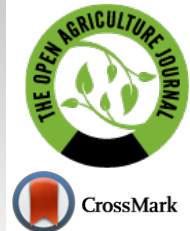




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## REVIEW ARTICLE

# Nutritional Evaluation of Insect's Pupae-Larvae and its Utilization in Poultry Compound Feed

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### Abstract:

This paper is aimed to review the nutritional evaluation of insect's pupae-larvae and its utilization in poultry compound feed, using an appropriate keyword search in agricultural and biological science. The paper surveys previous studies on the nutrient composition of insect's pupae-larvae and its utilization in poultry compound feed. The literature review shows that most of the insect species have higher nutritional values and amino acid profiles than the regularly used feed such as fishmeal and soybean meal. In addition, studies find that the broiler chicken quality is not affected or even improved in some scenarios when insect-based feed substitutes the conventional feed by 10% - 100%. However, the growth performance of laying chickens is limited using the insect-based feed.

**Keywords:** Compound feed, Conventional feed, Insect meal, Nutrient composition, Pupae-larvae, Poultry.

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## 1. INTRODUCTION

For centuries, insects have been a part of the human diet and are currently consumed by humans in many parts of Asia, Latin America, and Africa. These are considered as supplement diets of approximately 2 billion people [1]. Due to the current food insecurity situation prevailing in many developing countries and future challenges of feeding over 9 billion people in 2050, lately, these have received wide attention as a potential alternate major source of protein [2]. As a result of increasing incomes, urbanization, environment and nutritional concerns, and other anthropogenic pressures, the global food system is undergoing a profound change.

Poultry feed contributes 60-80% of the total production cost with the protein ingredient accounting for about 70% of the total feed cost [3]. Poultry production currently depends on fish and soy meal as the main protein ingredients, utilizing 10% [4] and over 85% [5] of the total world's fish and soy meal, respectively.

These conventional protein sources have become scarce and expensive [3] thus affecting poultry and other livestock species production. The impact is and will continually be felt most in developing countries where fish and poultry contribute about 61% of the human protein intake [6]. By considering the growth rate of the poultry sector in developing country and the

requirement of major poultry feed ingredients like maize, fish meal, and soya bean meal, more emphasis should be taken to identify more new feed resources with their quality and availability [7]. The Food and Agriculture Organization of the United Nations (FAO) recommended insects as an alternative protein source in poultry feed [4]. However, the practice of insect as poultry feed in Ethiopia is not known but scavenging chickens use insects as one of their protein sources [8], in addition, there is no compiled profiles that shows the nutritional composition of different edible insects and their replacement level that can motivate policymakers and researchers to focus on insects. Therefore, this paper will nutrient composition and utilization of insect pupae-larvae in the poultry diet and help researchers who want further investigation insect meal production and replacement levels in Ethiopia.

## 2. METHODOLOGY

Appropriate keyword search engines biased towards agricultural and biological sciences were conducted. The sets of keywords used were: 'insects for feed', 'insect nutrient /chemical composition', 'insect utilization', 'insect for poultry', and 'protein sources' as well as several combinations of them. Journal websites publishing research on insects such as the Journal of Insects as Food and Feed and Journal of African Entomology were also searched. Information published by Universities and research and development organizations involved with insects for food and feed, as well as non-

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scientific articles and websites on livestock and fish production were also reviewed to capture information on-going research that is yet to be published. Tables and Graphs are used to present the difference of nutritional values, amino acid profiles, and utilization of insects on broiler and layer chicken performance.

### 3. LITERATURE REVIEW

#### 3.1. Nutritional Value and Utilization of Insects in Poultry Feed

##### 3.1.1. Insects as Animal Feed

Insects as feed appear to be favorable; research by Smith and Barnes [9] reported over 70% consumer acceptance rates. Insect feed is perceived as “more sustainable, to have better nutritive value, but a lower microbiological safety compared to conventional feed”. Also, perceptions included a lower protein import dependency and a higher valorisation of waste; in general, consumers perceive benefits to outweigh the risks involved [10]. However, there is a need to better inform the public on the use of insects as feed, for example evidence from the recent European Food Safety Authority (EFSA) report which demonstrates that “insects raised on pure vegetable substrates in feed does not pose chemical or biological risks to consumers” [11].

In a traditional Ghanaian home in northern Ghana, each farmer has several termitaria that are harvested daily to augment the protein requirements of their poultry birds. This is harvested very early in the morning (before sunrise) with cow dung, dried grass, and/or corn cobs/stalk and given to the fowls. This is fed to the fowls first in the morning before allowing them out of their pen to forage on their own. This is repeated in the afternoon and evenings depending on their availability [12]. Such a practice not only provides cheap and good nourishment for the birds but also helps the farmers keep their birds in check since the fowls will always return on time

for ‘mid-day lunch and dinner’. This serves as a security check and also prevents the fowls from roaming very far from home. Throughout West Africa, termites are collected in the wild to feed poultry [13]. Chippings of termite mounds are collected and given to poultry on-farm, particularly to chicks [13].

In Ethiopia, about 99% of poultry are managed under extensive management systems where they fulfilled their nutritional requirements through scavenging. Among the different scavengable feed categories, insect feed is common [8]. Hailemariam *et al.* [14] also observed that about 4.21% of the crop physical composition of scavenging layers chickens were insects at different seasons of the year. Moreover, using insects as poultry feed is a common and traditional practice in the African continent. Accordingly, there are high numbers of edible insects reported in the world (Table 1).

Accordingly, worldwide, insects commonly used as animal feed are the black soldier fly, the housefly, mealworm beetles, locust-grasshopper-cricket, and silkworm [12]. Accordingly, the nutritional composition of insects and insect meal and their use as a component in the diets of both broilers and laying chickens are discussed hereunder.

##### 3.1.2. Nutrient Composition

The crude protein content varied considerably across insect species and life stages (Table 2). Growing conditions and sample preparation (*e.g.*, insufficient removal of growing substrates) contribute to the observed variation within insect species and life stage. The highest crude protein content was found for the silkworm pupae (75.5% of dry matter) followed by housefly pupae and earthworm larvae (70.95% and 63.04% of dry matter, respectively), *visa-vise*, relatively lower crude protein was recorded similar for termites and black soldier fly prepupae (42.3% of DM) (Table 2); Arango Gutierrez *et al.* [15] reported 40 to 45% of crude protein content for black soldier fly prepupae. The main protein source used in poultry feed, soybean meal and fishmeal has a crude protein content of 51.8% and 70.8% of dry matter, respectively [16, 17].

**Table 1. Number of edible insect species reported in the world.**

Order	Common English Name	Number of Species
Thysanura	Silverfish	1
Anoplura	Lice	3
Ephemeroptera	Mayflies	19
Odonata	Dragonflies	29
Orthoptera	Grasshoppers, cockroaches, Crickets	267
Isoptera	Termites	61
Hemiptera	True bugs	101
Homoptera	Cicadas, leafhoppers, mealybugs	78
Neuroptera	Dobson flies	5
Lepidoptera	Butterflies, moths (silkworms)	253
Trichoptera	Caddis flies	10
Diptera	Flies, mosquitoes	34
Coleoptera	Beetles	468
Hymenoptera	Ants, bees, Wasps	351
<b>Total</b>		<b>1,681</b>

Source [12].

**Table 2. Chemical composition of commonly used insects in comparison to fishmeal and soybean meal.**

Insects	GE (MJ/Kg DM)	CP (% in DM)	CF (% in DM)	EE (% in DM)	Ash (% in DM)	Ca	P	Source
Grasshoppers	21.75	47.55	8.2	9.15	4.55	ND	ND	[18] [19]
Maggots (housefly larvae)	15.72	48	5.89	31.76	ND	ND	ND	[20]; [21]
Black soldier fly larvae	22.1	56	7	24.75	15.3	7.56	0.90	[22]; [17]
Black soldier fly prepupae	ND	42.3	ND	ND	ND	ND	ND	[15]; [17]
Housefly larvae	22.25	51.35	5.1	17.5	11.75	0.47	1.6	[17]
Housefly pupae	24.3	70.95	15.7	15.25	7.65	ND	ND	[21]; [17]
Mealworm larvae	26.8	45.83	3.97	34.3	2.51	1.65	ND	[23]; [17]
Termites	4.55	42.3	11	41.0	5.0	ND	ND	[24]
Silkworm pupae	22	75.6	7.25	21.65	6.95	ND	ND	[25]; [26]
Soybean meal	18.23	51.8		3	6.61	0.39	0.69	[17]
Fish meal	15.38	70.8	6.7	14	8.05	4.34	2.79	[27]; [16]

GE = Gross Energy, MJ/KG = Mega joule per Kilogram, CP = Crude Protein, CF = Crude Fiber, EE = Ether Extractor, ND = Not Determined, DM= Dry Matter;

Contents of crude fat for insects are presented in Table 2. Accordingly, high crude fat is registered for termites, mealworm larvae, maggots (housefly larvae), black soldier fly larvae, and silkworm pupae with 41.0, 34.3, 31.76, 24.75, and 21.65% of dry matter, respectively. Within these insects' species and specific life stages, considerable variation in crude fat content was reported (Table 2). Relatively lower crude fat content was noted for grasshoppers, housefly larvae, and housefly pupae (9.15, 17.5, and 15.7% of dry matter, respectively). However, this lower content of crude fat recorded for the upper mentioned insects is higher in comparison to the substrates of conventional feeds of soybean meal and fishmeal which contains 3% and 14% of dry matter, respectively [16, 17].

Information on crude ash content was readily available for grasshopper (4.55% of DM), black soldier fly (15.3% of DM), housefly larvae and pupae (11.75% and 7.65% of DM, respectively), mealworm larvae (2.51% of DM), termites (5.0% of DM), and silkworm pupae (6.95) (Table 2). Except for few insects, insects meal constitutes higher contents of ash than the conventional feeds of soybean meal (6.61% of DM) and fishmeal (8.05% of DM).

### 3.1.3. Amino Acid Profiles

The amino acid composition (g/100 g of total amino acids) of the insect's meal indicated that amino acids lysine and methionine is higher in insect's meal than the conventional feeds of fishmeal and soybean meal (Table 3). For instance, silkworm pupae meal indicates that amino acids lysine (7.52) and methionine (3.88) is higher in silkworm pupae meal than fishmeal and soybean meal [28]. Ji *et al.* [29] reported that the silkworm meal amino acid profile is almost similar but superior to soybean meal for better performance. Silkworm meal had a high proportion (58.84%) of essential amino acids (Table 3); lysine (7.52), methionine + cystine (4.85), arginine (6.31), phenylalanine (5.58), and valine (5.70). However, leucine

(7.04) was lower than that of soybean meal (7.5), but in the case of mealworm, leucine (10.7) was higher than that of leucine in fishmeal and soybean meal (7.2 and 7.72) respectively. As far as the amino acid profile is concerned, almost all insects' meal can replace the conventional feed resources of fishmeal and soybean meal without limiting of the essential amino acids (Table 3). However, if a diet is inadequate in any essential amino acid, protein synthesis cannot proceed beyond the rate at which that essential amino acid is available. That amino acid is called a limiting amino acid [17]. The results of the present literatures in Table 3 regarding the amino acids profile inspired the replacement of fishmeal and soybean meal with insect meal in poultry ration.

## 3.2. Performance of Poultry Fed Insects as Feed Ingredient

### 3.2.1. Broiler chickens

According to Teun and Guido [17], under intensive poultry rearing conditions, common housefly larvae (maggots) should be used in a dry form. Replacement of fishmeal by 50% maggot meal shows significant differences on feed intake, bodyweight gain and feed conversion ratio, and economics of production (Table 4). Awoniyi *et al.* [32] conducted a performance study with 3- to 9-wk-old broiler chickens that were fed five isonitrogenous and isocaloric diets in which maggot meal replaced 0, 25, 50, 75, and 100% of 4% fish meal in the diet. The diet with 25% of fish meal protein replaced with maggot meal was the most efficient in terms of average weekly body weight gain and protein efficiency ratio. At 9 wk of age, however, live, dressed, and eviscerated weights, as well as relative length, breadth, and weights of the pectoral and gastrocnemius muscles, were not significantly influenced by the diets. Hwangbo *et al.* [33] and Pretorius [21], also observed that 25% maggot meal diet yielded better live weights, feed intake, and daily gain compared to the 25% fish meal diet. Moreover, maggot meal could replace 100% groundnut cake (22% of the diet) with no adverse effect [34].

**Table 3. Comparative essential amino acid profile (g/100g of total essential amino acids) of insect meal and conventional feed of soybean meal and fishmeal.**

Insects		Essential Amino Acid Profile												Source	
		Arginine	Cystine	Histidine	Isoleucine	Leucine	Lysine	Methionine	Phenylalanine	Threonine	Tryptophan	Tyrosine	Valine		Total
BSF	Larvae	5.2	ND	3.6	4.4	7.2	6.5	1.9	4.0	3.3	1.22	ND	6.7	44.0	[30]
	Pre-pupae	5.1	ND	3.7	4.5	6.8	5.7	1.7	3.9	3.9	ND	ND	6.1	41.4	[17]
HF	Larvae	4.9	0.7	2.8	3.2	5.7	6.9	2.2	5.0	3.3	3.2	5.1	4.4	47.5	[20]
	Pupae	4.7	0.4	2.4	3.5	5.3	5.5	2.1	4.4	3.2	ND	5.2	4.2	40.9	[17]
MW	Larvae	5.8	5.8	3.6	6.7	10.7	6.4	2.1	5.4	5.1	1.6	7.8	8.2	69.0	[17]
GH	Meal	5.6	1.1	3.0	4	5.8	4.7	2.3	3.4	3.5	0.8	3.3	4.0	41.5	[18]; [31]
		4.69	0.52	2.79	4.33	6.5	6.6	2.12	5.17	4.48	ND	6.32	5.3	48.8	[26];
SW	Pre-Pupae	6.31	0.97	3.28	4.73	7.04	7.52	3.88	5.58	5.58	1.70	6.55	5.7	58.84	[28]
	Pupae	6.2	0.8	2.4	4.2	7.2	7.5	2.7	3.9	4.1	1.0	3.1	4.9	48	[16]
	FM	2.90	0.74	1.02	2.07	7.72	2.62	0.52	2.12	1.66	0.65	3.11	2.6	27.73	[28]

Note:BSF= Black Solider, HF= Housefly, MW= Mealworm, GH= Grasshopper, EW= Earthworm SW= Silkworm, FM= Fishmeal, SBM= Soybean Meal; ND= Note Determined;

**Tables 4. Effects of replacing conventional feeds with different sources of insect on the performance of broilers as compared with the control treatment group.**

Insect Feed	FI (g/d)	BWG (g/d)	DW (Kg)	FCR	M (%)	Source
Maggot meal at 50% FM replacement	45.71*	189.2*		4.26*	0.00	[38]
BSFLM at 33.3% FM replacement	152.2	53.8	1.71	0.354	ND	[39]
Silkworm Pupae meal replacing 100%of SBM	4434.7	-2003.7 *	1.377	2.21	ND	[37]
Mealworm larvae replacing 100%of SBM	192.4	53.40	ND	-3.62*	ND	[40]

Note: FI= Feed intake; BWG= Body weight gain; FCR= Feed conversion ratio; DW= Dressing weight; M= Mortality ; \* = indicated that there is slight difference; \*\* = indicated that there is high significant difference; -ve = signs indicated negative impacts comparing to the conventional dietary conventional feed.

Black Soldier Fly Larvae Meal (BSFLM) contains a high amount of crude protein and ether extract. The feed intake levels and growth of the birds indicate that the BSFLM contain reasonable amounts of essential amino acids that could guarantee the quality of protein in the BFLM (Table 2). Feed intake was high for all birds in both the control group and treatment 33.3% of diet contacting BSFL meal (Table 4). However, the mean feed intake for both groups were similar. This clearly suggests that the BSFLM was palatable as standard fish meal and had no adverse effect on feed consumption. The similarities in feed intake and growth variables observed between the control group and the group fed Black Soldier Fly Larvae Meal (BSFLM) based diet indicated that replacing 33.3% of fish meal with BSFLM did contribute significantly to the protein needs of the birds. This contributed to the similarity in both weight gain and feed conversion efficiency. Moreover, the levels of essential amino acids in BSFLM appeared to be sufficient to comply with requirements for poultry [17, 30].

Feed intake and weight gain was slight effects with the 100% replacement of soybean meal by silkworm pupae meal; however, the highest feed intake and body weight was recorded for diet replacing 75% soyaben meal with silkworm meal (Table 4). Khatun *et al.* [35, 36] also reported that the silkworm meal has a pleasant taste and is palatable and acceptable by broiler birds. According to Rafi *et al.* [37], feed conversion ratio of the birds showed no significant differences at any inclusion level of the silkworm meal. Khatun *et al.* [35]

recommended that improved performance of broilers with the replacement of soybean meal by silkworm meal (up to 75%) could be related to its higher content of essential amino acids, minerals, and energy.

Replacement of dietary fishmeal by Maggot meat at 50% shows a significant effect in feed intake, body weight gain and feed conversion ratio (Table 4). Based on these results, it seems that maggot meal could be an inexpensive replacement for fish meal in broiler-chick feeding. Têguia *et al.* [41]. also concluded that maggot meal could replace fish meal in broiler diets based on technical and economic criteria. Moreover, the replacement of fishmeal at 33.3% of BSFLM has no difference on feed intake, body weight gain, and feed conversion ratio. Pretorius [21] also reported that House fly larvae meal supplementation in a three-phase feeding system significantly increased average broiler live weights at slaughter, total feed intake, cumulative feed intake, and average daily gain when compared with commercial corn-soy oil cake meal diet. Pretorius [21] conducted a performance study with broilers using seven dietary treatments consisting of a commercial diet (corn-soy) and diets supplemented with 10% housefly larvae meal, 10% fish meal, 25% housefly larvae meal, 25% fish meal, 50% housefly larvae meal, and 50% fish meal. The diets were formulated according to nutrient specifications, but for the 25 and 50% larvae and fish meal diets, protein supply was greater than the requirement. No significant differences in performance results were observed between a 10% housefly larvae meal and a 10% fish meal supplementation. Broilers fed

the 10% larvae meal or 10% fish meal diets had significantly greater breast muscle portions relative to carcass weight than the chicks that received the commercial corn-soy based diet. The 25% housefly larvae meal supplementation significantly improved broiler live weights, feed intake, and cumulative feed intake when compared with the 25% fish meal supplementation diet in the growth phases.

Rafi *et al.* [37]. showed that 100% of the silkworm meal may be replaced with soybean meal in the broiler finisher ration without having an adverse effect on blood profile and carcass quality. However, the best results in feed intake and live body weight may be achieved with 75% replacement of soybean meal by silkworm meal in the commercial broiler finisher ration.

Dutta *et al.* [42] found that grasshopper meal can replace a significant quantity of fish meal in broiler ration when he fed 0%, 50%, and 100% grasshopper meal to broiler chicken. Liu and Lian [43] recorded that grasshopper meal could replace up to 40% of fishmeal in broiler diets with similar growth rate and feed consumption as the control diet. Ojewola *et al.* [44] found that using grasshopper meal (unspecified species) in broiler diets at 2.5-7.5% led to decreased weight gain and feed efficiency of broilers, in spite of an increase in the protein content of the carcass. In addition, Ojewola *et al.* [45] recorded that using grasshopper meal at 2.5% led to a decrease in the cost of the diet and increased profitability without affecting the performance of the broiler. Muftau and Oloredo [46] found the best results when he replaced grasshopper meal (*O. hyla*) in Japanese quail diets. The control of grasshopper populations has been achieved by the rearing of free-range chickens. Furthermore, Khusro *et al.* [47] found that free-range chickens fed on grasshoppers had a preferable taste and a higher market price than those fed with conventional commercial feed. Wang *et al.* [48] mentioned that the grasshopper, *Acrida cinerea* (Thunberg), could be an accept-able raw material in broiler feed. Moreover, Sun *et al.* [49] found that chicken that ate grasshoppers on farms produced superior quality meat and reduced the grasshopper populations that damage the pastures.

### 3.2.2. Laying Chickens

In a performance study with 50-week-old laying hens, all the diets contained whole-cassava root meal (390.2 to 424.6 g/kg) as a source of energy with soybean meal and cassava leaf

meal (plant protein sources) supplying 50 and 25% of the total dietary protein, respectively [50]. The results indicated that maggot meal can replace fish meal in diets based on cassava roots and leaves; it could replace 50% of the dietary animal protein supplied by fish meal without adverse effects on egg production and shell strength [50]. However, Jubril *et al.* [51] observed a slight decrement on egg production per hen on replacing 100% of fishmeal by maggot meal.

The egg weight was slightly lower in hens fed BSFL at 50 g/kg compared with those fed the basal diet and BSFL at 10 g/kg (Table 5). This could be because the energy level in the diet utilization of hens fed BSFL at 50 g/kg was lower than in the diet utilization of hens fed the basal diet and those fed BSFL at 10 g/kg [22]. This is also true that energy levels decreasing from 2800 to 2700 kcal/kg, egg weight decreased from 47.66 to 46.41 g (Table 5). Dutta *et al.* [42] reported that increasing dietary energy had positive effects on egg weight. The same yolk color and fertility rate slightly lower in the diet fed BSFL than the hens fed the control diet (Table 5). However, the feed conversion ratio was significant higher with the inclusion of BSFL in the layer diet. Finke [52] reported that the replacement of fish meal with larvae meal by 100 g/100 g led to a significant increase in the feed conversion ratio of laying hens. Feed intake and weight gain were not influenced by dietary treatments of BSFL (Table 5).

The results of egg production, egg weight, body weight, and feed efficiency are presented in Table 5. The egg production, egg weight and feed efficiency throughout the experimental period, in spite of significant difference, suggests that the quality of Silkworm Pupae (SWP) protein was better to that protein concentrate for laying hen (Table 5). However, Dutta *et al.* [42] found a reduction of intake and weight gain in diets based on 50 to 100% substitution of fishmeal by silkworm meal; they suggested that SWP contained some factors, which impaired the digestive utilization of nutrients that in turn reflected egg production (Table 5). Other findings also reported that replacing 100% of protein concentrations by silkworm pupae meal showed the best technical and economical performance on feed to egg conversion ratio, egg size, shell thickness, grading, light yellow yolk, no mortality, feed cost, and cost per dozen eggs [48]. Mahanta *et al.* [53] also observed that 50 and 100% substitution of fishmeal by silkworm pupae detrimental effects on certain breeding performance such as ejaculation volume, quantity, and quality of spermatozoa of poultry.

**Tables 5. Effects of replacing dietary conventional feeds with different protein sources of insect meal on the performance of layers as compared with the control treatment group.**

Insect Feed	FI (g/d)	BWG (g/d)	FCR	HDEP (%)	EW (g)	Source
BSFL replacing 100% Fishmeal	79.4	48.5	1.71**	+58.8***	-46.41*	[22]
Maggot meal replacing 100% FM	125	1.64	3.83	-55.2*	64.8	[51]
Silkworm meal replacing 100% SBM	125.12	1.44	2.16	63.5	61.04	[28]
SWP replacing 100% protein concentration	107	1.45**	2.24*	79.33*	60.01	[36]

**Note:** FI= Feed Intake; BWG= Body weight gain; FCR= Feed conversion ratio; HDEP= Hen day egg production; EW= egg weight; YC= Yolk color; FR= Fertility rate; HA= Hatchability; \* = indicated that there is slight difference; \*\* = indicated that there is high significant difference; -ve = signs indicated negative impacts comparing to the conventional dietary conventional feed.

Egg yolk color was affected by dietary treatments; the egg yolk color of eggs laid by hens fed BSFL at 50 g/kg was significantly brighter than those fed the basal diet and BSFL at 10 g/kg. This indicates that the hens fed BSFL were not able to use the color pigments in yolk formation. Also, this could be due to the fact that BSFL are not a vegetable product, which could contain carotene or xanthophyllous pigments needed for egg coloration development. A similar result was observed by Jubril *et al.* [51], who found that yolk color was significantly decreased by replacement of fish meal with maggot meal in the laying chicken diet.

According to Mohammed Farooq *et al.* [22], shell thickness and shell weight were significantly affected by the dietary treatment of BSFL. Hens fed 100% fish meal gave the highest thickness and shell weight values. The shell thickness and shell weight were significantly decreased with increasing levels of BSFL in the diet. This could be due to the calcium content in the BSFL meal being lower than that of fish meal. This result is consistent with the findings of Agunbiade *et al.* [50] who reported a decrease in shell thickness and shell weight with increasing levels of BSFL in the layer diet. Fertility rate was show slight negative influence by supplemented BSFL dietary treatments [22]. However, Jubril *et al.* [51] reported increased hatchability of laying hens fed maggot meal.

Dietary supplementation of BSFL shows a significant effect on appearance, texture, taste, and acceptance of egg. The significant improvement observed in the taste of eggs produced by hens fed BSFL could be due to the glutamic acid content being high in BSFL meal (6.85 g/kg) [22].

In general, limited work has been done on using insect's meal as a feed ingredient in layer production and its effects on egg quality parameters, hence, more study for the future are required study its effects on egg productivity, quality, and palatability as long as insect meal has protein of high nutritional value. It can serve as a supplemental protein in poultry.

### 3.3. Digestibility

Little information was found about the nutrient digestibility of the selected insects in broiler chickens. Only three studies determined the apparent fecal digestibility of nutrients. Apparent fecal digestibility of dried housefly meal was evaluated in broiler chickens in two studies. Hwangbo *et al.* [33] fed 4-wk-old broilers a diet with 30% dried housefly larvae meal or soybean meal for 7 day. Pretorius [21] fed 3-wk-old broilers a corn meal-based diet containing 50% dried housefly larvae meal or dried housefly pupae meal. Hwangbo *et al.* [33] reported a very high apparent fecal digestibility of crude protein for housefly larvae compared with Pretorius [21] (98.5% vs. 69%). The latter study also showed that crude protein fecal digestibility was greater for housefly pupae than for the larvae. The digestibility of most amino acids was in both studies around 90% or greater. Pretorius [21] also reported considerably greater apparent fecal digestibility values for individual amino acids than for crude protein.

### CONCLUSION AND RECOMMENDATION

There are about 1,681 edible insect species; however, the

commonly used insects in poultry feeds are black soldier fly, the housefly, mealworm beetles, locust-grasshopper-cricket, and silkworm. Most insect species have higher nutritional values and amino acid profiles as compared with the commonly used conventional feed resources of fishmeal and soybean meal. Among the other insects, silkworm pupae contains higher levels of crude protein, gross energy, and the most limiting amino acids of lysine and methionine contents followed by housefly pupae, mealworm, and earthworm.

It is also proves that the potential of insects for use in poultry production systems. Insect based feed can replace conventional protein sources by 10-100% without affecting the growth performance of poultry, and in some cases, performing better than feeds with conventional protein sources such as fish and soybean meal.

The use of insects in poultry feed is a common practice under Ethiopian scavenging chickens. However, research and private sectors never received attention. Therefore, it is wise to give attention on the availability of edible insect species as animal feed, nutritional value, and their confounding effects for mass rearing and using under small to middium scale poultry farms.

Finally, in Ethiopia, using insect meal as a source of protein in poultry diets specifically and livestock, in general, has not been widely investigated. However, insect rearing such as silkworm for the purpose of silk production is a growing sector; the utilization of byproduct is underutilized. Therefore, it is time to knock every researcher to investigate the utilization of and diversification of silkworm pupae and the identification of potential insect substrates as protein sources.

Research on mass rearing of insects such as silkworm pupae, earthworm, and black soldier fly should be enhanced in Ethiopia to ensure the sustainability of using insects as feed and income diversification. This should include identifying suitable and acceptable substrates for these insects in quantities that fit commercial production. This will not only create employment but also promote sustainable insect production and increased community awareness and acceptability of the practice.

### CONSENT FOR PUBLICATION

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### CONFLICT OF INTEREST

The author declares no conflict of interest, financial or otherwise.

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