



GROWTH PERFORMANCE, ECONOMICS AND COST BENEFIT ANALYSIS OF BROILER CHICKENS FED DIETS CONTAINING GRADED LEVELS OF TOASTED DEFATTED BLACK SOLDIER FLY LARVAE MEAL

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ABSTRACT

It is evident that over 70% of the expenses related to broiler production are assigned to feed expenditures. Hence, BSFL production holds the potential to offer a sustainable source of protein that is cost-effective and can rival conventional protein sources in the industry. The necessity to augment the supply of animal protein for human consumption arises from the escalating demand for affordable poultry meat globally. This study aimed at evaluating the effects of diets containing graded levels of toasted defatted black soldier fly larvae meal (TDBSFLM) on performance, economics and cost benefits of broiler chickens. A total of 200 chicks were used for the trial. The birds were randomly allotted to five (5) dietary treatments of forty (40) birds per treatment and were replicated four (4) times with 8 birds per replicates in a completely randomized design (CRD). Toasted defatted black soldier larva meal (TDBSFLM) was included at graded levels 0, 2.5, 5, 7.5 and 10% each and were designated as T1, T2, T3, T4 and T5 respectively. Experimental diets and water were administered ad libitum at both starter and finisher's phases. All routine management practices were observed such as brooding, vaccination, administration of drugs and proper hygiene throughout the study. The result shows a significant ($p < 0.05$) effects of treatment in all the growth performance parameters measured at both starter and finishing phase except for total feed intake and daily feed intake. At finishing phase, a linear increase in the performance parameters was observed when BSFLM level increased. From the findings of this study, it was concluded that toasted defatted black soldier fly larva meal (TDBSFLM) up to 10% could be incorporated into broiler diet without any adverse effects on growth performance. More so, considering the live weight, cost per kg gain and profit of birds as the inclusion levels increase, it was therefore recommended that TDBSFLM at 10% inclusion level can be used in broiler chicken feed.

Keywords: Growth performance, economics, cost benefit, BSFLM, Broiler chickens and inclusion levels.

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INTRODUCTION

Insects have been considered as human food in some part of the world (Tabata *et al.*, 2017). Due to some societal distaste, the use of insect in poultry nutrition has been more preferred by consumers than direct consumption by humans. (De Marco *et al.*, 2015). The use of insect meals in animal feed formulation could be a novel way to improve feed and food security (Van Huis, 2013, Bukkens, 1997).

With the Recent developments in animal nutrition, there is a renewed interest in the use of insects as feed ingredients in animal nutrition. (Nyakari *et al.*, 2017, Spranghers *et al.*, 2017). Scientific literatures have established that edible insects have a high content of protein, essential amino acids, vitamins and minerals (Fitches *et al.*, 2019). It has also been demonstrated that insect meals can be used as a feed source or food, and as such it can significantly alleviate the global food problem (Van Huis, 2013, Nyakari *et al.*, 2017). There are numerous findings of some insect which are used as feed ingredients for livestock such as pigs, poultry, and fish (Vernooij *et al.*, 2019, Newton *et al.*, 2005).

The larvae stage of BSFL larvae has a unique characteristics that makes it one of the promising insect species for industrial and commercial production (Payne *et al.*, 2016). The prepupa has a high crude protein and ether extracts of up to 47% and 35% on a dry matter basis respectively. (Nyakari *et al.*, 2017, Newton *et al.*, 2005, Newton *et al.*, 1997, Oluokun , 2000). This makes them a potential and a suitable feed ingredient for pigs, poultry, and also fish diet. Therefore, the insects should be reared under controlled and healthy conditions. Facts from numerous studies have established that the partial inclusion of black soldier fly larvae in feed has shown a significant growth performance of commercial fish, poultry and pig (Newton *et al.*, 2005, Sheppard *et al.*, 1994, Oluokun, 2000, Solomon *et al.*, 1991). In the Europe, BSFL meal has been included in the European Union Feed Material Register, which makes the insect industry grow rapidly. The European government authorized the use of only seven species of insect including BSFL for use in aqua feed in 2017 in no time, there is a probability that Insect meal would be generally acceptable as an appropriate feed ingredient for use in pigs and poultry nutrition worldwide (Nyakari *et al.*, 2017, St Hilaire *et al.*, 2007).

It is evident that over 70% of the expenses related to broiler production are assigned to feed expenditures. Hence, BSFLM production holds the potentials to offer a sustainable source of protein that is cost-effective and can rival conventional protein sources in the industry.

The necessity to augment the supply of animal protein for human consumption arises from the escalating demand for affordable poultry meat globally (Nalle *et al.*, 2012). The replacement of fish meal by 50% and 100% using larvae meal resulted in a decreased cost of tilapia production by 18% and 28%, respectively (Ajani *et al.*, 2004). In a comparative analysis of cost of larvae production versus that of fish meal, Fashina-Bombata & Balogun (1997) noted that the cost of larvae meal production was significantly lower, accounting for less than 20% of the cost of producing the same quantity of fish meal. The rise in the price of fish meal is attributable to the diminishing potential supply (IMF, 2010). With the expansion of the global population, the competition between animals and humans for protein sources will intensify (Ravindran & Blair, 1993; Nalle *et al.*, 2012). Consequently, there is a necessity to establish alternative protein sources for animal feeds to uphold the affordability of protein. This study aimed at evaluating the effects of graded levels of toasted defatted black soldier fly larvae meal (TDBSFL) on performance, economics and cost benefits of using on broiler chickens.

MATERIALS AND METHODS

Description of study area

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

Source of Black soldier fly larvae

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

Processing of Black soldier fly larvae

Toasted defatted larvae

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

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

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

Chemical analysis of Black soldier fly larvae meal

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

Design and Managements of experimental birds

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

Experimental diets

T1 - Control (0% Toasted/Defatted BSFLM inclusion (TDBSFLM0%))

T2 – Toasted/Defatted BSFLM inclusion (TDBSFLM 2.5%)

T3 - Toasted/Defatted BSFLM inclusion (TDBSFLM 5%)

T4 - Toasted/Defatted BSFLM inclusion (TDBSFLM 7.5%)

T5 - Toasted/Defatted BSFLM inclusion (TDBSFLM 10%)

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

	Treatments				
	T1 (Control) (0%)	T2 (TDBSFLM) (2.5%)	T3 (TDBSFLM) (5%)	T4 (TDBSFLM) (7.5%)	T5 (TDBSFLM) (10%)
Ingredients (%)					
Maize	47.20	47.20	47.20	47.20	47.20
Maize offal	10.00	10.00	10.00	10.00	10.00
Soybean meal	41.00	38.50	36.00	33.50	31.00
Toasted defatted BSFL	0.00	2.50	0.00	0.00	0.00
Toasted defatted BSFL	0.00	0.00	5.00	0.00	0.00
Toasted defatted BSFL	0.00	0.00	0.00	7.50	0.00
Toasted defatted BSFL	0.00	0.00	0.00	0.00	10.00
L-lysine HCL	0.10	0.10	0.10	0.10	0.10
DL-methionine	0.20	0.20	0.20	0.20	0.20
Vit/min premix	0.25	0.25	0.25	0.25	0.25
Bone meal	0.50	0.50	0.50	0.50	0.50
Salt	0.50	0.50	0.50	0.50	0.50
Total	100	100	100	100	100
Calculated Analysis					
Metabolizable energy (Kcal/kg)	2925.52	2937.28	2949.03	2960.79	2972.54
Crude protein	23.19	23.33	23.48	23.62	23.76
Crude fibre	4.67	4.78	4.89	5.00	5.12
Fat	3.40	3.50	3.61	3.71	3.81
Lysine	1.38	1.31	1.24	1.16	1.09
Methionine	0.51	0.50	0.48	0.47	0.45
Calcium	0.40	0.39	0.39	0.38	0.38
Phosphorus	0.32	0.31	0.31	0.30	0.29

Biomix chick premix per kg of diet: Vit. A 10,000 IU; Vit. D₃ 32,000 IU; Vit. E 23,000mg; Vit. K 2,000mg; Vit. B₁ 1,800mg; Vit B₅ 500mg; Pantothenic acid 7,500mg; Vit. B₁₂ 150mg; Folic acid 750mg; Biotin 100mg; Choline Chloride 300,000mg; Cobalt 3,000mg; Iodine 1,000mg; Iron 20,000mg; Manganase 40,000mg; Selenium 200mg; Zinc 30,000mg; Antioxidant 1250.

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

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

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

Biomix chick premix per kg of diet: Vit. A 10,000 IU; Vit. D₃ 32,000 IU; Vit. E 23,000mg; Vit. K 2,000mg; Vit. B₁, 800mg; Vit B₅ 500mg; Pantothenic acid 7,500mg; Vit. B₁₂ 150mg; Folic acid 750mg; Biotin 100mg; Choline Chloride 300,000mg; Cobalt 3,000mg; Iodine 1,000mg; Iron 20,000mg; Manganese 40,000mg; Selenium 200mg; Zinc 30,000mg; Antioxidant 1250.

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

Data collected

Growth Performance of broiler chickens fed diets containing graded levels of toasted Black soldier fly larvae meal.

Weekly performance of the birds was determined by measuring the body weight gain (BWG), feed conversion ratio (FCR). Body weight gain of each week was calculated by subtracting the previous week gain from the current week weight. The feed intake of each bird recorded weekly was calculated by subtracting the weight of the diet used from the total weight of the diet allocated to the pen. Feed conversion ratio was calculated by dividing feed intake of each bird by the corresponding body weight gain. A feed conversion value close to 1 signifies more feed efficient to BWG of the bird.

$BWG (g) = (\text{final body weight, g} - \text{initial body weight, g})$

$FCR = (\text{total feed intake, g}) / \text{final body weight, g} - \text{initial body weight, g}$

3.1.10 Cost- Benefit Analysis of Feed containing graded levels of toasted defatted Black soldier fly larva meal.

At the end of the research study (d56), the following parameters were used to determine the cost-benefits of the feed used as described by Medugu *et al.* (2010).

$\text{Cost of feed per Kg (N)} = \frac{\text{Quantity of ingredients X cost per Kg ingredients}}{100}$

$\text{Cost of feed consumed per bird (N)} = \text{Cost per kg of feed X total feed intake per bird (kg)}$

$\text{Cost per kg gain} = \text{Cost of feed per kg x Feed Conversion ratio}$

$\text{Production cost} = \text{Cost of vaccine} + \text{cost of drugs} + \text{cost of transportation} + \text{cost of water} + \text{cost disinfectant}$

$\text{Total cost} = \text{Cost of feed consume per kg per bird} + \text{Cost of production} + \text{cost of chicks}$

$\text{Cost benefit ratio} = \text{Total cost} / \text{feed intake}$

$\text{Revenue generated per bird} = \text{Final Weight (kg)} \times \text{cost price/kg live weight}$

$\text{Profit} = \text{Revenue generated} - \text{total cost}$

Statistical analysis:

All data obtained were subjected to analysis of variance using the general linear model procedure of Statistical Analysis System (SAS, 2010). Significant differences among treatment means were separated using Tukey, T-test and Duncan multiple range test (Duncan, 1955).

RESULTS

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

The performance of broiler chickens fed graded levels of Black soldier fly larvae meal (BSFLM) at the finisher phase is presented in Table 3. In all the parameters measured, the value of final weight (FW) (2066.5, 2146.0, 2430.1, 2523.3, 2811.1g), total weight gain (TWG) (1461.5, 1431.7, 1745.1, 1715.3, 2007.1g), total feed intake (TFI) (3791.91, 3895.68, 3731.3, 3890.17, 3967.38g), and daily feed intake (DFI) significantly ($P < 0.05$) increased with increasing the inclusion levels from 0 to 10% across all the treatment. Similarly, an improved FCR ($p < 0.05$) had been observed in bird fed T4 (1.54) and T5 (1.41) compared to other treatments at the finisher's stage.

Economics and cost benefit analysis of broiler chickens fed graded levels of toasted Black soldier fly larvae meal (0-8 weeks)

The results of the economics and cost benefits analysis of broiler chickens fed graded levels of toasted Black soldier fly larvae meal from starter to finishers phase are presented in Table 3. The cost of feed per kg of broiler chickens fed graded levels of TDBSFLM ranged from ₦117.75 to ₦128.99 with the highest value obtained in T3 (₦128.99) while the lowest cost in T1 (₦117.75). The highest cost of feed consumed per bird was recorded in T4 (₦750.08) and the lowest was recorded in T1 (₦654.73). Cost per kg gain were higher in T1 (₦211.95) while the lowest was obtained in T5 (₦173.76). T4 (₦1700.08) had the highest total production cost and T1 (₦1604.69) had the lowest. The cost benefit ratio were as follows ₦288.61, ₦290.53, ₦299.24, ₦291.01 ₦285.96 for T1-T5 respectively with the highest value recorded in T3 (₦299.24) while the lowest was obtained

in T5 ₦285.96. Furthermore, the highest revenue generated and profit was recorded in T5 (₦4215.00) and (₦2536.04) while the least values in (₦3000.00 and (₦1395.31) respectively were recorded in T1.

Table 3: Growth performance, Economics and cost benefit analysis of broiler chickens fed diets containing graded levels of toasted Black soldier fly larvae meal (week 0-8)

Parameters	Treatments					SEM
	T1 (TDBSFL0)	T2 (TDBSFL2.5%)	T3 (TDBSFL5%)	T4 (TDBSFL7.5%)	T5 (TDBSFL10%)	
Final weight (g)	2006.5 ^b	2146.0 ^b	2430.1 ^{ab}	2523.3 ^{ab}	2811.1 ^a	246.22
Total Weight gain (g)	1461.5 ^b	1431.7 ^b	1745.1 ^{ab}	1715.3 ^{ab}	2007.1 ^a	201.72
Total Feed intake (g)	3791.91	3895.68	3731.30	3890.17	3967.38	137.73
Feed conversion Ratio	1.88 ^a	1.81 ^b	1.53 ^{bc}	1.54 ^c	1.41 ^c	0.03
Mortality (%)	0.00	0.00	0.00	0.00	0.00	0.00
Cost of feed per kg (₦/kg)	117.75	123.28	128.99	128.44	124.12	NA
Cost of feed consume/bird (₦)	654.73	700.23	719.76	750.08	728.06	NA
Cost per kg gain (₦/kg)	211.95	211.09	193.48	192.66	173.76	NA
Total cost (₦)	1604.69	1650.23	1669.76	1700.08	1678.06	NA
Cost benefit ratio (₦/kg)	288.61	290.53	299.24	291.01	285.96	NA
Revenue generated (₦)	3000.00	3210.00	3645.00	3780.00	4215.00	NA
Profit (₦)	1395.31	1559.77	1975.24	2079.92	2536.04	NA

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

Note: Cost of feed, total cost and revenue generated were calculated based on market price of ingredients and items during the study period.

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

Discussion

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

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

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

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

In this present study, zero morbidity and mortality was observed at the finisher's stage. It is suggested that the antioxidant of the BSFLM due to the presence of chitin appears to have a beneficial effects by improving the immune response of chickens (Sanchez *et al.*, 2017, Oliveira *et al.*, 2008). It was proved that the chitin found in BSFLM exhibits a prebiotics properties as well as bacteriostatic effects on bacterial (Ngo and Kim, 2014)

Economics and cost benefit analysis of broiler chickens fed different inclusion levels of toasted Black soldier fly larvae meal (0-8 weeks)

The total cost and cost of feed consumed per bird increased as the inclusion levels of Black soldier fly larvae meal increases across all the treatment groups. The increase in the inclusion level of BSFLM in broiler diet and the concomitant increase in total feed cost, total cost and final body weight agreed with the work of Mijinyawa *et al.* (2016) and Anankware (2018), who reported that increasing the level of BSFLM resulted in increased feed intake, live body weight of the birds than those fed non-BSFLM diet. The higher feed consumed per bird, total

cost and cost per kg gain recorded in this study was higher than that of Medugu *et al* (2010), who reported N213.56 and N113.99 as the highest feed cost and cost per kg gain respectively. This could be attributed to the difference in price of ingredients as at the time the research were conducted. Furthermore, the higher feed intake and total cost observed in T4 and T5 were in turn translated to higher live weight and profit as supported by Mijinyawa *et al.* (2016).

Conclusion

From the findings of this study, it was concluded that

1. Toasted defatted black soldier fly larva meal (TDBSFLM) up to 10% could be incorporated into broiler diet without any adverse effects on growth performance.
2. Incorporation of BSFLM improved the cost benefits of using it in the diets of broiler chickens

Recommendation

Considering the live weight, cost per kg gain and profit of birds as the inclusion levels increase, it is therefore recommended that TDBSFLM at 10% can be used in broiler chicken feed.

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