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Growth performance, clinical evaluation and sensory impact of black soldier fly larval meal as protein resource on grower-finisher guinea fowls reared under tropical conditions

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Abstract

The study was conducted with the view to determine the impact that larval meal from black soldier fly (BSFLM) would have on growing guinea fowls when used utilized as fishmeal replacer. BSFLM, produced from decaying mango fruits, were harvested, dried, milled and used for the feeding trial. BSFLM replaced fish meal in the ratios of 0, 20, 40, 60, 80 and 100% to produce six dietary treatments which were iso-caloric and iso-nitrogenous. Two hundred and forty eight-week old grower guinea fowls with mean live-weight of 273.2 ± 10.9 g were tagged, weighted and randomly assigned to six floor pens. Each bird was treated as a replicate. Feed and water were provided *ad libitum*. During the entire period which lasted ten weeks. Feed consumption differed among the treatment groups (P = 0.0072) with the 100% fishmeal diets recording the lowest. However, daily gain was found to be significantly (P=0.009) higher for birds fed high BSFL diets compared to the control (fishmeal diet). The inclusion of BSFLM in the diets seemed to have elicited positive linear effect on the weight gains of the guinea fowls (R^2 = 0.91) with increasing concentration resulting in higher live weight gains. The FCR also differed between treatments ($P<0.05$) but similar for 100% fishmeal (control) and 100 % BSFLM diets. The study further revealed that BSFLM replacement of fish meal in guinea fowl diets would not adversely affect the haematopoietic ability of the birds. Organ and haematopoitic integrity were equally assured regardless of the protein types used as well as levels of inclusion.

Keywords: blood chemistry, carcass**,** haematology, organoleptic properties, protein

Introduction

Poultry production has been advanced to provide a rapid means of producing animal protein to meet the nutritional requirements of the ever increasing human populace (Taiwo et al. 2005). However, sustainable feeding of poultry has been a major setback in sub-Saharan African resulting in huge imports of both poultry products and feedstuffs. The search for safe and suitable but equally nutritious protein alternatives to meet the well-known challenge of high cost of feed resulting from soaring prices of the conventional feedstuffs such as fishmeal and soybean (Mmereole 2008; Dei et al. 2013) continue unabated. Coupled to this, is the issue of their seasonal unavailability and stiff competition with humans who usually use them as part of the staple meal. Additionally, the increasing human population has been reported to require a corresponding increasing demand for the conventional feed ingredients (Dei et al. 2013).

The black soldier fly (*Hermetia illucens* Linnaeus 1758) is a fly (Diptera) of the *Stratiomyidae* family (Tran et al. 2015) which has been proposed since the 1990s and actually tested as an efficient way of disposing of organic waste into fat- and protein-rich biomass suitable for various beneficial applications such as protein source for all livestock and poultry among others (Diener et al. 2011; van Huis et al. 2013; Wallace et al. 2017). Moreover, the major advantage that *Hermetia illucens* has over other insect species used for biomass production is that the adult does not feed and thus, require no special care. It is also not a vector as the adult flies are neither attracted to human habitat nor foods (van Huis et al. 2013). BSF fly larvae being voracious, convert organic waste in a quick fashion into valuable biomass, restraining bacterial growth and hence, markedly preclude the generation of offensive odour. Furthermore, the larvae species aerate and dry up the manure which enhances odour reduction (van Huis et al. 2013). The larvae have been reported to contain natural antibiotics as well as modify the micro-flora of manure which eventually reduces harmful bacteria such as *Escherichia coli* 0157:H7 and *Salmonella enterica* (van Huis et al. 2013).

Globally, several insect species, including black soldier fly, have been fed in various life cycle stages to animals (Anankware et al. 2015; Wallace et al. 2017). However, the use of the black soldier fly larvae as feed for poultry in West Africa is uncommon (Kenis et al. 2014). This study was therefore undertaken with the aim of ascertaining the impact that black soldier fly larval meal (BSFLM) would elicit on growth performance, survivability, sensory and carcass characteristics, haematological and biochemical indices as well as economics of production of grower-finisher guinea fowl reared under tropical conditions

Materials and Methods

Study location and conditions

The study was conducted at the guinea fowl resource centre of CSIR-Animal Research Institute, Katamanso station, Accra where the larval production was also carried out. The station is in the coastal savannah zone of Ghana with a mean annual rainfall of 730 mm and two rainy seasons namely major (May – mid-July) and minor (mid-August – October). Generally, there is very little variation in temperature throughout the year. The monthly temperature ranges between 24.7 (August) and 28 ^{o} C (March) with an annual mean of 26.8 ^{o} C. The relative humidity is usually high with values ranging from 65 to 95%. Wind speed reportedly ranges between 8 and 16 km per hour (Wallace et al. 2012).

Production of BSFLM

Two-day old larvae of black soldier flies were inoculated on an unprocessed fruit waste mixture composed of 60% watermelon, 20% avocado and 20% mango. The larvae were harvested using a passive sieving system 10 days after inoculation when they were considered to be at the "white larvae stage" and this was to minimize chitin concentration. The harvested larvae were kept overnight in a bowl of saw dust in order to allow the emptying of gut content. They were, then, washed with clean water, dried and milled in a hammer mill (3000 rpm, 2 mm sieve; KNUST, Kumasi, Ghana). The milled meal was stored until required for use.

Experimental diets, animals and design

The black soldier larvae meal was systematically mixed with other ingredients at specified concentrations to produce six experimental diets. All the diets were iso-caloric and iso-nitrogenous and were fed to the keets *ad libitum* including water from eight to eighteenth weeks of age. The fishmeal component of the experimental diets was replaced with BSFLM in the following percentage ratio: T1 (Control) – 100% FM: 0% BSFLM, T2 – 80% FM: 20% BSFLM, T3 – 60% FM: 40% BSFLM, T4 – 40% FM: 60% BSFLM, T5 – 20% FM: 80% BSFLM, and T6 – 0% FM: 100% BSFLM. The composition and nutrient values for the diets are shown in Table 1. Two hundred and forty eight-week old grower guinea fowls with mean live-weight of 273.2 ± 10.9 g were tagged, weighted and randomly assigned to six floor pens. Each of the concrete floor pens was of 360 x 210 x 420 cm dimension and covered with 5 cm good quality wood shavings. Each pen was equipped with two bell drinkers, two feeder trays as well as a florescent bulb for lighting.

Chemical analysis

Proximate composition, calcium, phosphorus and gross energy content of the experimental diets were determined using methods as described in A.O.A.C. (1990). The diets were analyzed for nitrogen content using the micro-Kjeldahl method (A.O.A.C. 1990).

Biochemical and haematological assays

At day 79 (08.00 GMT), which was the last day of the study, before feeding, four guinea fowls (two males and two females) were randomly selected from each dietary treatment groupings. Blood was aseptically drawn from the jugular vein with disposable 5 ml plastic syringe. 2 ml blood was transferred gently into labelled vacutainer tubes containing EDTA for whole blood count and the remaining 3 ml into the other vacutainer tubes laced with gel and used for blood chemistry assay. Enumeration of erythrocytes and leukocytes were carried out manually using the procedures described by Samour (2013). Blood was diluted (1:200) with Natt-Herrick solution, and counting of RBCs was done using Improved Neubaeur haematocytometer. Haemoglobin was determined using spectrophotometer (Cecil 1000 series, England) at 540 nm using Drabkin's solution. Packed cell volumn (PCV) was determined by duplicate capillary tube. The tubes containing blood samples were centrifuged at 1,200 *g* in a micro-capillary centrifuge (Model MB) and read with a Hawksley haematocrit reader. Thin blood smears were stained with Giemsa and examined microscopically under oil immersion for leukocyte characterization. For each blood smear, a minimum of 200 leukocytes were counted for the determination of differential leukocyte values. For blood chemistry assay, blood samples were centrifuged at 3,000 rpm for 5 minutes and the sera used to determine some key lipid, protein and enzyme profiles. These assays were made with the aid of reagent kits (Spinreact SA, Ctra. Santa Coloma, Spain) and the targeted biochemical indices quantified using an automatic device, HITACHI 902 (Japan).

Sensory evaluation

At the end of the study, six birds (three cocks and three hens) per treatment were slaughtered and processed to evaluate the impact of the experimental diets on organoleptic properties of guinea fowl meat. The processing techniques were in accordance with approved methods for the processing of meat. The breast muscles of the cooked guinea fowl meat were cut into pieces, cooked with a common recipe and packaged for the assessment. A total of 19 taste panellists were trained for the organoleptic evaluation. They washed their mouths with water after tasting each meat sample and assessed attributes which included tenderness, juiciness, texture, flavour intensity and overall acceptability. Soon after that, they ranked the meat samples on the Likert scale of 1 – 8 with 1 being the poorest and 8 the best (Teye et al. 2006).

Statistical analysis

Data generated were subjected to analysis of variance using Genstat 14th Edition (VSN International 2011). Data on growth performance of grower-finisher guineas were subjected to analysis of covariance (ANCOVA) where initial weights of the birds were used as covariates in the analysis. Means were separated using Duncan's Multiple Range Test. The results from sensory evaluation were subjected to analysis of variance using SPSS version 17. The differences were partitioned using the least significant difference (LSD).

Results

The influence of graded BSFLM replacement of fish meal on growth performance of grower-finisher guinea fowl is presented in Table 2. The final weight of the birds at the age of 18 weeks significantly differed ($P<0.001$). Birds that were fed full BSFL (100%) exhibited the highest live weights and these were markedly higher than the other treatment groups including the control. The ADG of birds fed these diets were equally found to be significantly

(P=0.009) higher compared to the wholly fish meal diet. The inclusion of BSFLM in the diets seemed to have elicited a positive linear effect on weight gain of the guinea fowls (R^2 = 0.91) as shown in Fig. 1. Feed consumption also differed among the treatment groups (P=0.0072) with diets 3, 4 and 5 exhibiting similar consumption pattern just as those fed the 100% fish meal (control). The FCR demonstrated similar responses relative to those fed diets 2, 3, 4 and 5 but had significantly (P = 0.0008) higher appreciation when compared to birds fed the control diet.

Black soldier fly larvae meal inclusion did not affect the survivability of the birds as 80 – 100% fishmeal replaced diets demonstrated significantly (P<0.05) higher survivability compared to the other treatment groups (see Fig. 2). The haematogram assays (Table 3) showed that full or partial replacement of fish meal with BSF larval meal in guinea fowls diets did not compromise (P>0.05) the erythropoietic function as well as WBC differentials. However, increasing BSFLM beyond 20% elicited significantly (P<0.05) higher MCH concentration. Similarly, graded BSFLM levels did not impact plasma electrolyte, lipid, metabolites and enzyme concentration in grower-finisher guinea fowls (Table 4).

The responses of some carcass characteristics and organs of the birds to the dietary treatments were similar (P>0.05) except for dressed weight which was significantly (P=0.049) different (Table 5). Dressed weight was higher (P<0.05) for birds fed diets 40-100% BSFLM but comparable (P>0.05) to the control diet (100% fishmeal diet). An assessment by both male and female trained panellists of the impact of the dietary treatments on organoleptic properties of guinea fowl meat indicated similar (P>0.05) tenderness, juiciness and texture for all the dietary treatment groups (Table 6). However, meat of birds fed 100% BSFLM-rich diet was adjudged to have the best flavour generation. Also, including BSF larval meal from 60 to 100% in place of fish meal in growing guinea fowl diets would elicit overall acceptance just like 100% fish meal inclusion. Lower BSFLM inclusion up to 40% were the least rated in terms of acceptability. The sensory properties were similarly rated (P>0.05) for meats from both cocks and hens, except for acceptability which favoured (P<0.05 meat from hens (Fig. 3).

Discussion

The study was conducted to evaluate the impact of BSFLM on the productive performance and meat qualities of growing guinea fowls. The experimental diets were formulated to contain similar energy and protein (Table 1). The feed intake of 58 – 75 g/d/bird observed in this study was found to be similar to the 63 – 78 g/d/bird reported by Agbolosu and Teye (2012) but lower than the 130 – 133 g/d/bird reported in by Teye et al. (2000) for growing guinea fowls. However, the weight gains of 9.2 - 10.5 g/d/bird observed was found to be slightly higher than the 6.2 – 7.1 g/d/bird Agbolosu and Teye (2012) reported for similar birds. Differences in diet composition could be responsible for this observation. In this study, high BSFLM inclusion (60 -100%) in diets, supported growth better than the high fishmeal diets (60-100%). The high weight gain and FCR observed for birds fed (100% BSFLM) indicate the potential of BSFLM to grow older guinea fowls (8 – 18 weeks) economically.

The survival of guinea fowls under intensive system after 8 weeks of age is known to be high and therefore, the over 85 - 100% survival exhibited in this study is not unusual. Furthermore, the high survival rate observed for grower-finisher guinea fowls regardless of the protein source as well as the level of inclusion was similar to the 82.5 – 98.7% reported for similar birds by Agbolosu and Teye (2012).

The determination of heamatological as well as biochemical parameters provide valuable information for the evaluation of the health status of humans and animals though the lack of reference values for avian blood profile usually restricts its usage (Talebi et al. 2005). The immune organs such as spleen and thymus gland are important for the maintenance of normal immune function of animals (Feng et al. 2007; Ravindran et al. 2006; Wallace et al. 2012) and the lymphoid organ weights are prevalently assessed as a measure of immune status of poultry (Pope 1991). In this study, the weight of spleen, as well as its index, were similar (P>0.05) for the treatment groups. It can, therefore, be deduced that the inclusion of BSF larval meal regardless of levels was as good a protein source as fish meal in maintaining the immune function and status of growing guinea fowls.

Table 4 showcased the blood lipids of grower-finisher guinea fowls fed graded BSF larval meal. High serum cholesterol and triglycerides are reportedly linked to heart disease, stroke and heart attack (Kaplan and Szabo 1983; Shutler et al. 1987; A.D.A.M. 2005). The results obtained relative to the blood chemistry profile as well as the heart risk ratios did not present black soldier fly larval meal as hypercholesterolaemic nor artherogenic agent. Relative to the control diet which had 100% fish meal as the main protein source, there were no significant (P>0.05) differences in any of the cholesterol profiles determined. Further to this, the background diet was not high in cholesterol or fat which usually is the case when the cholesteroleamic potential of a protein source or material is being ascertained (Shutler et al. 1987; Marfo et al. 1990; Wallace et al. 2001; Landi Librand et al. 2007).

The results showed that there was no significant (P>0.05) variations in the serum concentration of urea, creatinine nor any of the electrolytes assayed. This is suggestive of the fact that BSFLM as protein replacement of fish meal would not disrupt the osmolality likewise the osmotic balance of the blood of the birds neither would it engender disease state (e.g. diabetes insipidus, hypokalemia, hyperadrenalism, etc.) that would create distortions in the electrolyte balance with dire consequences (Kaplan and Szabo 1983). Kaplan and Szabo (1983) have reported that serum creatinine and urea levels yield useful information on the impairment or dysfunctional state of the kidney. Levels of urea and creatinine are commonly used markers of renal physiology and pathology and elevated concentrations of these metabolites indicate nephrotoxicity (Gowda et al. 2010). It can be suggested that the statistically (P>0.05) similar serum creatinine and urea concentrations of BSFLM fed birds relative to the control diet imply that kidney impairment or dysfunction did not occur.

Several biomarkers have been well established and used to investigate the physio-pathological status of certain vital organs of the body of animals (Abdel-Wareth et al. 2014) and the intact integrity of the organs is markedly amplified by the status of the liver for instance. The liver is the site of the biosynthesis of most of the plasma proteins of the blood and thus, the impairment of the hepatic cells would have reflected in the serum proteins assayed namely total protein, albumin and globulin (Lehninger 1984). In this study, the AST and ALT concentration which usually become elevated in liver diseased state (Moss et al. 1987) were found to be statistically similar (P>0.05) in the BSFLM fed birds just as the control birds. The non-incidence of any diseased state in the guinea fowls were further emphasized by the relatively similar response of the ALT/AST (De Ritis) ratios determined among birds fed the various dietary treatments. The levels of these enzymes coupled by their relative concentrations in the plasma are always indicative of the incidence of myriad of diseases. For instance, in toxic or viral hepatitis, ALT is reported to be characteristically as high as or higher than AST, and the ALT/AST (De Ritis) ratio, which normally is less than 1, approaches or becomes greater than unity (Moss et al. 1987; Tietz, 1987).

Although the final live weights were higher for BSFLM-rich diets compared to fishmeal–rich diets, dressed weights were found to be similar. This could be attributed to the fewer number of birds sampled for assessment. The diets however did not show significant effect on the other organs measured. The results suggest that including BSFLM at all the levels studied would elicit similar impact as fish meal in terms of texture, juiciness and tenderness of the carcasses of the birds fed those diets. However, the diet effect on meat flavour and acceptability was evident with the complete BSFL diets recording the best flavour and acceptability ratings. Similar to an earlier report (Al-Qazzaz et al. 2016), BSFL inclusion in diets of laying hens improved appearance, texture, taste and acceptance of eggs. Meat acceptability is principally influenced by meat flavour and tenderness (Reicks et al. 2012). Robbins et al. (2003) suggested that the combination of taste and odour, as well as mouth feel and juiciness, affect flavour perception. Meat flavour and palatability are largely influenced by the fat content volatiles from lipid sources. Small proportion of oxidized fatty acids from lipid sources can be sufficient to alter flavour significantly (Belitz et al. 2009). Feed affects the physico-chemical and organoleptic parameters of meat, including carcass composition, degree of fattening, fatty acid profile of meat and formation of short branched-chain fatty acids (Khan et al. 2015) and can therefore be used to improve poultry meat flavour (Fanatico et al. 2007). Feed supplements including dietary fat source, dl-α-tocopheryl acetate and ascorbic acid were reported to have influenced the flavour of chicken meat (Jayasena et al. 2013). Birds fed a diet containing 8% herring meal resulted in fishy, unpleasant, rancid, or stale flavoured raw meat (Poste 1990).

In the current study, the meat characteristics measured were not different between hens and cocks (Fig. 3) except for meat acceptability. The sex of an animal has been reported to influence the flavour and general acceptability of meat (Crouse et al. 1981). A significant influence of sex on the fatty acid profile of *longissimus dorsi* (Lorenzo et al. 2013) as well as a larger infiltration of fat content in females (Horcada et al. 1998) has led to the suggestion that that the meat of females should be juicier than the meat of males. Forrest (1975) reported tenderer, juicier, and more flavourful, with higher overall palatability scores of roasted ribs from steers than roasts from bulls. Vani et al. (2006) explains that variations in nucleotide content in muscles can be due to the differences in species, breed, age, sex etc. These can result in different levels of flavour precursors, causing variations in the type and concentration of volatile compounds. In contrast, Franco et al. (2011) reported no significant difference of meat quality between sexes.

Conclusion

The results obtained in this study demonstrated that BSFLM did not cause any physio-pathological anomalies in the grower guinea fowls used neither would it at any level of inclusion adversely impact on growth performance. Organ and haematopoietic integrity were assured regardless of the protein type used in formulating the diets as well as levels of inclusion. It is observed that BSFLM could replace fishmeal up to 100% in grower-finisher guinea fowl diet without compromising on the organoleptic attributes of the carcasses.

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Conflict of interest

The authors declare that they have no competing interests.

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Table 1, Experimental diets for grower-finisher guinea fowls

	Dietary treatments (FM:BSFLM)					
Ingredients	100:0	80:20	60:40	40:60	20:80	0:100
Yellow maize	63.4	65.0	65.0	64.0	63.0	63.0
Soybean meal	14.0	11.0	11.0	12.0	13.0	14.0
Fishmeal	3.00	2.40	1.80	1.20	0.60	-
BSFL	-	0.60	1.20	1.80	2.40	3.00
Lysine	0.50	0.50	0.50	0.50	0.50	0.50
Methionine	0.25	0.25	0.25	0.25	0.25	0.25
Wheat bran	15.2	16.0	16.0	16.0	16.0	16.0
Iodated salt	0.2	0.25	0.25	0.3	0.35	0.35
Oyster shells	2.60	2.70	2.70	2.65	2.60	2.60
Dicalcium phosphate	1.00	1.00	1.00	1.00	1.00	1.00
Vit and Min premix	0.30	0.30	0.30	0.30	0.30	0.30
Calculated analyses (%)						
ME (MJ/kg)	15.6	15.7	15.3	15.4	15.4	15.3
Crude protein	11.5	11.4	11.4	11.4	11.3	11.3

**Vitamin/mineral premix*: Vit. A – 800 IU; Vit. D – 500 IU; Vit. E – 2.5 mg; Vit. K – 1 mg; Vit. B2 – 2 mg; Vit. B12 – 0.005 mg; Folic acid – 0.5 mg; Nicotinic acid – 8 mg; Calcium panthotenate – 2 mg; Choline chloride – 50 mg; Manganese – 50 mg; Zinc – 4 mg; Copper – 4.5 mg; Cobalt – 0.1 mg; Iodine – 1 mg; Selenium – 0.1 mg; *ME* – Metabolizable energy; Vit – vitamin; Min - mineral

Table 2, Growth performance of grower-finisher Guinea fowls fed BSFLM

Parameters	Dietary treatments (FM:BSFLM)						SEM	P-value
	100:0	80:20	60:40	40:60	20:80	0:100		
Initial weight (g)	318	254	228	285	307	292	10.9	0.132
Final weight(g)	960^{b}	897^{c}	880^{c}	974^{b}	1008^{ab}	1029^{a}	16.0	0.000
Ave. Daily gain(g/bird/day)	9.16^{c}	9.19^{c}	9.31^{bc}	9.84^{abc}	10.0^{ab}	10.5^{a}	0.136	0.009
Feed intake	58.0^{a}	69.3^{b}	71.1^{ab}	70.6^{ab}	75.3^{a}	65.1^{bc}	1.46	0.007

(g/bird/day)								
FCR	6.34^{bc}	7.57^{a}	7.64^{a}	7.18^{ab}	7.52^{a}	6.18^{c}	0.162	0.0125

^{abc}Means in a row with same or no superscripts are not significantly different (P>0.05)

Ave. – Average; *FCR* – Feed conversion ratio

Table 3, Haematogram and leukogram response of grower guinea fowl fed graded BSFLM diets

Parameter	Dietary treatments (FM:BSFLM)						SEM	P - value
	100:0	80:20	60:40	40:60	20:80	0:100		
RBC(x 10^6/L)	3.47	3.15	3.31	3.14	3.24	3.02	0.0660	0.480
PCV (%)	43.8	38.8	46.8	45.3	43.3	43.8	0.825	0.101
MCV (fl)	127	125	142	144	134	146	2.96	0.107
MCH, (pg)	39.0^{b}	39.2^{b}	46.4^{a}	46.0^{a}	42.4^{ab}	47.2^{a}	1.05	0.033
MCHC (%)	29.3	31.4	32.7	31.9	31.7	32.4	0.352	0.0507
WBC (x10^9/L)	20.0	15.1	18.0	18.3	17.8	18.2	0.561	0.275
Neutrophils (%)	29.8	23.3	42.0	31.0	34.0	36.3	2.44	0.394
Lym (%)	53.0	62.8	38.3	47.8	52.5	49.8	3.14	0.324
Basophils (%)	1.75	0.250	0.50	1.50	1.00	1.00	0.200	0.260
Eosinophils (%)	12.3	13.5	18.5	18.0	11.3	10.8	1.89	0.658
Monocytes (%)	3.25	0.25	0.75	1.75	1.25	2.25	0.442	0.442
Spleen index	0.50	0.51	0.45	0.45	0.52	0.51	0.0250	0.968

RBC red blood cell, *PCV* packed cell volume, *WB*C white blood cell, *Lym* lymphocytes, *MCHC* – Mean Cell Haemoglobin Concentration; *MCH* – Mean Cell Haemoglobin; *MCV* – Mean Cell Volume

^{abc}Means in a row with the same or no superscript are not significantly different (P>0.05)

Table 4, Effect of BSFLM on serum concentrations of lipids, electrolytes, metabolites and enzyme

Parameter	Dietary treatments (FM:BSFLM)						SEM	P - value
	100:0	80:20	60:40	40:60	20:80	0:100		
Total Chol (mmol/L)	3.55	2.78	4.38	2.98	4.18	3.13	0.242	0.331
Triglyceride (mmol/L)	2.10	2.14	2.37	1.39	2.06	1.76	0.206	0.854
HDL (mmol/L)	1.22	1.15	1.39	1.95	1.59	1.84	0.116	0.208
LDL (mmol/L)	1.32	0.648	1.90	0.443	2.15	0.855	0.281	0.458
LDL/HDL Ratio	5.61	0.280	2.52	1.42	0.840	1.10	0.611	0.106
Creatinine (mmol/L)	24.8	29.6	32.8	30.5	40.3	38.1	1.88	0.065
Urea (mmol/L)	9.44	8.77	9.48	8.12	8.63	8.52	0.175	0.168
Na^+	144	99.0	102	117	106	87.4	7.62	0.394
K^+	3.10	2.50	2.75	2.03	2.83	2.18	0.221	0.779
Cl^-	122	115	117	119	119	122	1.63	0.864
ALT (μ/L)	6.32	6.14	14.0	8.34	8.49	9.67	1.36	0.600
AST (μ/L)	230	234	270	234	267	232	7.96	0.515
ALP (μ/L)	1360	1857	1651	984	1742	1492	93.1	0.071
GGT (μ/L)	1.50	4.17	2.60	1.30	10.0	0.440	1.51	0.530
D. Bil (μmol/L)	1.33	4.15	4.55	3.42	5.08	5.94	0.901	0.815
T. Bil (μmol/L)	2.66	4.19	6.60	3.39	9.52	3.64	1.21	0.634
Albumin (g/L)	14.5	13.8	15.0	14.6	14.5	14.1	0.330	0.956
Total protein (g/L)	32.9	29.5	40.0	29.0	32.9	27.0	1.76	0.375
Globulin (g/L)	18.4	15.7	25.0	14.4	18.5	12.9	1.78	0.484

Tot. Chol total cholesterol, *HDL* high-density lipoprotein, *LDL* low-density lipoprotein, *ALT* alanine transaminase, *AST* aspartate transaminase, *ALP* alanine phosphatase, *GGT* gamma glutamyl transferase, *D. Bil* direct bilirubin, *T. Bil* total bilirubin

[abc]Means in a row with the same or no superscript are not significantly different (P>0.05)

Table 5, Effect of BSF larval meal on live weight and some organs of Guinea fowl (g)

Parameters	Dietary treatments ‘(FM:BSFLM)						SEM	P-Value
	100:0	80:20	60:40	40:60	20:80	0:100		
Live weight	1161	1058	1224	1135	1165	1181	17.8	0.119
Dead weight	1114	1013	1174	1087	1113	1119	17.2	0.150
Blood weight	46.9	44.8	50.4	48.2	52.2	62.1	2.01	0.106
Dressed weight	785^{a}	680^{b}	837^{a}	741^{ab}	773^{ab}	770^{ab}	15.4	0.0490
Dressing	67.7	64.3	68.3	65.3	66.2	65.1	0.524	0.161
Head	36.4	36.0	39.8	39.6	40.1	39.3	0.806	0.578
GIT[†]	42.0	43.7	47.1	45.3	42.5	44.3	1.27	0.862
Heart	6.70	6.05	6.33	7.05	7.98	7.05	0.282	0.217
Liver	11.7	13.1	12.2	12.5	13.1	15.5	0.578	0.550
Gizzard	23.4	32.4	24.8	25.9	25.9	22.3	1.26	0.0825
Spleen	0.575	0.525	0.550	0.500	0.600	0.600	0.0260	0.885

[ab]Means in a row with the same or no superscript are not significantly different (P>0.05)

[†]*GIT* – Gastro intestinal tract

Table 6, Impact of dietary treatments organoleptic properties of guinea fowl meat (Likert scale)

Organoleptic properties	Dietary treatments (FM:BSFLM)						SEM	P-value
	100:0	80:20	60:40	40:60	20:80	0:100		
Tenderness	4.92	5.21	5.08	4.97	4.58	5.37	0.104	0.345
Juiciness	4.50	4.87	4.89	4.95	4.79	5.06	0.0776	0.386
Texture	4.53	4.87	5.03	5.05	4.50	4.95	0.0856	0.228
Flavour	4.39^{a}	4.39^{a}	5.05^{b}	4.29^{a}	4.92^{a}	5.18^{b}	0.0968	0.017

Acceptability	4.75[ab]	2.75[a]	3.00[a]	5.14[b]	5.32[b]	5.66[b]	0.148	0.001

[ab]Means in a row with the same or no superscript are not significantly different (P>0.05)

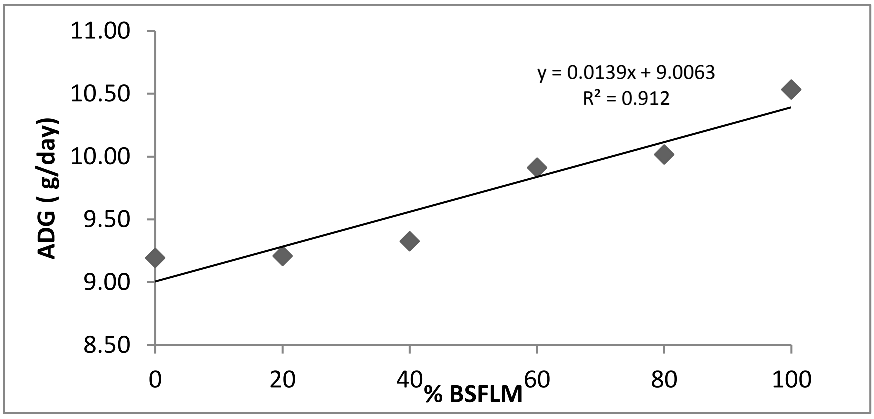

Fig. 1. Regressional analysis of fish meal replacement with BSFLM relative to ADG [P = 0.0030; S.E. = 0.180]

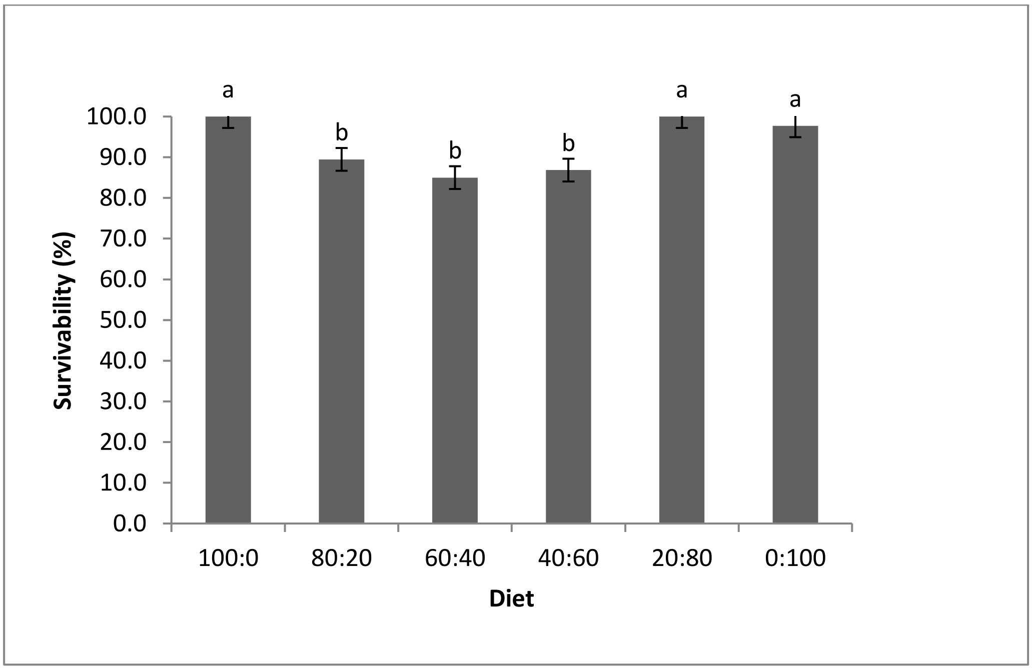

Fig. 2. Survivability of grower-finisher guinea fowls fed diets containing varying levels of BSFLM

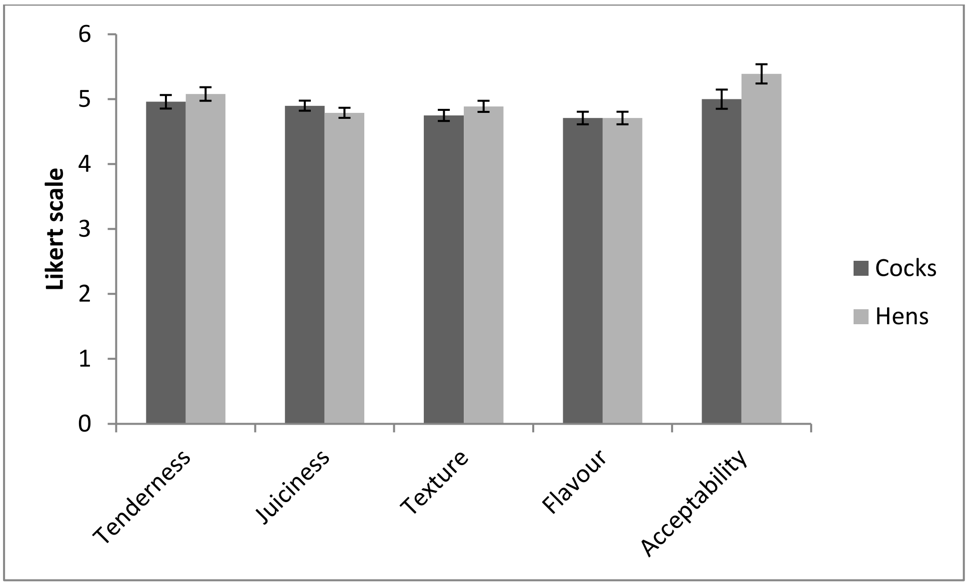

Fig. 3. Sensory evaluation of guinea fowl meat from cocks and hens