Global Advanced Research Journal of Agricultural Science (ISSN: 2315-5094) Vol. 7(8) pp. 272-280, August, 2018 Issue.
Available online http://garj.org/garjas/home

Full Length Research Paper

Potential of the black soldier fly (*Hermetia illuscens*) as a replacement for fish/soybean meal in the diet of broilers

[1]Anankware P. J., [2]Ayizanga R. A., [3]Opoku O.,[4]Obeng-Ofori D.

[1]Department of Horticulture and Crop Production, School of Agriculture and Technology, University of Energy and Natural Resources, Sunyani, Ghana
[2]Department of Animal Science, University of Ghana, Legon – Accra, Ghana
[3]Department of Animal Science, Faculty of Agriculture, Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana
[4]Catholic University College of Ghana, Fiapre, Sunyani, B/A, Ghana

Accepted 17 August, 2018

The Ghanaian feed industry imports over 90% of its protein hence making poultry and fish feed very expensive. This makes it difficult for local farmers to compete with their foreign counterparts, thus pushing a lot of people out of jobs. This study evaluated the potential of the Black Soldier Fly (BSF) meal as a replacement for fish/soybean meal in the diets of broilers. The experiment was conducted at the poultry section of the Animal Science department of the Kwame Nkrumah University of Science and Technology. One hundred and eighty unsexed day old Cobb-500 broilers were grouped into 15 birds per replicate with four replicates per treatment under three treatments. Three experimental diets for both starter and finisher phases of broiler production were formulated with T0 (Fish+Soy) serving as control, T1 (BSFL+Soy) and T2 (BSFL+Fish) as the experimental diets. The crude protein of BSFL (44.82) was the highest and BSFL+Soy (20.76) recorded the lowest crude protein. The highest feed intake was recorded from BSFL+ Fish (5.72kg) and the control recorded the highest water intake (12.15 l). In terms of total weight gain and final weight, BSFL+Fish was superior ($p < 0.05$) to BSFL+Soy but statistically ($p > 0.05$) similar to the control. Conversely, there were no significant ($p > 0.05$) differences between feed conversion ratio (FCR) and mortality rate for all the experimental diets. There were significant ($p < 0.05$) differences in all carcass parameters measured except for empty intestine and abdominal fat weights. Again, (BSFL+Fish) was better ($p < 0.05$) than (BSFL+Soy) for heart weight and liver weight. Wings, breast and thigh weights were significantly ($p < 0.05$) heavier for birds fed on BSF but not for drumstick, and back weights. Birds fed with BSFL+Soy had relatively lower ($p < 0.05$) wings compared to those fed with BSFL+Fish. Haematological parameters were not significantly ($p > 0.05$) different among treatments except for white blood cell count and mean cell volume. BSFL can be used as a replacement for soybean meal and for partial replacement of fish meal to reduce cost of poultry production.

Keywords: Black Soldier Fly; Feed intake; Blood cell; Haematological parameters; Feed conversion ratio; Carcass and Crude protein

INTRODUCTION

The high rate of increase in world population has made advances in agricultural technology imperative. Dairy, poultry, livestock and fish are the main sources of animal proteins for human nourishment. It is therefore, important that the animals and fishes are properly reared with complete diets formulated by the combination of essential nutrients in the right proportions (AIFP, 2004). It is well known that maggots, which appear during the biological treatment of chicken droppings, improve the growth rate of broiler chicken (Awonyini *et al*., 2003). The pollution problems caused by livestock effluent, and the mass accumulation of poultry waste, could be solved by using chicken droppings as a growth medium for certain living organisms, including house flies (*Musca domestica* L.) (Boushy, 1991) as the resulting maggots offer a high protein feed for poultry and fish (Zuidhof *et al*., 2003; Ogunii *et al.,* 2007).

Poultry keeping, according to Abbey *et al.* (2008) is still an economically feasible occupation for many Ghanaians. However, the cost of poultry production keeps rising due to the high cost of feedstuffs. This has stimulated interest in the development of non-conventional feeds (Adejuyitan, 2011) which may increase profitability of farmers. The cost of feed constitutes up to 70% of the cost of producing broilers (The poultry site, 2007) and this makes broiler production too expensive for many farmers. Alternatives to conventional feed ingredients used in formulating broiler feed will help reduce the cost of production and boost local chicken production.

Maggot meal has been reported to be a possible alternative to the expensive protein sources (Sheppard, 2002; Ogunji *et al*., 2007). Calvert *et al*. (1971) suggested the use of maggots as a replacement for some key ingredients in feeds and this was further corroborated by Teotia and Miller (1974). It is cheaper, has good nutritional value, and less tedious to produce than other animal protein sources. It is also produced from wastes, which otherwise would constitute an environmental nuisance. According to Hwangbo *et al.* (2009), dried house fly maggots and pupae contain 56.9 and 60.7% crude protein and 20.9 and 19.2% crude fat, respectively. They have protein and amino acid compositions similar to fish meal and can replace 7% of the fish meal in broiler chicken feed (Hwangbo *et al.,* 2009). Many earlier studies are available on the utilisation of maggots as poultry feed supplement (Onifade *et al*., 2001).

However, the efficacy of the black soldier fly maggot in broiler chicken production is still debatable. In particular, the efficiency of black soldier fly (*Hermetia illucens* L) larvae (BSFL) on broiler growth performance is still unknown in terms of carcass characteristics and the success of reaching market weight. Therefore, the objective of this study was to evaluate the use of black soldier fly larvae as a replacement for fish/soybean meal in the diets of broiler chickens.

*Corresponding Author's Email: anankware@yahoo.com

MATERIALS AND METHODS

The study was conducted at the Poultry Section of the Department of Animal Science of the Faculty of Agriculture, Kwame Nkrumah University of Science and Technology (KNUST), Kumasi spanning eight weeks (February-April, 2015).

Source(s) of Black Soldier Fly Larvae (BSFL)

The BSFL were obtained from a specially prepared unit for the growing of the BSFL using the method as described by Devic *et al.,* (2014). BSFL were reared on3 kg moist spent grain (brewery waste) + 2 kg dry fish feed factory waste + 0.5 litre yeast (liquid) + 4.5 litres of water. Eggs were obtained through adults kept in captivity in large cages (80cmx80cmx150 cm) (Figure 1). These cages are made of a metallic frame covered with a small mesh net. Each cage was mounted on a wooden table to prevent interference by predators (Figure 1). During the night and on rainy days, the cages were kept in a building roofed with transparent plastic sheets (to allow more sunlight) and they were often carried outside to enjoy a direct sunlight. Temperature and humidity were not controlled and so depended on the weather. Five thousand adults were stocked at a time in a cage and they did not require any food, only water was provided using a water reservoir, which delivered water on an absorbing paper sheet at every 30 minutes approximately, water drops were sprayed.

The oviposition sites were made of an odorous substrate (usually brewery solid wastes or moist poultry manure) placed in a bowl, covered with cardboard strips and dried leaves. In general females prefer laying eggs in dried small crevices. For this reason, pieces of cardboard were placed inside the cage for the purpose of oviposition. Eggs were collected from the oviposition sites every two days.

Masses of eggs were then weighed and transferred into small plastic containers (approximately 0.15 - 0.2 mg eggs per container) for 5 to 7 days; duration for the eggs to hatch.

Figure 1: Rearing cage for Black Soldier Fly

After hatching, the small larvae were transferred into culture boxes (45 cm x 76 cm x 16 cm)prepared with a mixture of 3 kg moist spent grain (brewery solid waste) + 2 kg dry fish feed factory waste + 0.5 L yeast (liquid) + 4.5 L water. Five thousand to six thousand five hundred larvae were fed on this mixture for six to seven days (feed is provided *ad libitium* to allow a maximised growth). Throughout the growth period, the boxes are covered by a nylon net held in place by an elastic band to prevent other flies' oviposition.

Larvae were harvested (separated) from the substrate by hand collection. In each box, the substrate was pushed to one side of the box and left for a few minutes. The larvae were then easily harvested (collected) at the bottom of the box where they had migrated (the substrate was removed progressively to allow the larvae migration and for easier collection). Eight hundred grammes larvae were collected on average per box. The larvae were then divided into two, a large portion representing about 80% to 90% of the harvest and a small portion representing 20% or 10%. The large portion was processed into dried larvae for protein whereas, the small portion was allowed to pupate and emerge into adults to continue the cycle.

The large portion larvae were washed with water and placed in buckets containing sawdust overnight to empty their guts. Drying was achieved through gas oven drying for 2 hours or by sun-drying for two to four days depending on the availability of sunshine.

When the small portion larvae (larvae intended to continue the cycle) had reached the stage of prepupae (defined by the change of the colour from white/cream to brown), they were transferred into another container containing sawdust, and kept there until they had turned into imagos. The adults were put into a cage to lay eggs to continue the cycle. Within a cohort or batch of production (i.e. larvae produced from the same batch of eggs) one or two boxes were not harvested in order to get new pupae to repopulate the cages. Pupae were usually kept in a small plastic cage awaiting emergence of adults so as to protect them against some parasitoids. Adults were transferred into the large cages when they emerged (Devic *et al.,* 2014).

Experimental Diets

Three experimental diets were formulated for both starter and finisher phases of broilers as outlined in Tables 1 and 2. In the experimental diets, BSFL replaced fish meal and soybean meal in T1 and T2, respectively whiles all other components of the diet remained same in all the treatments.

Experimental Birds and Design

Two hundred unsexed day old Cobb-500 commercial strains of broiler chickens were purchased for the study. The chicks were obtained from Akate farms, a commercial hatchery located in Kumasi, Ghana and reared in a common brooder house for the first 28 days (0 – 4 weeks). One hundred watt electric bulbs were used to provide continuous light and heat during the brooding stage. One hundred and eighty birds were selected and randomly

Table 1: Percent ingredients in starter diet used to raise broiler birds

Starter diet	**% of Formulation**		
Item	T0 (Control)	T1	T2
Maize	56	56	56
Fishmeal	12	0	12
Soybean meal	15	15	0
Wheat bran	15	15	15
BSF prepupae	0	12	15
Oyster shell	1.25	1.25	1.25
Premix	0.50	0.50	0.50
Salt	0.25	0.25	0.25
Total (%)	**100**	**100**	**100**

Table 2: Percent ingredients in grower-finisher diet used to raise broiler birds

Grower-finisher diet	**% of Formulation**		
Item (%)	T0 (Control)	T1	T2
Maize	60	60	60
Fishmeal	10	0	10
Soybean meal	13	13	0
Wheat bran	15	15	15
BSF Prepupae	0	10	13
Oyster shell	1.25	1.25	1.25
Premix	0.50	0.50	0.50
Salt	0.25	0.25	0.25
Total (%)	**100**	**100**	**100**

assigned to the three treatments with four replicates in a completely randomised design. From the first day of the experiment, birds were grouped into 15 birds per replicate for the three treatments.

Housing

The birds were raised in a deep litter house partitioned into 12 pens measuring 1.82 m x 1.75 m x 0.75m giving a floor space of 0.20 square meters per bird. The pens were thoroughly cleaned and washed with disinfectant before the start of the experiment. Wood shavings were spread on the floor to about 5cm depth to provide litter for the birds.

Management of Birds

Feed and water were offered *ad libitum* because the experiment did not require any form of restricted feeding.
Routine and periodic management practices such as vaccination, drug administration and maintenance of cleanliness within and outside the poultry pens were carried out. Birds were vaccinated against Gumboro, and Newcastle diseases and medication for Coccidiosis was provided at three days of age and again in the third week using Sulfadimidine Sodium 33% (Bremer Pharma GMBH, Germany) via the drinking water. Besides, all necessary bio security measures (Traffic control, sanitation and culling of sick birds) aimed at preventing diseases were put in place during the experiment. Then again, international protocols on the use of animals for experiments were followed using the Institutional Animal Care and Use Committees guidebook (IACUS, 2002).

Parameters Measured

Among the parameters of interest in the study were daily feed intake, total feed intake, water intake, live weight gain, mortality and blood metabolite profile. At the end of the

Table 3: Chemical composition of BSFL, fishmeal and soybean meal

Sample	Dry matter [g/g]	Ash* [%]	Crude protein* [%]	Crude fat* [%]	NDF* [%]	ADF* [%]	Energy (Kcal/g)
BSFL	0.92	17.71	44.82	18.03	39.94	15.57	-
BSFL+Fish	0.87	10.92	21.53	7.56	59.74	10.41	331.43
BSFL+Soy	0.87	7.67	20.76	5.94	43.21	10.37	332.97
Fish+Soy	0.87	14.32	22.61	5.45	43.75	8.13	327.42

Table 4: Effect of BSFL larvae on growth performance of birds

Growth performance indices/bird	Treatments			SEM	P-value
	T0	T1	T2		
Daily feed intake (kg)	0.101^{a}	0.084^{b}	0.103^{a}	0.002	0.001
Total feed intake (kg)	5.63^{a}	4.72^{b}	5.72^{a}	0.12	0.001
Initial weight (kg)	0.51	0.66	0.64	0.089	0.483
Daily weight gain (kg)	0.031^{ab}	0.024^{b}	0.037^{a}	0.002	0.002
Total weight gain (kg)	1.70^{ab}	1.32^{b}	2.07^{a}	0.10	0.002
Final weight (kg)	2.35^{ab}	1.98^{b}	2.71^{a}	0.098	0.002
FCR*	3.41	3.60	2.78	0.25	0.111
Daily Water Intake (l)	0.215^{a}	0.18^{b}	0.208^{a}	0.003	0.001
Water Intake (l)	12.15^{a}	10.08^{b}	11.66^{a}	0.13	0.001
Mortality (%)	11.7	5.0	1.7	4.19	0.279

$^{a,b:}$ Mean values in the same row with different superscript are significantly ($p<0.05$) different.
**FCR = Feed conversion ratio; SEM= Standard Error of Means*; T0 (Control), T1 (BSFL+Soy), T2 (BSFL+Fish)

feeding trial, a sample of the birds (5 males and 5 females) were euthanized and carcass parameters taken. Feed conversion efficiency was determined as well.

Chemical Analysis

Proximate analysis of BSFL was carried out at the Department of Animal Science's Nutrition laboratory, KNUST-Kumasi and repeated at the International Centre for Insect Ecology and Physiology (ICIPE) in Nairobi, Kenya. The metabolisable energy (ME) of BSFL was determined using the equation of NRC (1994): ME (kcal/kg) = (35 x %CP) + (85 x %CF) + (35 x %NFE).

Statistical Analysis

Analysis of variance was conducted on the data collected using GenStat Discovery Edition Version 12, 2012 and the Least Significant Difference (LSD) was used to separate the means that were found to be significant at the 5% significance level.

RESULTS

Proximate Composition of Feed

The chemical composition of BSFL, fish meal and soybean meal is shown in Table 3. BSFL had the highest crude protein (44.82%), followed by T0 (Fish+Soy) (22.61), T2 (BSFL+Fish) (21.53) and the least being T1 (BSFL+Soy) (20.76). In terms of crude fat, BSFL had the highest value (18.03%) followed by T2 (BSFL+Fish), T1 (BSFL+Soy) and T0 (Fish+Soy) with 7.56%, 5.94% and 5.45%, respectively.

Effect of BSFL on Growth Performance of Birds

Table 4 presents the effect of BSFL formulated meal on the growth performance of the birds. The highest feed intake

Table 5: Effect of BSFL on carcass parameters of birds

Carcass Indices (g)	Experimental Diets			SEM	P-value
	T0	T1	T2		
Live weight	3002[a]	2290[b]	3100[a]	740.00	0.0001
Bled weight	2930[a]	2230[b]	3000[a]	680.00	0.0001
Defeathered weight	2840[a]	2100[b]	2820[a]	630.00	0.0001
Heart weight	11.25[ab]	9.75[b]	12.75[a]	0.85	0.0669
Liver weight	66.5[a]	44.5[b]	69.13[a]	4.67	0.0019
Shank weight	104.88[ab]	94.38[b]	113.13[a]	4.87	0.0414
Head weight	67.13[a]	51.25[b]	67.63[a]	2.00	0.0001
Neck weight	162.38[a]	143.38[b]	168.3[a]	5.34	0.0096
Full gizzard weight	68.25[a]	48.13[b]	62.38[a]	2.53	0.0001
Empty gizzard weight	45.38[a]	34.13[b]	45.88[a]	1.66	0.0001
Full intestines weight	143.25[a]	117.13[ab]	123.88[a]	7.67	0.0065
Empty intestines weight	81.88	77.88	71.88	5.58	0.4563
Abdominal fat weight	35.13	45.13	41.32	3.73	0.1849
Dressed weight	2430[a]	1670[b]	2360[a]	680.00	0.0001

[a, b:] *Mean values in the same row with different superscript are significantly ($p < 0.05$) different. SEM= Standard error of means*

Table 6: Effect of BSFL on primal cuts of birds

Primal cuts/bird/g	Dietary Treatments			SEM	P-value
	T0	T1	T2		
Wings	264[ab]	181[b]	270[a]	19.00	0.0761
Thighs	323[a]	204.5[b]	313[a]	16.83	0.0268
Drumsticks	345	275	354	40.12	0.4230
Back	508	348.5	429.5	41.72	0.1570
Breast	809[a]	491.5[b]	708[a]	76.1	0.1237

[a, b:] *Mean values in the same row with different superscript are significantly ($p<0.05$) different.*
SEM= Standard Error of Means

was recorded fromT2 (BSFL+ Fish) (5.72kg) and the control group had the highest water intake (12.15 l). Total feed intake, daily feed intake, daily water intake and total water intake followed the same trend. Treatment T0 (control) and T2 (BSFL+Fish) were significantly ($p < 0.05$) better than T1 (BSFL+Soy) in terms of the above parameters. In terms of total weight gain and final weight, T2 (BSFL+Fish) was superior ($p < 0.05$) to T1 (BSFL+Soy) but statistically ($p > 0.05$) similar to the control. However, there were no significant ($p > 0.05$) differences between the treatments with respect to feed conversion ratio (FCR) and mortality rate (Table 4).

Effect of BSFL on Carcass Parameters of Birds

There were significant ($p < 0.05$) differences among treatments in all carcass parameters measured except for empty intestine and abdominal fat weights (Table 5). Consistently, T1 (BSFL+Soy) was significantly ($p<0.05$) lower than T0 (control) and T2 (BSFL+Fish) for live weight, bled weight, defeathered weight, liver weight, head weight, neck weight, full and empty gizzard weights and dressed weight. Statistically, T2 (BSFL+Fish) was better ($p < 0.05$) than T1 (BSFL+Soy) for heart weight and liver weight. For full intestine weight, the control (T0) was statistically ($p < 0.05$) superior to T2 (BSFL+Fish) (Table 5).

Effect of BSFL on Primal Cuts of Birds

Wings, breast and thigh weights were significantly ($p < 0.05$) influenced by BSFL but not for drumstick, and back weights (Table 6). Birds fed with T1 (BSFL+Soy) had relatively lower ($p< 0.05$) wings compared to those fed with T2 (BSFL+Fish). With respect to thigh and breast weights,

Table 7a: Effect of BSFL on haematology of birds

Haematological indices	Experimental Diets			SEM	P-value
	T0	T1	T2		
HCT (%)	31.6	30.92	30.66	0.96	0.7761
Hb (g/dl)	10.9	9.86	9.65	0.32	0.4930
MCH (pg)	40.5	42.14	40.93	0.68	0.2294
MCHC (g/dl)	32.24	31.89	31.45	0.28	0.1642
MCV (fl)	125.5^{b}	132.19^{a}	129.98^{ab}	1.63	0.0267
RBC ($x10^9$/l)	1.90	2.35	2.37	0.24	0.0310
WBC ($x10^9$/l)	2.59^{a}	2.32^{b}	2.29^{b}	0.064	0.0076

$^{a, b:}$ Mean values in the same row with different superscript are significantly ($p < 0.05$) different. HCT=Haematocrit, Hb=Haemoglobin, MCH=Mean cell haemoglobin, MCHC=Mean cell haemoglobin concentration, MCV=Mean cell volume, RBC=Red blood cells, WBC=White blood cell, pg=pictogram, g/ld=gram per decilitre, l=litre, fl=Femtolitre, %=Percentage, SEM= Standard error of means.

Table 7b: Effect of BSFL on haematology of birds

Haematological indices	Experimental Diets			SEM	P-value
	T0	T1	T2		
PLT (ul)	1875^{ab}	2500^{a}	1000^{b}	490.23	0.0868
LYM (%)	78.91	74.81	75.0	2.31	0.3833
MXD (%)	16.71	20.46	19.91	1.74	0.2804
NEUT (%)	4.13	4.73	5.09	0.81	0.6992
RDWcv (%)	16.19^{a}	13.96^{b}	17.55^{a}	0.65	0.0030
LYM (ul)	211437.5^{a}	172887.5^{b}	170987.5^{b}	8571.65	0.0044
MXD (ul)	43325	47875	45900	4702.97	0.7923
NEUT (ul)	10725	11100	11912.5	2071.09	0.9180

$^{a, b:}$ Mean values in the same row with different superscript are significantly ($p < 0.05$) different. SEM= Standard error of means, PLT (ul)= Platelets, LYM (%)= relative (%) content of lymphocytes, LYM (ul)= the absolute content of lymphocytes, MXD (%)= relative (%) content of mixture, MXD (ul)= the absolute content of the mixture, NEUT (%)= relative (%) content of neutrophils, NEUT (ul)= the absolute content of neutrophils, RDWcv (%)= the relative distribution width of red blood cells by volume, coefficient of variation

T1 (BSFL+Soy) was statistically ($p < 0.05$) lower than the control and T2 (BSFL+Fish) which were similar.

Effect of BSFL on Haematology of Birds

Values recorded for haematology were not significantly ($p > 0.05$) different among treatments except for white blood cells (WBC) and mean cell volume (MCV) (Table 7a). For WBC, BSF larvae-supplemented treatments (T1 and T2) were significantly ($p < 0.05$) lower than the control (T0) and in terms of MCV, T1 (BSFL+Soy) was significantly ($p < 0.05$) higher than the control (Table 7a).

The mean levels of absolute content of lymphocytes showed that, the highest value was recorded in the control with 211437.500ul. Significant differences were recorded among the treatments with respect to the absolute content of platelets (Table 7b). The T1 (BSF+Soy) was significantly ($p<0.05$) lower than the control and T2 (BSFL+Fish) which had the highest value for relative distribution width, RDWcv (%). The mean values of the other indices measured were not significantly ($p > 0.05$) different.

DISCUSSION

The crude protein of BSFL was the highest and T1 (BSFL+Soy) the lowest. The crude protein of BSFL as recorded per the analysis was higher than dried black soldier fly (*Hermetia illucens*) meal (42% crude protein and 35% fat) as recorded by Newton *et al.*(1977). The differences may be attributable to the differences in the diets of the maggots. However, our crude protein value (44.8%) compares favourably with the 45.2% reported by Hale (1973). Dry matter and ash values for BSFL were greater than the other formulations. This contradicts the findings of Newton *et al.* (1977) who reported that the dry matter and ash values for soybean were significantly ($p<0.05$) higher than the larval diet.

The highest feed intake was recorded from T2 (BSFL+ Fish) and the control recorded the highest water intake. The high feed intake might be due to the increased palatability of the BSFL and the fish meal. Generally, there is a high correlation between feed intake and water intake. So, it was surprising that, the highest feed intake was recorded from T2 (BSFL+Fish) whilst the highest water intake was recorded in the control. From metabolic point of view, the fibre, proteins and fatty acids in the control enhanced water intake by the birds compared to the T2 (BSFL+Fish). Then again, the components of the control T0 (Fish+Soy) tends to be denser than the T2 (BSFL+Fish) hence, a likely reason for the increased water intake (Lott *et al.,* 2003). In terms of total weight gain and final weight, T2 (BSFL+Fish) was superior to T1 (BSFL+Soy) but statistically similar to the control. The findings of this study corroborate the findings of other researchers. For instance, Pretorius (2011) reported that house fly larvae meal supplementation in a three-phase feeding system significantly increased average broiler total feed intake, cumulative feed intake, and average daily gain when compared with commercial corn-soy oil cake meal diet. Hwangbo *et al.,* (2009) performed studies using diets containing 5, 10, 15, or 20% maggots fed to broilers, to determine their effects on growth performance and carcass quality. The results showed that feeding diets containing 10 to 15% maggots improved carcass quality and growth performance of broiler chickens. Atteh and Ologbenla (1993) and Bamgbose (1999) concluded that inclusion rates greater than 10% in the diet of broilers decreased intake and performance, perhaps due to the darker colour of the meal, which may be less appealing to chickens.

Consistently, T1 (BSFL+Soy) produced significantly lower live bird weight, bled weight, defeathered weight, liver weight, head weight, neck weight, full and empty gizzard weights and dressed weight than T0 (control) and T2 (BSFL+Fish). The effect of maggot meal on carcass characteristics of broiler chickens was reported by Teguia *et al.* (2002). They observed that broilers fed maggot meal diets had carcass quality that were similar to the control, and the liver and gizzard increased in size, but no signs of toxicity were observed. Indeed, none of the numerous studies on maggots as animal feed has revealed any health problems (Sheppard and Newton, 1999). In feeding broilers, nutritional factors such as the protein and energy content of feed can greatly affect carcass characteristics and fat accumulation (Leenstra, 1989). The T1 (BSF+Soy) had poor carcass characteristics because it had the least protein, fat and energy contents.

Wings, breast and thigh weights were influenced by BSFL meal but not for drumstick, and back weights. Birds fed with T1 (BSFL+Soy) had relatively lower wings compared to those fed with T2 (BSFL+Fish). With respect to thigh and breast weights, T1 (BSF+Soy) was lower than the control and T2 (BSFL+Fish), both of which were similar. This might be attributable to the poor nutritional composition of T1 (BSFL+Soy). However, Awoniyi *et al.* (2003) observed that maggot meal supplementation had no significant influence on dressing percentage and breast muscle weights. Besides, Hwangbo *et al.* (2009) reported that birds from the groups that received maggot supplementation showed significantly higher dressing percentage, breast muscle, and thigh muscle (presented as a ratio to carcass weight) than the control group. The observed discrepancies between this work and that of the Awoniyi *et al*., (2003) and Hwangbo *et al.* (2009) may be due to the fact that, whereas they did partial replacement (supplemented the feeds), our trials had total replacement of soy in one treatment and fishmeal in the other.

All the haematological parameters measured fell within the normal physiological ranges of haematological components of broilers. Similar results were reported by Aeangwanich *et al.,* (2004). The mean levels of absolute content of lymphocytes was highest in the control. This probably improved the immune system of birds fed this meal since lymphocytes determine the specificity of the immune response to infectious microorganisms and other foreign substances. This should have reduced mortalities in the birds fed on the control diet, unfortunately, the control recorded the highest mortality.

CONCLUSION

Black Soldier Flies (BSFs) are abundant in Ghana. These insects do not transmit diseases and so they do not pose any health threat to man as house flies do. These convenient converters of waste can also be employed in the sanitation industry to degrade municipal waste and at the same time generate cheap protein that can be used in the feed industries. BSF larvae are capable of out-competing larvae of other flies and so this could be wisely used to prevent the proliferation of other fly species in public wastes. BSFL that are reared on household wastes (fruits and leftover food) can also be consumed by man. Furthermore, decomposed waste can serve as a rich organic manure for the production of vegetable and ornamental crops. The use of BSFL for decomposing waste will greatly reduce the eutrophication (leaching) of nutrients and associated toxins into water bodies. BSFL can successfully be used as a replacement of soybean and for partial replacement of fish meal to reduce cost of poultry production. A major limitation of the study was the absence of palpability tests for meat from birds fed on the various diets. Future work should include palatability tests as well as the cost benefit ratios of the three treatments. It would also be useful to evaluate the effect of BSFL on layers.

ACKNOWLEDGEMENT

Authors are grateful to the Association of African Universities (AAU) for funding this project. Many thanks to Mr. Benjamin A. Mensah, Dr. Jacob A. Hamidu, Dr. Kwaku Adomako and Prof. Charity Comfort Atuahene, all of the Department of Animal Science for the valuable logistical and statistical support they rendered to us in the course of this project.

REFERENCES

Abbey TK, Alhassan MB, Ameyibor K, Essiah JW, Fometu E, Wiredu MB (2008). Integrated Science for Senior High Schools. Unimax Macmillan Ltd., Accra, pp 469 – 470

Adejuyitan JA (2011). Tiger nut processing: Its food uses and health benefits. American Journal of food technology 6(3): 197 – 201, 2011.

Aeangwanich W, Simarakas S, Chinrasri O (2004). Haematological erythrocytes and serum biochemical value of the Thai indigenous chicken (*Gallus domesticus*) in North-Eastern Thailand. Songkalanakarian Journal of Science and Technology, 26 (3): 425-430.

AIFP (2004). Farming Nigeria's waters: newsletter of the Aquaculture and Inland fisheries Project (AIFP) of the Special Programme for Food Security. Technical Note No. 5, April, 2004.

Atteh JO, Ologbenla FD (1993). Replacement of fish meal with maggots in broiler diets: effects on performance and nutrient retention. Nigerian J. Anim. Prod. 20:44–49.

Awoniyi TAM, Aletor VA, Aina JM (2003). Performance of broiler chicken fed on maggot meal in place fishmeal. Int'l Journal of Poultry Science. 2 (40): 271-274.

Bamgbose AM (1999). Utilisation of maggot meal in cockerel diets. Indian Journal Animal Science 69:1056–1058.

Boushy AR (1991). House-fly larvae as poultry manure converters for animal feed: A review. Bioresour. Technol., 38, 45-49 (1991).

Calvert CC, Martins RD, Eby HJ (1971). Biodegraded hen manure and adult houseflies: Their nutritional value to the growing chick. Livestock Waste Management and Pollution Abatement, Proceedings International Symposium on Livestock Wastes, Ohio State University. 319-320.

Devic E, Anankware JP, Murray F, Little DC (2014). Breeding flies in Ghana: Implications of scaling up from pilot trials to commercial production scale. Book of Abstracts of Conference on Insects to Feed the World, the Netherlands 14-17 May 2014.

GenStat Discovery Ed. Version 12. (2012).

Hale OM (1973). Dried Hermetiaillucens larvae (Diptera: Stratiomyidae) as a feed additive for poultry. J. Ga. Entomol. Soc. 8: 16-20.

Hwangbo J, Hong EC, Jang A, Kang HK, Oh JS, Kim BW, Park BS (2009). Utilisation of house fly-maggots, a feed supplement in the production of broiler chickens. Journal of Environmental Biology, 30(4): 609-614.

Institutional Animal Care and Use Committee Guidebook 2nd Edition (2002). provided by the OLAW office of NIH.

Leenstra FR (1989). Influence of diet and genotype on carcass quality in poultry, and their consequences for selection. In: Recent Developments in Poultry Nutrition (Eds.: D.J.A. Cole and W. Haresign). Butterworths, UK, pp. 131-144.

National Research Council Annual report 1993-94. (1994). Ottawa. https://books.google.com.gh/books?isbn=0470376686. Accessed on April 01, 2015.

Newton GL, Booram CV, Barker RW, Hale OM (1977). Dried Hermetiaillucens larvae meal as a supplement for swine. J. Anim. Sci. 44:395-399.

Ogunji JO, Nimptsch J, Wiegard C, Schulz C (2007). Evaluation of the housefly maggot meal (magmeal) diets on catalase, glutathione S-transferase and glycogen concentration in the liver of Oreochromisniloticus fingerlings. Comp. Biochem. Physiol. A, Molecular and Integrative Physiology, 147 (4):942-947.

Onifade AA, Odunguwa OO, Fanimo AO, Abu AO, Olutunde TO, Arije A, Badatu GM (2001). Effects of supplemental methionine and lysine on the nutritional value of house fly larvae meal (Musca domestica) fed to rats. Bioresour. Technol., 78, 191-194.

Pretorius Q (2011). The evaluation of larvae of Musca domestica (common house fly) as protein source for broiler production. MSc. thesis, Department of Animal Science, Stellenbosch University, Stellenbosch, South Africa. (Accessed 26 Nov. 2014).

Sheppard C (2002). Black soldier fly and others for value – added manure management. University of Georgia, Tifton G.A.31794, USA.

Sheppard C, Newton L (1999). Insect Digestion of Manure. In Lorimor J 2002. Manure management white paper written for the National Center for Manure and Animal Waste Management. AWARE v7.n1.

Teguia A, Mpoame M, Okourou MJA (2002). The production performance of broiler birds as affected by the replacement of fish meal by maggot meal in the starter and finisher diets. Tropiculture. 4: 187-192.

Teotia JS, Miller BF (1974). Nutritive content of housefly pupae and manure residue. British Poultry Science. 15: 177-182.

The poultry site (2007). Economic Approach to broiler production. http:www.thepoultrysite.com/- articles/849/economic-approach-to-broilerproduction. Accessed on February, 2016.

Zuidhof MJ, Molnar CL, Morley FM, Wray TL, Robinson FE, Khan BA, Goonewardene LA (2003). Nutritive value of house fly larvae as a feed supplement for turkey poults. Anim. Feed Sci. Tech., 105, 225-230.