OPTIMAL BROILER PRODUCTION FUNCTIONS USING BLACK SOLDIER FLY LARVAE MEAL AS PROTEIN SUBSTITUENT.

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Abstract:

This investigation was performed to provide information on the optimal broiler production, with emphasis on feed cost reduction by substitution of conventional protein inputs, with a novel black soldier fly larvae meal (BSFLM). Graded inclusion levels of BSFLM were substituted for full fat soy bean meal FFSBM) at 1.5%, 2.5%, 3.5%, 4.5%, and 5.5%. There was significant reduction (p< 0.5) in marginal production cost (MPC) from 2.5% substitution levels. The MPC reduction showed positive progression at higher inclusion levels, the optimal inclusion was 4.5%. Other evaluated performance indices were growth rate, feed consumption, feed conversion efficiency, marginal cost analysis, quadratic programming, feed cost index, and profitability index. BSFLM substitution is indicated as a viable cost reduction strategy, for small and medium scale broiler production in the post-covid 19 economy.

Key words; Post covid19 Economy, Feed cost reduction, Black Soldier Larvae

INTRODUCTION

Distortionary impact of the Covid19 global epidemic; The Covid19 pandemic has led to significant impacts on life as we knew it. On January 2020, the World Health Organization (WHO) declared COVID-19 as a global health epidemic.

According to a recent World Bank publication, (World bank report, April 2020), it is projected that there will be a 2.1 percent decline in GDP growth for sub-Saharan Africa and a loss between US$37 billion and US$79 billion due to the pandemic. The publication has predicted the potential of COVID 19, creating a serious regional food security crisis and contraction of agricultural production between 2.6 percent and 7 percent should there be trade blockages." (FAO, 2020).

The negative impact of the Covid 19 pandemic on agricultural primary production can be better examined, by narrowing down the study to a specific subsector of the food production value chain. The production of broilers in Nigeria has been selected as a specific area of study.

In response to dwindling foreign exchange income due to poor sales returns from crude oil, a lot of pressure has been on the local currency, the Naira. The domino inflationary pull has distortions and negative in several existing paradigms within the poultry production value chain, leading to increase in the price of all agricultural produce across the board. Poultry feed inputs, which have alternative use as human food, have experienced upwards price pressures.

Shift in food primary production costs upwards; for the poultry industry, this will include feed, drugs, day-old chicks etc.

Shift in consumer demand patterns; Price will become a major determinant of food choice. Consequently, protein food demand will decline in favour of energy foods.

Shift in food production models; as costs increase, small to medium scale producers will be pushed out of production, since they would not be able to leverage on the economics of large-scale production, unlike the large scale producers.

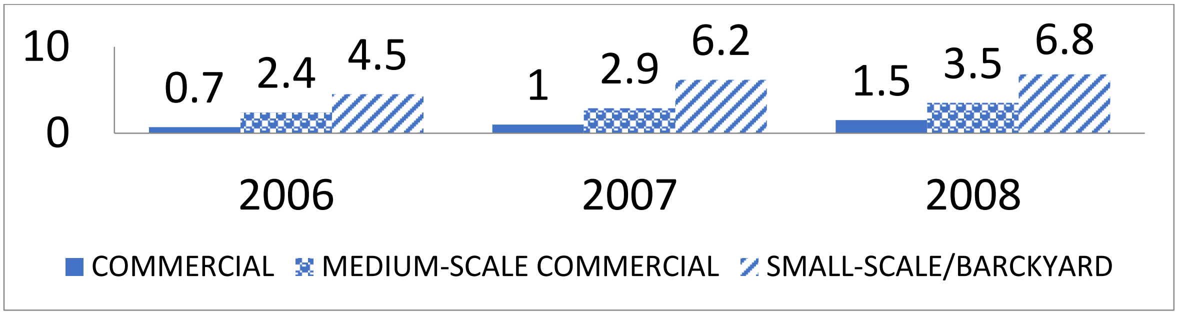
Overview of poultry production Table 1.0 shows the general structure of the broiler production subsector.

TABLE 1. STRUCTURE OF POULTRY (BROILER) PRODUCTION

TOTAL BIRDS ¬ 150 MILLION

SECTOR I- COMMERCIAL PRODUCERS (MORE THAN 10,000 BIRDS)
SECTOR II- MEDIUM-SCALE COMMERCIAL (2,500 – 10,000 BIRDS)
SECTOR III A – SMALL-SCALE COMMERCIAL (500 – 2,500 BIRDS)
SECTOR IIIB – BACK YARD (A FEW – 1,500 BIRDS)
SECTOR 4 – (A FEW – 200 BIRDS OR MORE) (SOURCE-FAO 2008)

B - COMPARATIVE ANALYSIS OF BROILER PRODUCTION SECTORS (2006 – 2008)



It is obvious that the small-scale/backyard poultry producers, form the bulk of its production economy. They would also be the most negatively affected by the progressive production inputs distortions.

As a countermeasure, there must be a paradigm shift in food production systems to ensure that they are sustainable and profitable at small-holder levels to avert hunger and malnutrition.

Poultry feed as focus of intervention; Feed cost remains the greatest production impute cost, in broiler production. Kamran et al, (2008); Moosavi et al, (2011), impacting directly on farm productivity, thus on broiler profitability.

High cost of imputes particularly protein source namely; soybean cake, groundnut cake and fish meal has always been a serious challenge affecting commercial poultry production. (Adeniji 2007), it is economically intelligent, therefore, to focus on cheaper protein sources as a sustainable measure in ensuring that smallscale producers are effective participants in the post Covid 19 economy. The most utilized feed protein source currently, is soy bean meal (SBM).

The similarity of insect dry matter (DM) content to soy bean meal dry matter example fat (30–40% DM) and protein content (40–60% DM), Makkar et al.(2014) Makes insect attractive as possible soy bean meal substitute. Since commercial production of these insects will be cheaper than soy meal, it makes a lot of sense to use it to replace soy beans perhaps it might lead to stabilization of broiler production cost. Scavenging Chickens are very well known to pick insects as part of their meal throughout their life, this clearly shows that they adapted to feeding on insects as part of their meal Bovera et al. (2015a). Its therefore very reasonable to include insect in the poultry ration as a protein source and to initiate commercial insect production for that purpose. Insect is recommended by FAO for use in human as food and animal feed as a tool for poverty alleviation (FAO 2010).

Available literature strongly supports a total or partial replacement of SBM with insect meal. There has been, no report of negative effects on growth of insect meal fed chicks, rather there has been many descriptions of similar or even better growth performance in chicks when compared to SBM. Also there is no report of negative effect on digestibility of nutrients. Rather digestibility seem to improved, with insect meal in poultry diet when compared with SBM: this is particularly true when the insect meal has a comparable amino acid profile and replaces the whole of SBM in the diet Khatun et al. (2003, 2005).

Much research effort before now, had been on the use of the insects rather than the immature stages in poultry diets. In this study, the focuses will be on the black soldier fly larvae an immature stage of the insect.

Black soldier fly larvae (Hermetia illucens)

Naturally BSF larvae are found in poultry manure, but they also grow well in organic wastes like vegetables fish offal and coffee bean pulp. There is a suggestion that the larvae contain natural antibiotics, Newton et al. (2008). The larvae can be used either dried and ground or live and chopped.

Chitin found in the exoskeleton of the insect has been show to affect positively the poultry immune systems, and this can reduce antibiotic usage. Also of interest is the insects ability to digest manure in great quantity, thus helping a great deal in west management.

Effect of black soldier fly meal on poultry performance

BSF has been well studied and referenced as protein substitute in poultry feed (Hale 1973). They are not normally seen as pest or pathogen vectors as they avoid human contact. Oluokun (2000) demonstrated that the nutritional profile of BSF is comparable to fish meal, and, in some aspects, better than SBM. He thus suggested that BSF meal could replace fish meal or soybean meal, partially or completely, in the broiler diets with no adverse effect on the Physiological parameters including, body weight gain (BWG), feed intake (FI) and feed conversion ratio (FCR). The feeding of dried BSF larvae as a substitute for SBM resulted in a similar BWG but a lower FI as compared to control indicating an improved FCR Makkar et al. (2014). Feeding trail carried out by Maurer et al. (2016) with partly defatted meal of dried BSF larvae in small groups of laying hens, contained 12 and 24% meal replacing 50 or 100% of soybean cake used in the respective control diet. There were no significant differences between feeding groups all through the three weeks of the experiment with regard to egg production, FI, egg weight and feed efficiency. The tendency was (P = 0.06) lower albumen weight in the 24% meal group; there was no difference in yolk and shell weights. No health disorders or mortality was recorded. The DM of faeces increased with increasing proportions of meal in the diet, with a significant difference between 24% meal and the control groups (P = 0.03). Increased black faecal pads was observed in the 12% and 24% meal groups. Higher DM of faeces and Presence of dark, firm faecal pads and higher faecal DM with 24% suggest that in this diet the proportion of meal was too high. The causes of these differences are not well understood. Cullere et al. (2016) tested three diets in growing broiler quail as control, 10% defatted BSF larvae meal (substituted 28.4% soybean oil and 16.1% SBM) and 15% defatted BSF larvae meal (substituted 100% soybean oil and 24.8% SBM). They observed the same BWG, FI, FCR and mortality rate in all the dietary groups of quail. Apparent digestibility of nutrients (DM, OM, CP, EE and starch) was overall comparable among the three groups except EE, whose digestibility was the highest (P < .001) in control (92.9%) and 15% BSF meal (89.6%) groups. Broiler quails did not express any preference toward control or 15% BSF meal diets in a feed trail choice and there was no difference in breast meat weight and yield, among all groups.

Cost advantage of substitution of BSF meal in poultry diet; BSF larvae are harvested and processed into meals with no purchasing cost. This study was aimed at assessing the possibility of substituting BSF meal that is readily can be easily and cheaply available for soy bean meal, which is a relatively expensive conventional protein concentrate in broilers feed. BSF meal is an insect protein source that can be easily produced in large amounts and have no food value to humans.

MATERIALS AND METHODS

In the study, Two hundred and forty unsexed day-old broiler chicks OF THE Arbour Acre genetic pool were obtained through veterinary agents. The birds were allocated to six dietary treatments randomly, with four replicates of ten chicks for each treatment group. The five experimental diets had BSFLM meal substituted for SBM AT 1.5% 2.5%, 3.5%, 4.5% and 5.5 % inclusion levels. The feed was formulated to be iso-proteinic (23%), and iso-calorific (3,100 kCal/kg). The birds were vaccinated as per schedule against Gumboro, New Castle disease, infectious bursal disease, and fowl pox.

BSFLM Preparation; In an adaptation of the method described by Sheppard et al (2002), a colony of adult black soldier flies were obtained and trapped in a wooden frame box, having sides covered with fly mesh. The bottom of the box contained broiler grower feed (18% protein, 2900kCal/kg energy). The feed was thoroughly sprinkled with water, when larvae appeared, the feed mass was transferred to transparent plastic buckets containing clean water thoroughly stirred. The larvae floated to the water surface, was collected using a narrow-meshed sieve, and oven dried at 55° for 36 hours. The dried larvae were ground using a conventional kitchen blender, deposited in plastic zip-loc pouches, and placed in a refrigerator. The A.O.A.C. (1980) method was used to perform proximate analysis.

Daily feed intake and weekly weight gain data were collected. All the data were subjected to analysis of variance using the model for completely randomized design and where significant, treatment means were compared by using Duncan's multiple range test (Steel and Torrie, 1980). The nutritional composition of the BSFLM is shown in TABLE 1.

TABLE 1.0- CHEMICAL COMPOSITION BSFLM (ON DRY BASIS)

DRY MATTER	CRUDE PROTEIN	ETHER EXTRACT	CRUDE FIBRE	ASH	GROSS ENERGY
92%	41%	34.8%	7.0%	16.1%	5203.49 kcal/kg

The day old chicks were housed in gas=heated brooding chamber, and were fed ad libitum, during the period of the experiment.

Data treatment Exclusion parameters: Star et al (2020), method was adapted to mark specific observation outlier and excluded from the dataset before statistical analysis, should the residual (fitted—observed value) be greater than 2.5 times the standard error of the residuals data of the set (ANOVA). All observation on feed intake and weight was considered outlier, and not used for the calculation of corresponding feed consumption and growth.

TABLE 2.0 – EXPERIMENTAL DIET FORMULATION

INGREDIENTS	**CONTROL**	**1.5**	**2.5**	**3.5**	**4.5**
Maize	60.25	60.25	60.25	60.25	60.25
Fish meal	3.00	3.00	3.00	3.00	3.00
Blood meal	5.00	5.00	5.00	5.00	5.00
Groundnut cake	7.00	7.00	7.00	7.00	7.00
Salt	0.25	0.25	0.25	0.25	0.25
Mineral Vit. Premix*	0.25	0.25	0.25	0.25	0.25
Bone meal	1.00	1.00	1.00	1.00	1.00
Oyster shell	1.25	1.25	1.25	1.25	1.25
Full fat soybean meal	22.00	20.50	19.50	18.50	17.50
BSFLM	00.00	1.50	2.50	3.50	4.50
Total	100.00	100.00	100.00	100.00	100.00
Proximate Composition (Analysed Values)					
Dry matter (%)	95.51	94.87	94.99	96.61	95.92
Crude protein (%)	21.50	21.58	21.65	21.80	21.48
Ether extract (%)	5.22	5.43	5.58	6.72	6.81
Crude fibre (%)	3.32	3.26	2.96	3.27	4.35
Ash (%)	1.82	1.77	1.61	1.97	2.20
M. E. (Kcal/Kg)	3,143	3,133	3,220	3,117	3,165

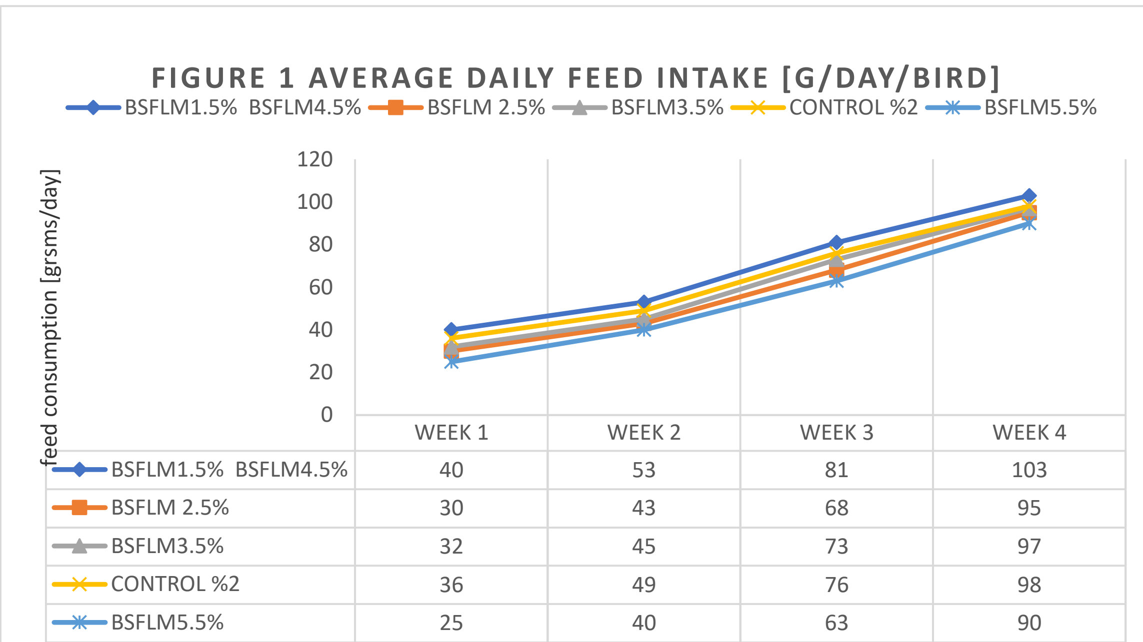
Vitamins supply per Kg:-Vit A, 8000IU; Vit D3, 1200IU, Vit E, 3IU, Vit K3, 2mg; Vit B2, 3mg; Vit B3, 10 Zinc, 50mg; Copper 2mg; Iodine 1.2mg, Cobalt, 0.2mg; Selenium, 0.1mg Vit B5, 150mg; Manganese, 80mg.

Results and discussion.

Comparative feed intake; the average feed intake of the six dietary groups are presented in figure 1. There was significantly higher difference (p>0.05) in feed consumption between the dietary groups BSFLM 1.5, BSFLM 2.5, BSFLM 3.5, BSFLM 5.5, and the control dietary group. The BSFLM 4.5% group did not show significant difference in feed consumption vis a vis the control group.

In (2014) Makkar et al, had demonstrated that feeding of dried BSF larvae as a substitute for SBM gave a similar BWG but a lower FI as comparable to control thus showing an improved FCR.

It is possible that the observed slight lower feed intake levels for the test dietary groups, might be due to the chitin levels in the feed.



	WEEK 1	WEEK 2	WEEK 3	WEEK 4
BSFLM1.5% BSFLM4.5%	40	53	81	103
BSFLM 2.5%	30	43	68	95
BSFLM3.5%	32	45	73	97
CONTROL %2	36	49	76	98
BSFLM5.5%	25	40	63	90

Growth rate:

Figure 2, depicts the mean growth rate per week of the dietary treatment groups, in comparison to the control group. The mean growth rate is calculated as the mean value of the cumulative growth rates per week for the various dietary treatment groups.

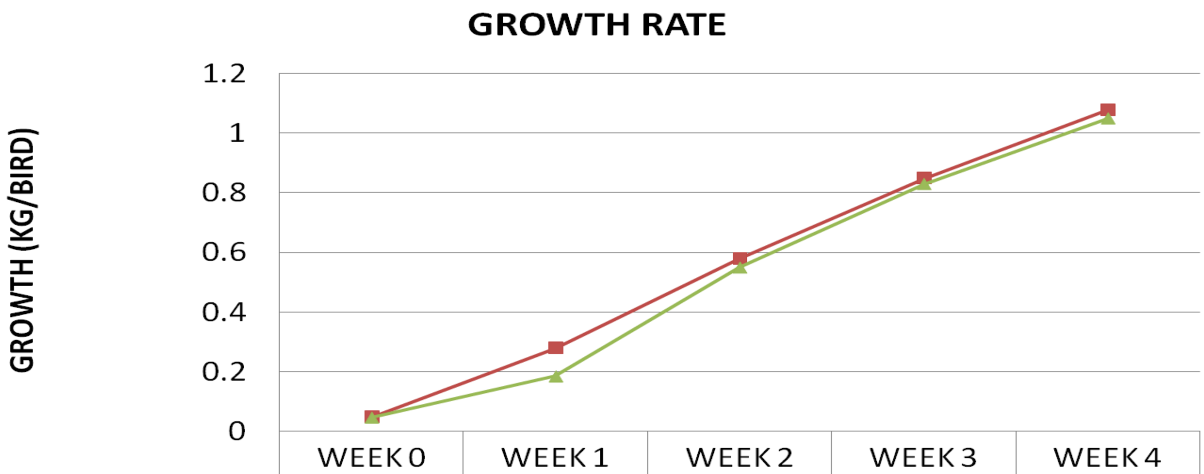
The mean growth rate for the treatment groups compared favourably with the control. Bovera et al (2015) had obtained similarly encouraging results, when they substituted varying inclusion rates of yellow mealworm larvae (Tenebrio molitor), for soybean meal in broiler diets.

Also, Awoniyi et al (2003), formulated five isocaloric and isonitrogenous diets to broilers, in which they replaced fish meal with various levels of maggot meal, and found that optimal growth rate was at 25% substitution level. They noted that maggot meal was a suitable alternative for fish meal at specified optimal inclusion levels.

Growth performance data for the experimental group was encouraging, this may be attributable to the amino acid and metabolizable energy profile of BSFLM. According to Oluokun (2000), who compared BSF larvae with SBM on broiler production. The BSF meal is comparable to fish meal, and, in some aspects, better than SBM in its nutritional profile. Oluokun thus suggested that BSF meal could replace fish meal or soybean meal, partially or completely, in the broiler diets no adverse effect on the body weight gain (BWG), feed intake (FI) and feed conversion ratio (FCR).

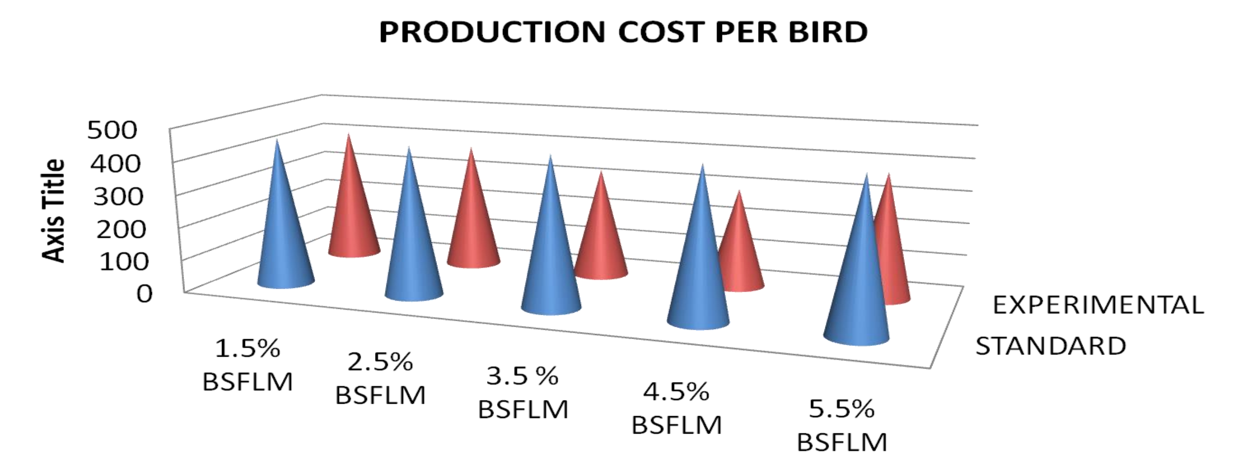
In a feeding trail carried out by Maurer et al. (2016), with partly defatted meal of dried BSF larvae in small groups of laying hens, He used experimental diets contained 12 and 24% meal replacing 50 or 100% of soybean cake used respectively in the control diet. There were no significant differences between feeding groups with regard to egg production, FI, egg weight and feed efficiency for three-week duration of the trail. The tendency was lower albumen weight (P=0.06) in the 24% meal group; with no difference in yolk and shell weights. There was no record of mortality and no sign of health disorders.

Figure 2- Comparative growth rates for the dietary groups.



	WEEK 0	WEEK 1	WEEK 2	WEEK 3	WEEK 4
Column1					
EXPERIMENTAL	0.048	0.28	0.58	0.85	1.08
STANDARD	0.047	0.1852	0.55	0.83	1.05

Key economic indicators



	1.5% BSFLM	2.5% BSFLM	3.5 % BSFLM	4.5% BSFLM	5.5% BSFLM
STANDARD	454.5	454.5	454.5	454.5	454.5
EXPERIMENTAL	410	385.4	335.8	302.8	382.3

The average percentage reduction in cost of production per bird (APCR), for the duration of the trial, was calculated. This was used as an economic indicator, to determine the cost advantage, if any, of using BSFLM as alternative protein source in broiler diet.

The APCR was derived from the formula APCR $\frac{\boldsymbol{COST\ OF\ STD - COST\ OF\ XPD}}{\boldsymbol{COST\ OF\ STD}}\ \boldsymbol{X\ 100}$

Where STD – Standard Diet

XPD – experimental diet

Profitability was maximized at the 4.5% inclusion level, were the APCR value was 33.4

Conclusion and recommendations

Obviously, BSFLM provides a highly economically viable, alternative protein source in broiler feed production.

More work is needed in the areas of developing an efficient production process for BSFLM for the small-scale poultry farmer.

It is also important to work on developing a pool of genetically standardized, variants of the black soldier fly, with emphasis on chitin content, fat levels, and amino acid profile (especially the essential amino acids).

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