determine the feed intake. The individual feed intake was calculated by dividing the feed intake by the number of birds in each replicate. The Feed Intake (FI) was calculated as FI = Feed Offered – Feed Leftover.

Feed Conversion Ratio (FCR) was calculated at the end of the experiment by dividing feed intake by weight gain. Records of mortality were observed and livability was the percentage of

Table 1. Ingredient composition of broiler starter diets (%)

Ingredient (%)	T1 NC	T2 100% IF PC	T3 100% SMF	T4 50% IF 50% WLM	T5 50% SMF 50% WLM	T6 100% WLM
Maize	56.00	56.00	56.00	56.00	56.00	56.00
Maize bran	1.10	1.10	1.10	1.10	1.10	1.10
Soybean meal	39.00	34.50	34.50	34.50	34.50	34.50
Fishmeal	0.00	4.50	0.00	2.25	0.00	0.00
SMF	0.00	0.00	4.50	0.00	2.25	0.00
WLM	0.00	0.00	0.00	2.25	2.25	4.50
Fixed ingredients	3.65	3.65	3.65	3.65	3.65	3.65
Premix*	0.25	0.25	0.25	0.25	0.25	0.25
Total	100	100	100	100	100	100
Calculated Analysis						
Energy (Kcal/kg)	3003.54	3010.74	3026.45	3010.74	3018.59	3010.74
Crude Protein (%)	21.54	22.89	21.79	22.73	22.18	22.58
Av. P (%)	0.59	0.69	0.56	0.69	0.63	0.69
Calcium (%)	1.17	1.43	1.16	1.44	1.30	1.44
Lysine (%)	1.38	1.45	1.25	1.45	1.35	1.45
Methionine (%)	0.58	0.64	0.56	0.64	0.58	0.64

**A kilogram of diet contained the following vitamins and trace minerals – 12500 IU Vitamin A, 2500 IU Vitamin D 3, 40 mg Vitamin E, 2 mg Vitamin K 3, 3 mgVitamin B 1, 5.5 mg Vitamin B 2, 55 mg Niacin, 11.5 mg Calcium Pantothenate, 5 mg Vitamin B 6, 0.025 mg Vitamin B 12, 500 mg Choline chloride, 1 mg Folic acid, 0.08 mg Biotin, 120 mg Manganese, 100 mg Iron, 80 mg Zinc, 8.5 mg Copper, 1.5 mg Iodine, 0.3 mg Cobalt, 0.12 mg Selenium, 0.12 mg Antioxidant.*

Fixed ingredients = 2% bone meal, 1% limestone, 0.25% salt, 0.15% lysine and 0.25% methionine. Av. P = Available phosphorus

Table 2. Ingredient composition of broiler finisher diets (%)

Ingredient	T1 NC	T2 100% IF PC	T3 100% SMF	T4 50% IF 50% WLM	T5 50% SMF 50% WLM	T6 100% WLM
Maize	40.00	40.00	40.00	40.00	40.00	40.00
Maize bran	23.10	26.10	26.10	26.10	26.10	26.10
Soybean meal	33.00	27.00	27.00	27.00	27.00	27.00
Fishmeal	0.00	3.00	0.00	1.50	0.00	0.00
SMF	0.00	0.00	3.00	0.00	1.50	0.00
WLM	0.00	0.00	0.00	1.50	1.50	3.00
Fixed ingredients	3.65	3.65	3.65	3.65	3.65	3.65
Premix*	0.25	0.25	0.25	0.25	0.25	0.25
Total	100	100	100	100	100	100
Determined Analysis						
Energy (Kcal/kg)	3204.76	3309.63	3204.45	3203.03	3014.85	3222.96
Crude Protein (%)	19.60	23.45	19.25	20.65	17.50	18.90
Av. P (%)	0.55	0.61	0.52	0.61	0.56	0.61
Calcium (%)	1.16	1.33	1.15	1.33	1.24	1.33
Lysine (%)	1.22	1.20	1.06	1.20	1.13	1.20
Methionine (%)	0.56	0.58	0.53	0.58	0.56	0.58

**A kilogram of diet contained the following vitamins and trace minerals – 12500 IU Vitamin A, 2500 IU Vitamin D 3, 40 mg Vitamin E, 2 mg Vitamin K 3, 3 mgVitamin B 1, 5.5 mg Vitamin B 2, 55 mg Niacin, 11.5 mg Calcium Pantothenate, 5 mg Vitamin B 6, 0.025 mgVitamin B 12, 500 mg Choline chloride, 1 mg Folic acid, 0.08 mg Biotin, 120 mg Manganese, 100 mg Iron, 80 mg Zinc, 8.5 mg Copper, 1.5 mg Iodine, 0.3 mg Cobalt, 0.12 mg Selenium, 0.12 mg Antioxidant.*

Fixed ingredients = 2% bone meal, 1% limestone, 0.25% salt, 0.15% lysine and 0.25% methionine. Av. P = Available phosphorus

live birds that survived in each replicate group which was calculated as:

$$\text{Livability \%} = \frac{\text{number of live birds X 100}}{\text{number of birds/replicate}}$$

Nutrient Digestibility of the Experimental Diets

Nutrient digestibility trial was carried out at the 5th week of the experiment for 5 days. Six birds from each treatment were randomly selected for the trial. The birds were housed in individual battery cage cells for total faecal collection. An allowance of 80% of their daily feed intake was used for the trial. A pre-adjustment period of 2 days was observed while the last three days, faecal collection was done using polythene bags placed at the bottom of the cage cells. The faecal samples collected were oven-dried to a constant weight, bulked and representative samples collected for proximate analysis.

Serum Enzymes Parameters

Six blood samples for each treatment were collected on the 35th day of the study. Blood samples were drawn from the jugular vein of the birds close to the neck using a 5 ml Syringe for serum enzymes which were collected in bottles that did not contain any anticoagulant. Blood samples collected were analyzed for serum enzymes: Alanine aminotransferase (ALT) using IFCC (1986), Aspartate aminotransferase (AST) using IFCC (1986), Alkaline phosphatase (ALP) using Reitman and Frankel (1957). Total protein and Globulin using Tietz (1995) and (Doumas et al., 1971), respectively.

Organoleptic Properties

At the end of the experiment, six birds were randomly selected from each treatment (i.e two per replicate), placed in a separate pen with appropriate tagging for identification. The birds were starved for 12 hours, killed by decapitation (cutting off the head), thereafter exsanguinated, defeathered and eviscerated. Thigh meat samples were cut for organoleptic assessment.

Ten (10) semi-trained panelists were selected from within the staff and students of the University to assess the cooked thigh meat samples according to AMSA (1995). Meat preparation was done using a wet cooking method. The samples were wrapped in impervious polythene pouches which could not be destroyed by the cooking process, the meat samples were cooked at 100 °C for 15 minutes. The panelist assessed the meat samples based on Texture, Juiciness, Flavour, Appearance, and General acceptability. The assessment was based on a 9 point hedonic scale. The score was arranged in descending order, the maximum score of 9 was given to extremely likely conditions while the lowest score of 1 was for the poorest condition.

Statistical Analysis of Data

Data collected were subjected to One-way ANOVA using SAS (1999). Significant means were separated by the Duncan option of the same statistical software. A probability of 5% was considered significant ($P < 0.05$).

Results and discussion

The proximate composition of WLM, IF and SMF is shown in Table 3. The crude protein of WLM (42.7%) was lower than Imported Fishmeal (60.9%) and *Schilbe mystus* fishmeal (54.6%). The crude fibre contents of WLM (8.2%) was however higher than both imported fishmeal (3.2%) and *Schilbe mystus* (3.5%). The nitrogen-free extract was generally low for WLM (7.30%), IF (8.00%), and *Schilbe mystus* fishmeal (5.30%). The 42.7% CP of Westwood larva meal obtained in this study was higher than the crude proteins obtained by other authors. Osasona and Olaofe (2010) and Akinawo and Ketiku (2000) showed 20% and 33.12% CP, respectively. However, Omotoso (2006) and Amao et al. (2010) documented 55.5% and 66.74%, respectively. The variation in CP of WLM could be due to various edaphic factors of the environment where the shea butter trees grow thereby influencing nutritive values of Westwood Larva meal. Further, processing of Westwood larva by parboiling for 15 minutes may also contribute to the variation in CP content of WLM in the present study. The high crude fibre 8.20% obtained for WLM in this study was close to the average value of 11.08% reported by Bibiana et al. (2014). The high crude fibre could be due to the chitin, the black scale like fibrous covering of the larva exoskeleton. The crude protein obtained for *Schilbe mystus* fishmeal (54.6%) in this study was higher than 47.6% reported by Ademola et al. (2017). Maidala et al. (2016) reported 52.71% CP for local fishmeal made from Winnows and a much higher value of 60% CP for fishmeal made from *Liza abu*. The variation in the CP of *Schilbe mystus* fishmeal might be due to the methods of processing, freshness of the fish before processing and source of the fish (specie and habitat). The crude protein of imported fishmeal used in this study (60.9%) was lower than 72–77% CP content reported by FIN (2015) for imported fishmeal obtained from different species of fish. The reduction in the CP content might be due to the species of fish used in producing the imported fishmeal, the time the product spent on shelf before purchase and processing methods as earlier suggested by Khatoon et al. (2006).

The amino acid profile of Westwood Larva meal is presented in Table 4. Westwood Larva meal had high lysine content (7.05%) compared to methionine content (0.91%) which was in very low concentration. Glutamic acid (14.76%) and aspartic acid (10.31%) were found to be the most abundant amino acids present in WLM while tryptophan (0.07%) and ornithine (0.70%) were the least abundant. The amino acid profile of WLM obtained in this study agreed with the findings of Bibiana et al. (2014) who reported the presence of isoleucine, leucine, methionine, phenylalanine, threonine, valine, lysine at varying amount and other non-essential amino acids at low but measurable amount. The amounts of lysine (7.05%) and methionine (0.91%) in WLM in the present study conform to the findings of Bibiana et al. (2014) who reported on 3 samples of WLM lysine (5.64%, 5.33% and 6.24%) and methionine (2.35%, 2.38%, and 2.22%) respectively for each sample. The observation on lysine and methionine on WLM concurred with the report of Bibiana et al. (2014). De Marco et al. (2015) found that insect meal contains lower amount of methionine compared to fishmeal which is to be considered when formulating diets based on insect proteins. Hence, the profile of amino acid in WLM particularly with the abundance of lysine content in the present study may contribute to protein accretion and breast muscle development, leading to improve growth performance if methionine content is adequately supplied for the need of broilers.

The growth performance of broiler starters and finishers is presented in Table 5. The heaviest ($P < 0.0001$) final body weights (FBW) and maximum average daily gain (ADG) were observed in broiler starters and finishers (FBW, $P = 0.0003$) fed 100% IF (T2). Starters fed 50% WLM that replaced 50% IF (T4) had FBW and ADG similar to those fed 100% IF. Broiler starters and finishers fed diets without animal protein (T1) had the lowest final body weights and ADG. The ADG of broiler starters fed 50% WLM plus 50% SMF or 100% *Schilbe mystus*-fishmeal were similar to those fed 100% WLM. Broiler starters fed diet containing 100% IF (T2) had the best ($P < 0.0001$) feed conversion while the worst feed conversion ratio was observed in broiler starters fed diet without fishmeal (NC). Feeding 50% WLM as a replacement for *Schilbe mystus* FM to broiler finishers led to significantly better FBW than those fed 100% *Schilbe mystus* fishmeal. Similar FBW was noticed in broilers fed 100% WLM and those fed 50% WLM as a replacement for imported fishmeal. Highest ($P = 0.037$) livability percentage was observed in broiler chicken fed 50% WLM as a replacement for *Schilbe mystus* fishmeal. The lowest livability percentage was noticed in the NC group. The improved final body weight of broiler finishers fed diets containing 50% Westwood larva meal as replacement for *Schilbe mystus*- fishmeal when compared to those fed 100% *Schilbe mystus* fishmeal concurred with the findings of Oyegoke et al. (2014) who reported an improved performance in broiler starters fed 50% WLM as a replacement for conventional fishmeal. The heaviest FBW of broiler chicken fed 100% imported fishmeal in this study showed that imported fishmeal was the better nutritional value than the local fishmeal. The significant improvement in FBW of broiler finishers fed 50% WLM as replacement for *Schilbe mystus* fishmeal revealed that WLM was rich animal protein. The inferior performance of broiler finishers fed diet without animal protein indicated that animal protein particularly fishmeal cannot be totally replaced by vegetable protein. Cho and Kim (2010) suggested that amino acid profile of animal protein complements and provides synergistic effect with other vegetable protein in broiler diet to promote fast growth and reduced feed cost. The performance characteristics of broiler chicken fed locally prepared fishmeal showed that the final live weights were affected by the different levels of locally prepared fishmeal (Maidala et al., 2016). The high livability percentage of broiler chicken fed 50% WLM as a replacement for *Schilbe mystus* fishmeal and those fed 100% WLM suggested the mortality was low probably indicating that WLM was a good protein source. FIN (2015) reported that diets including fishmeal reduce infection and promote health leading to higher productivity and reduced losses. It is believed that the omega-3 content in fishmeal improved immune status and lessened inflammatory conditions. Sing et al. (1990) also reported that fishmeal contained all the essential amino acids, especially lysine and methionine in adequate quantities required for poultry.

The nutrient digestibility of broilers chicken fed Westwood larva meal as a replacement for imported and *Schilbe mystus* fishmeal is presented in Table 6. Broiler chicken fed 100% *Schilbe mystus* FM diet had the highest ether extract digestibility (P = 0.049), followed by those fed 100% IF diet. The lowest ether extract digestibility was observed for those fed 50% SMF plus 50% WLM. Broiler chicken fed diet without animal protein had the highest NFE digestibility (P = 0.015) Superior NFE digestibility was noticed in chicken fed diet without fishmeal. Broilers fed 100% IF and those fed 100% *Schilbe mystus* fishmeal had better NFE digestibility (77.51% and 82.09%, respectively), than those fed 50% *Schilbe mystus* FM plus 50% WLM (67.25%). Broiler chicken fed diet containing 100% WLM (53.93%) had the highest crude fibre digestibility while the lowest crude fibre digestibility (P = 0.003) was observed in those fed diet containing 50% SMF plus 50% WLM (6.6%). The high ether extract and nitrogen-free extract digestibility observed in broiler chicken fed 100% *Schilbe mystus* fishmeal revealed that this local fishmeal was highly nutritious and effectively utilized. Similarly, improved ether extract and crude fibre digestibilities were also observed in broiler chicken fed 100% WLM in this study. This observation was consistent with the finding of Khan et al. (2018) who reported that groups of birds fed 60% maggot meal (insect meal) as a replacement for fishmeal had higher ether extract digestibility than those fed 100% fishmeal. The increased ether extract digestibility may be due to the high fat content of Westwood larva meal and *Schilbe mystus* fishmeal. The improved crude fibre digestibility observed in the broilers fed 100% WLM suggested the fibre level in WLM could be tolerated and utilized by broiler chicken. The highest nitrogen-free extract observed in broiler chicken fed diet without fishmeal indicated that the energy content of the diet was better utilized. However, protein utilization in the plant protein diet fed to broiler chicken may have been compromised.

The serum enzymes and proteins of broiler chicken fed Westwood larva as a replacement for imported- and *Schilbe mystus*-fishmeal is presented in Table 6. Feeding 100% WLM to broiler chicken caused elevated level of serum ALT (P = 0.034). Replacing imported fishmeal by 50% WLM also significantly (P < 0.0002) increased the serum ALP activity for chicken. However, broiler chickens fed 100% IF and those fed 100% *Schilbe mystus* fishmeal had the lowest serum alkaline phosphatase. The elevated level of alkaline phosphatase observed in broiler chicken fed 50% WLM as a replacement of imported fishmeal indicated good bone formation. Guyton (1991) reported that ALP level in the blood is usually a good indicator of bone formation since osteoblasts secrete large quantities of this enzyme. The highest level of ALT observed in broilers fed 100% WLM could be associated with damages on the hepatocytes. This might have resulted from the chitin present in the insect meal which sometimes interferes with the health status. Yen (2010) also suggested that some insects causes allergic reactions, botulism, parasitizes and food poisoning, this might have also raised the level of ALT in blood serum.

The organoleptic properties of thigh meat of broiler chicken fed Westwood larva meal as a replacement for imported and *Schilbe mystus* fishmeal is presented in Table 7. Thigh meat of broilers fed diet 100% WLM (T6) had a moderately light colour (P = 0.0027), richly flavoured (P < 0.0001), moderately juicy (P = 0.0002) and most generally acceptable (P = 0.0006) than those fed other diets. Chicken fed 50% SmF plus 50% WLM (T5) was the least colourful, minimal juiciness, less flavoured and least ac-

Table 3. Proximate composition of Westwood larva meal, *Schilbe mystus* and Imported-fishmeal

Parameters (%)	IF	SMF	WLM
Crude protein	60.90	54.60	42.70
Crude fibre	3.20	3.50	8.20
Ash	9.00	5.30	5.50
Ether extract	13.52	21.45	32.40
Nitrogen-free extract	13.38	15.15	11.20
Moisture content	8.00	5.30	7.30
Dry matter	92.00	94.76	92.70

ceptable thigh meat. The thigh meat of broiler chicken fed 100% IF had similar levels of colour, flavour, juiciness and general acceptability with those fed diet without animal protein (NC). The most colourful, richly flavoured, most juicy and highest acceptable thigh meat was obtained in broiler chicken fed 100% Westwood larva meal partly. This observation agreed with the findings of Victor (2017) who reported that aroma, taste and overall acceptability of cooked breast meat of chicken fed 5, 10 and 15% Black Soldier Fly larva (BSFL, an insect meal) meal in broiler diet all recorded a 5 point and above on the hedonic scale. The sensory response sug-

Table 4. Amino acid profile of Westwood larva meal

Amino Acids (%)	WLM	Amino Acids (%)	WLM
Isoleucine	3.41	Aspartic acid	10.31
Leucine	6.90	Cysteine	1.03
Lysine	7.05	Glutamic acid	14.76
Methionine	0.91	Glycine	3.86
Threonine	4.02	Histidine	2.99
Valine	4.94	Ornithine	0.70
Phenylalanine	4.50	Pyrolysine	1.77
Trytophan	0.07	Proline	2.99
Arginine	5.24	Serine	5.13
Alanine	2.69	Tyrosine	2.82

Table 5. Growth performance of broiler starters (1–21 day) and finishers (22–42 day) fed Westwood larva meal, imported- and *Schilbe mystus*-fishmeal (g/bird)

Parameters	T1 NC	T2 100% IF PC	T3 100% SMF	T4 50% IF 50% WLM	T5 50% SMF 50% WLM	T6 100% WLM	P-value	SEM
Initial BW (g/bird)	42.31	42.30	42.31	42.30	42.31	42.31	0.379	0.0014
Final BW (g/bird)								
@ 21st day	290.30^{c}	709.09^{a}	572.73^{b}	692.17^{a}	615.15^{b}	546.97^{b}	< 0.0001	24.49
@ 42nd day	890.32^{c}	1432.78^{a}	1182.22^{b}	1362.05^{ab}	1394.91^{a}	1297.22^{ab}	0.0003	59.63
Av Daily Gain (g/bird)								
@ 21st day	11.81^{c}	31.75^{a}	25.26^{b}	30.95^{a}	27.28^{b}	24.03^{b}	< 0.0001	1.17
@ 42nd day	28.57	34.46	29.03	31.90	37.13	35.73	0.174	2.60
Av. Daily intake (g/bird)								
@ 21st day	49.42	50.80	55.50	50.67	50.80	59.49	0.425	3.77
@ 42nd day	118.05	95.48	129.53	94.24	104.44	120.90	0.401	13.72
Feed conversion								
@ 21st day	4.20^{a}	1.61^{c}	2.19^{bc}	1.64^{c}	1.86^{bc}	2.52^{b}	< 0.0001	0.21
@ 42nd day	4.34	2.78	4.55	2.95	2.85	3.38	0.156	0.56
Livability (%)	70.45^{b}	88.64^{a}	85.35^{ab}	85.10^{ab}	97.22^{a}	91.67^{a}	0.037	4.87

^{abc} Means along the same row with different superscript are significantly different (P < 0.05)
SEM = Standard Error of Mean

Table 6. Nutrient digestibility and Serum enzymes of broiler chicken fed diets containing Westwood larva meal, imported and *Schilbe mystus* fishmeal

Parameters	T1 NC	T2 100% IF PC	T3 100% SMF	T4 50% IF 50% WLM	T5 50% SMF 50% WLM	T6 100% WLM	P-value	SEM
Nutrient Digestibility								
DM (%)	67.02	67.90	69.52	63.59	58.17	65.60	0.558	4.43
EE (%)	78.91^{bc}	84.17^{ab}	86.85^{a}	83.87^{ab}	75.98^{c}	80.72^{abc}	0.049	2.24
NFE (%)	84.63^{a}	77.51^{ab}	82.09^{ab}	73.10^{bc}	67.25^{c}	72.92^{bc}	0.015	3.03
CP (%)	52.89	69.62	54.01	59.51	50.81	60.51	0.221	5.35
CF (%)	42.90^{a}	21.75^{bc}	44.63^{a}	52.88^{a}	6.60^{c}	53.93^{a}	0.003	7.08
Ash (%)	11.68	21.14	26.16	15.95	6.33	17.43	0.600	8.03
Serum Enzymes								
AST (IU/L)	126.00	118.24	131.08	127.74	129.70	115.27	0.407	6.29
ALT (IU/L)	25.61^{b}	23.17^{b}	25.51^{b}	27.09^{b}	27.66^{b}	37.17^{a}	0.034	2.92
ALP (IU/L)	28.29^{bc}	19.49^{c}	19.72^{c}	40.55^{a}	30.60^{b}	21.37^{bc}	0.0002	3.09
Total Protein (g/dL)	2.88	2.64	2.76	2.88	2.68	3.31	0.383	0.23
Albumin (g/dL)	1.01	1.05	0.99	0.92	1.04	1.20	0.409	0.09
Globulin (g/dL)	1.87	1.59	1.78	1.97	1.64	2.11	0.593	0.22

[abc] Means along the same row with different superscript are significantly different (P < 0.05)
SEM = Standard Error of Mean

Table 7. Organoleptic properties of thigh meat of broiler chicken fed Westwood larva meal, imported- and *Schilbe mystus*-fishmeal

Parameters	T1 control	T2 100% IF	T3 100% SmF	T4 50% IF 50% WLM	T5 50% SmF 50% WLM	T6 100% WLM	P-value	SEM
Colour	5.40^{b}	4.90^{b}	4.80^{b}	5.20^{b}	4.40^{b}	7.30^{a}	0.0027	0.26
Flavour	6.00^{bc}	6.30^{b}	5.20^{cd}	6.00^{bc}	4.70^{d}	7.90^{a}	< 0.0001	0.16
Juiciness	6.40^{b}	5.60^{bc}	5.10^{bc}	5.70^{bc}	4.90^{c}	7.80^{a}	0.0002	0.28
Tenderness	5.30	5.20	5.00	5.30	5.40	6.20	0.598	0.25
General acceptability	6.50^{bc}	6.90^{b}	6.00^{bc}	6.60^{bc}	5.40^{c}	8.10^{a}	0.0006	0.21

[abcd] Means along the same row with different superscript are significantly different (P < 0.05)

gested that the consumers prefer thigh meat from broilers fed Westwood larva meal. The high acceptability of broilers fed 100% Westwood larva meal supported the report of Litton (1993) that chicken fed grasshoppers (insect meal) have a delicious taste and are sold for a much higher price than chicken reared on commercial chicken feed.

Conclusion

It was concluded that Westwood Larva Meal has a good amino acid profile (though deficient in methionine) which can adequately support the growth of broilers, and could optimally replace *Schilbe mystus* fishmeal and imported fishmeal in broiler diet at 50% to support maximum growth rate of broiler chicken. The use of Westwood larva meal up to 100% led to elevated serum alanine aminotransferase activity. Feeding 100% WLM had the most colourful, richly flavoured, most juicy and best general acceptable thigh meat.

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