JKAU: Met., Env & Arid Land Agric., Sci **Vol. 31** No. 1, pp: 19 – 30 (1444 A.H. / 2022 A.D.)
DOI:10.4197/Met.31-1.3

Insect meal as promising feedstuffs for sustainable poultry nutrition and production with emphasis on black soldier fly *Hermetia illucens*: an updated review

Ali Kh. A. Ahmed, Khalid A. Asiry, Adel D. Al-qurashi, Najeeb M. Almasoudi, Magdi A.A. Mousa, Omer H. M. Ibrahim, Youssef A. Attia and Majed S. Alrefaei
Department of Agriculture, Faculty of Environmental Sciences,
King Abdulaziz University, Jeddah, Saudi Arabia

***Abstract*-- This paper aimed to review the recent advances in using insect meal in poultry nutrition to assess the suitable species, dietary inclusion level, and nutrients profile, advantage, and disadvantage as well. More than 50 research articles, review articles, short communications, and book chapters were obtained from various online databases i.e. Google Scholar, PubMed, and Scopus, using the following keywords insect breeding and insects in poultry nutrition, black soldier fly *Hermetia illucens* (BSF). The selected black soldier fly larvae (BSFL), and pupa (BSFP) are based on growing interest due to easy breeding, valuable protein resource, and economic value. The urgent needs for alternative and locally available feed resources have been substantially increased after the COVID-19 crisis due to different reasons such as lockdown, close of boards, airports, and seaports. Most developing countries are dependent on imported feedstuffs for animal nutrition which was greatly influenced during COVID-19, affecting animal feed chain supply for farm species. That has raised the need for alternative/nonconventional local protein sources to sustain animal protein production. The BSF is a promising and candidate feed resource based on recently published broilers, laying hens, Japanese quail, and ducks' studies.**

Keywords:Insects; poultry, feeds, animal protein, metabolizable energy, amino acids

INTRODUCTION

The Covid-19 crisis demonstrated the necessity of local and non-traditional feed resources and the research for new local resources to achieve food security from animal protein worldwide. The search for new feed sources is vital for poultry feeding. It is essential for the sustainability of the poultry industry in Saudi Arabia due to limiting feed resources due to scarcity of water and the nature of the arid and desert lands. Thus, the price of feed resources was increased dramatically in KSA in the last decades. The increase in poultry feed prices could be attributed to the increasing world's population, desertified land, competition between humans and animals for the same food resources, and the current trend for the use of cereals grains for biofuel production (Jozefak and Enbery, 2015; Khan, 2018; Cutrignelli et al., 2018). In the recent era, a lot of research has been conducted on the use of insects as promising protein sources in Europe, Africa, Asia, and North America (Makkar et al., 2014; Sayed et al., 2019). There is a worldwide interest in feeding poultry on black soldier fly (BSF). The available results indicated that insects are more than a promising food source—especially BSF as a new protein resource in broilers, layers, quails, barbary partridge and duck's feeding hens. Insect meals have many beneficial environmental aspects, including freeing the environment from organic waste and its harmful effects and reducing feed costs (Secci et al., 2018; Secci et al., 2020). It was found that insects are promising sources of protein in poultry feed, which are inexpensive sources that lead to preserving the environment from organic waste and its adverse effects (Bovera et al., 2015; Marono et al., 2015). In addition, they are easy to breed and show low production cost (Makkar et al., 2014; Sogari et al., 2019; Shumo et al., 2019).

The literature review indicates that 13 types of insects that can be used in poultry feeding have been identified (Makkar et al., 2014; Bovera et al., 2016; Sayed et al., 2019; Secci et al., 2018; Secci et al., 2020; Bovera et al., 2015; Marono et al., 2015; Sogari et al., 2019; Shumo et al., 2019), and 7 were approved by EU regulations as feeds (http://data.europa.eu/eli/reg/2017/893/oj) and foods; https://efsa.onlinelibrary.wiley.com/doi/10.2903/j.efsa.2021.6343. The most common types were the black soldier fly, followed by the housefly, the beetle, the locusts, the silkworm, and the cockroach. It was found that protein content ranged from 14 to 75%, the energy ranged from 14.2 to 17.9 MJ/kg, the fat was from3.61 to 35%, the calcium was 0.13 to 7.46%, and the phosphorous 0. 5-2.6%; methionine from1.4 to 3.5% and lysine from 4.7 to 7% (Bosch et al., 2014; Makkar et al., 2014; Bovera et al., 2015; Jozefak and Enbery., 2015; Maurer et al., 2015; Al-Qazzaz et al., 2016; Khan., 2018; Secci et al., 2018; Secci et al., 2020; Marono et al., 2015; Sogari et al., 2019, Shumo et al., 2019; Kawasaki et al., 2019). The literature review indicates that there has a vast difference in the chemical composition of the most common of the BSF used in poultry nutrition (Jozefak and Enbery., 2015; Khan., 2018; Makkar et al., 2014; Shumo et al., 2019; Kawasaki et al., 2019; Al-Qazzaz et al., 2016; Maurer et al., 2015). The amino acids composition of BSF like histidine was found to be 1.3-3.5%, cystine 0.1-2.6%, threonine 1.42-3.7%, methionine 0.58-6.1%, and lysine 2.22-6.6% (Makkar et al., 2014; Jozefak and Enbery., 2015; Shumo et al., 2019; Kawasaki et al., 2019; Al-Qazzaz et al., 2016).

The results also indicate that insect meals can be included in broiler diets up to 10% to replace traditional protein sources such as fish and soybean meals. On the other hand, it can be used in 6-7% in laying hens feed as well as ducks and quail diets, and the results of meat and egg quality indicate that using these levels, insects have no adverse effects on the quality of meat and egg (Makkar et al.,2014; Secci et al., 2020). Also, the BSF meal can be included in layers up to 50% to replace the traditional protein source such as fish meal and soybean meal (Khan., 2018; Makkar et al., 2014; Secci et al., 2018; Kawasaki et al., 2019; Al-Qazzaz et al., 2016; Maurer et al., 2015; Moula and Detilleux., 2019; Spranghers et al., 2017; Secci et al., 2020;). Furthermore, the consumer acceptance of meat and eggs produced from chicken-fed diets containing insects up to 10% showed no harmful effects on the physical and taste characteristics and the acceptance by consumers (Secci et al., 2020). (Al-Qazzaz. et al., 2016; Secci et al., 2018; Secci et al., 2020). Hence, this review focuses on using insect meal in poultry nutrition regarding the life cycle, importance, level, meat, egg quality, and consumer acceptance of poultry products.

MATERIALS AND METHODS

More than 50 research articles, review articles, short communications, and book chapters were obtained from various online databases i.e. Google Scholar, PubMed, and Scopus, using the following keywords insect breeding and insects in poultry nutrition, black soldier fly *Hermetia illucens* (BSF). In the second phase, the names of each black soldier fly larvae (BSFL), and pupa (BSFP) investigated together in the aforementioned databases. The literature obtained were classified and and reviewed to extract the crucial findings such as the importance of insects as poultry feedstuffs, advantages and disadvantages of insects in poultry feeding, species of insect meal used as poultry feed, optimum dietary inclusion level of insects in broilers, and layer rations, and effects of insect meal on meat and eggs quality and the influence on poultry products acceptance by consumers. Furthermore, it extracts key findings such as the life cycle of black soldier fly *Hermetia illucens*, its use in laying hen diets, chemical and amino acid composition of BSF, optimum levels of BSF in layers' diets, and the effect of BSF on quality and acceptance of eggs.

RESULTS

1. Importance of insects as poultry feedstuffs

Nowadays, insect meal is utilized as a cheap food resource in animal nutrition due to several advantages such as low cost of production, decrease environmental pollution due to the use of organic waste for breeding. Insects such as black soldier leaver, house fly, field crickets, and house crickets were found to be a good source for animal nutrition (Makkar et al., 2014; Bovera et al., 2015, Abd El-Hack et al., 2020). Insect meals can be used as a suitable protein resource to partly or replace the traditional feed resources such as fish and soybean meal (Secci et al., 2018; Secci et al., 2020; Bovera et al.,2015; Marono et al.,2015). In addition, insect meals can be used in human nutrition in other parts of the world in Asia and America. Africa and Europe (Khan ., 2018;Shumo et al.,2019; Hong et al., 2020; Stastnik et al., 2021). The positive effect of insect meals includes animal health, gut health, and no adverse impact on product quality or animal performance. Furthermore, insect meal is a source of a bioactive substance such as lauric acid, antimicrobial peptides, and chitin that have immune-enhancing effects (Makkar et al., 2014; Khan ., 2018; Shumo et al.,2019). In addition, there is a growing market trend and a reduction in the cost of organic waste disposal (Makkar et al.,2014; Sayed et al., 2019; Secci et al., 2018; Secci et al., 2020).

2. Species of insects used in poultry nutrition

Table (1) indicates the common ad scientific names of the insects used in poultry nutrition. The result reveals that the BSF is the predominant species used in poultry feeding, followed by house fly, mealworm, locusts, silkworm ad house cricket. Furthermore, the result showed that BSF was the most economical and nutritional species for poultry feeding.

Insect meals are a valuable source of amino acids, with methionine, the 1st limiting amino acid in poultry nutrition, ranged from 1.4-7.9% (references). House cricket is the lowest source of methionine, and BSF was the richest. The second limiting amino acid in poultry diets, lysine, was the highest in the silkworm and the poorest in the BSF (NRC, 1994).

TABLE (1). THE COMMON AND SCIENTIFIC NAME OF SOME INSECT SPECIES USED IN POULTRY NUTRITION

Series Number	Common name	The scientific name of the insect	Reference
1	Black Soldier Fly	*Hermetia illucens*	Makkar et al. (2014); Secci et al. (2018); Secci et al. (2020); Bovera et al. (2015); Marono et al. (2015); Sogari et al. (2019), Shumo et al.(2019); Khatun et al. (2005); Ramos-Elorduy et al. (2002); Giannone .(2003); Liu and Lian . (2003); Saikia et al. (1971); Abd El-Hack et al. (2020);Traksele et al.(2021); Maryam et al. (2021).
2	African Moth	*Gonnimbrasia zambesia*	Liu and Lian. (2003)
3	Field Cricket	*Acheta gryllus bimaculatus*	Makkar et al. (2014); Khatun et al. (2005); Liu and Lian., (2003); Rao et al. (2011).
4	House Cricket	*Acheta domesticus*	Makkar et al. (2014); Khatun et al. (2005); Giannone (2003); Liu and Lian .(2003);.

5	Locusts	*Schistocerca gregaria*	Makkar et al. (2014); Khatun et al. (2005); ; Adeyemo et al. (2008); Halder. (2012); Jintasataporn (2012).
6	Silk Worm	*Bombyx mori*	Makkar et al. (2014); Sayed et al. (2019); Spranghers et al. (2016); Khatun et al. (2005); Ssepuuya et al. (2017); Sheikh et al. (2005).
7	House Fly	*Musca domestica*	Makkar et al. (2014); Sogari et al. (2019); Khatun et al. (2005); Giannone (2003); Saikia et al. (1971)
8	Meal Worm	*Tendorio molitor*	Makkar et al. (2014); Khatun et al. (2005); Bovera et al. (2015); Marono et al. (2015); Sogari et al. (2019); https://www.technologynetworks.com/applied-sciences/articles/why-insect-meal-will-be-the-new-feed-for-animals-in-aquaculture-316569; https://www.idrc.ca/en/project/integrating-insects-poultry-and-fish-feeds-kenya-and-uganda.
9	Lesser Meal Worm	*Alphitobius diaperinus*	Saikia et al. (1971).
10	Tropical house cricket	*Grylloides sigillatus*	Saikia et al. (1971).
11	Jamaican field cricket	*Gryllus assimilis*	Saikia et al. (1971).
12	Cotton leaf worm	*Spodoptera littoralis*	Khan (2018).
13	Peach fruit fly	*Bactrocera zonata*	Khan (2018).

1-2. Comparison of the chemical composition of different insect meals:

The chemical composition of many available insect meals is shown in Table (2). The results indicate that the gross energy value for BSF and HF is similar (22.1 vs. 22.9). Furthermore, results showed the mealworm was the most abundant source of fat, and thus GE and Locusts were the lowest sources of fat and, therefore, GE crude protein value in insect meals ranged from 33-63.3%, with the house cricket, was the most fruitful source, and BSF was the lowest (33-42.1%).

The Ca and P are essential minerals for many body functions and bone and shell formation in chickens. The Ca level in insect meals ranged from 0.38 to 1.01%, with house Cricket being the most abundant Ca. The HF was found to be an excellent source of P, followed by BSF (References).

TABLE (2). THE CHEMICAL COMPOSITION OF THE MOST COMMON SPECIES OF INSECT MEAL USED IN POULTRY NUTRITION

Series Number	Common name	GE, kcal/kg	Fat,%	CP,%	Methionine,%	Lysine,%	Ca,%	P,%	References
1	*Black Soldier Fly*	5281	26	33-42.1	2.1-7.9	4.1-6.6	7.6-0.32	0.4-0.9	Bosch et al.. (2014); Makker et al. (2014); Shumo et al. (2019)
2	*House Fly*	5473	18.9	50.4	2.2	6.1	0.47	1.6	Bosch et al.. (2014); Makker et al. (2014).
3	*Meal Worm*	6405	36.1	52.8	1.5	5.4	0.27	0.78	Bosch et al.. (2014); Makker et al. (2014).
4	*Locusts*	5234	8.5	57.3	2.3	5.8	0.13	---	Makker et al. (2014).
5	*Silk Worm*	2438	25.7	60.7	3.0	7.0	0.38	0.60	Makker et al. (2014).
6	*House Cricket*	---	17.3	63.3	1.4	5.4	1.01	0.79	Bosch et al.. (2014); Makker et al. (2014).

1.3 Importance of black soldier fly:

1-3-1 Life Cycle and Rearing of Black Soldier Fly:

The BSF has four stages in which; the first stage is egg hatches in approximately four days. After that larvae stage has six instars. The larvae take about 22 days to complete their growth. Finally, the BSF larvae transformed to pre-pupa and converted to pupa stage (nonfeeding stage) in 14 days. In the end, BSF's life cycle takes about 45 days (**https://www.seip-eg.com/2020/05/black-soldier-fly.html;**AbdEl-hack et al.,2020), as illustrated in figure 1.

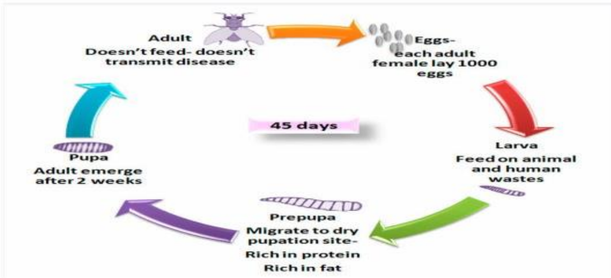

Figure 1: life cycle of BSF https://www.mdpi.com/agriculture/agriculture-10-00339/article_deploy/html/images/agriculture-10-00339-g002-550.jpg

The rearing condition of BSF under laboratory conditions needs a temperature of 27°C and relative humidity (R.H.) of 60% (37). For rearing and production, eggs should be gathered from breaks and fissures close to the larval substrate and accumulated in container woodwinds. BSF hatchlings are most effectively raised on layer squanders in solid bowls under confined layers (Abd El-Hack et al.,2020). A 100,000-bird confined layer house yields 42.26 huge loads of live weight of prepupae for June through August, which is reasonable for domesticated animals taking care of (Abd El-Hack et al.,2020). The BSF hatchling converts many naturals squanders; for example, ruined creatures feed into protein mass and soil compost. Schematic introduction of food blow bioconversion to animal feed employing rearing BSF is represented in Figure 2

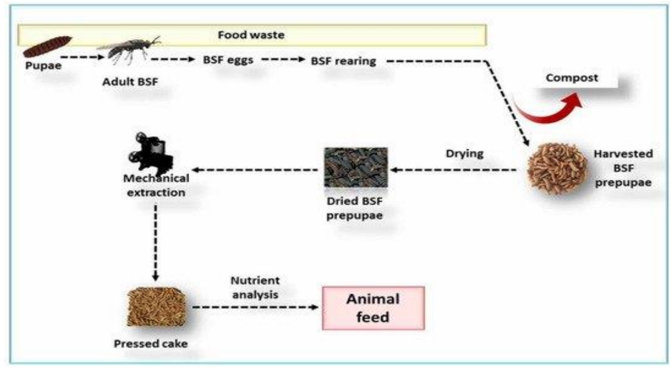

Figure 2: Food waste Bioconversion into animal feed via rearing insect, https://www.mdpi.com/agriculture/agriculture-10-00339/article_deploy/html/images/agriculture-10-00339-g003-550.jpg

1-3-2 Chemical composition of black soldier fly meal:

The chemical composition of the BSF meal is shown in table (3). The result indicates that the gross energy (GE), CP, fat, Ca, P-value have different chemical composition results because some BSF used whole BSF and others used defatted BSF. Also, the type of feed for BSF and life stage influence the chemical composition of BSF (1-6,9,10). In addition, BSF meals are good sources of Ca and P as well as energy.

TABLE (3). THE CHEMICAL COMPOSITION OF THE MOST COMMON BLACK SOLDIER FLY IS USED IN LAYING

Series Number	Common name	GE	CP,%	Fat,%	Ca,%	P,%	Reference
1	BSFL	5282	41.9-45	15-35	0.5-0.86	0.6-1.5	Makker et al., (2014); Khan ., (2018); Jozefiak and Enbery ., (2015); Maurer et al., (2015).
2	BSFL	3103	14.6	5.1	3.5	0.5	Kawasaki et al. (2019)
3	BSFP	3169	16.5	5.1	3.3	0.5	Kawasaki et al., (2019).
4	BSFL	-	16.32	3.61	4.75	0.69	Secci et al., (2020)
5	BSFL	5282	38.46	31.8	2.75	2.6	Shumo et al., (2019).
6	BSF defatted	-	59	11	0.98	0.63	Maurer et al., (2015)

GE= gross energy kcal/kg; CP= Crude protein; Ca=Calcium; P=Phosphorus

1.3.3 Amino Acid Composition and Protein Quality

Black soldier fly is a good source of amino acids, is displayed in table (4). As in Table (4), the rate of amino acids was less in BSF larva than BSF pre-pupa depends for (ISO, 1999). The source of feed for BSF influences the protein quality and thus composition of the essential amino acids according to the type of food provided (Bovera et al., 2015; Marono et al., 2015; Shumo et al., 2019). Bosch et al. (2014) found that nutrient contents of insect meals such as amino acid scores and in *vitro* organic matter and nitrogen digestibility varied substantially according to the feed. For, the first limiting AA for insect meals was the Met+ Cys. The differences could be due to chitin contents, which negatively affect the digestibility of organic matter and protein (Marono et al., 2015).

TABLE (4). SOME AMINO ACID COMPOSITION OF BLACK SOLDIER FLY.

Insect type	Histidine	Cysteine	Threonine	Methionine	Lysine	Reference
Black soldier fly larvae	3.7	NR	3.6	1.4	5.4	Bosch et al. (2014)
Black soldier fly pupae	4.2	NR	3.6	1.7	5.4	Bosch et al. (2014)
Yellow mealworm	4.6	NR	4.0	1.4	5.5	Bosch et al. (2014)
House cricket	5.7	NR	3.6	1.6	5.8	Bosch et al. (2014)
black soldier leavers	2.6	0.7	3.6	1.4	5.6	Jozefiak and Enbery .(2015)
Black soldier Fly	3	0.1	3.7	2.1	6.6	Makker et al. (2014)
Black soldier fly larvae	1.32	0.28	1.42	0.58	2.22	Kawasaki et al. (2019) *
Black soldier fly pupae	1.30	0.28	1.55	0.79	2.51	Kawasaki et al. (2019) *
Black soldier fly	1.476	2.646	2.236	2.193	2.863	**Al-Qazzaz** et al.(2016)
Black soldier fly	3.5±0.3	-	-	6.1±0.8	4.1±0.6	Shumo et al. (2019)

*mean number 3 was on BSF larvae, and number 4 was on BSF pre-pupae.

In the literature, chitin provides non-protein N and supports 1–7 % of the whole-body N (Finke, 2007). Differences in the chitin content of insect protein supplies may hinder the appraisal of protein quality (Bovera et al., 2015; Marono et al., 2015; Abd El-Hack et al., 2020; Traksele et al., 2021). Amino acids contents for insect species vary substantially among investigations (Bosch et al., 2014). For example, the Arginine content in the house crickets, in the current study was (5-7 % of CP) was within the range of other studies (Rumpold and Schlüter, 2013) (4·9–6·0 % of CP) but histidine was higher (3·4 v. 2.1–2·6 % of CP). According to the nutritional plan of insects, methionine in yellow mealworms varied from 0·48 to 1·80 % of CP (Ramos-Elorduy et al., 2002). With the use of insects as a protein supply in animal nutrition it would be essential to scrutinize and monitor the variation in the AA contents. Methionine and cystine in poultry meat meal were lower in the present study than reported in the literature, i.e., 1·05 vs. 1·07 % by Clapper et al. (2001) to 2·11 % by Johnson et al.(1998) and 0·69 %vs. 1·34 % by Clapper et al. (2001) and 2·66 % by Murray et al.(1997). The first limiting amino acid for most substrates was the sum Methionine + Cystine. The highest amino acid scores were recorded in the housefly pupae, followed by black soldier fly pupae and Morio worm, but the lowest scores were in the cockroaches (Bosch et al., 2014).

The In-vitro organic matter and nitrogen digestibility (%) of insects and some common animal protein supplies are presented in Table (5). According to Bosch et al. (2014) the in vitro organic matter and nitrogen digestibility of the Death's head cockroach and Black solider fly pupae were the lowest. However, the yellow mealworm, Morio worm and Lesser mealworm pupae had the highest organic matter digestibility. The most elevated nitrogen, the index of crude protein quality, was from Morio worm, House cricket, Lesser mealworm, and yellow mealworm (91.3-92%). The crude protein and amino acid scores were higher in black soldier fly and housefly than the other insect meals, but organic matter and nitrogen digestibility was lower (Bosch et al., 2014). The CP content and AA score of fish meal and house crickets were similar, but the former had a lower *in vitro* digestibility of N (85.7 vs. 91.7). The cockroaches were relatively high in CP, but the indispensable AA contents, the AA scores, and *in vitro* digestibility values were relatively low. Next to these indices of protein quality, other aspects such as the efficiency of conversion of organic side streams (Rumpold and Schlüter, 2013; Van Hus et al., 2014; Kovitvadhi et al., 2020) are essential. The economy of mass production (Rumpold and Schlüter, 2013; Abd El-Hack et al., 2020), and the safety of animal products (Rumpold and Schlüter, 2013; van der Spiegel et al., 2013; Hatab et al., 2020) are also important aspects. The animal nutrition preceptive will determine if insect species are included in future animal feed formulations (Maryam et al., 2021).

TABLE (5). IN VITRO ORGANIC MATTER AND NITROGEN DIGESTIBILITY (%) OF INSECT AND SOME COMMON ANIMAL PROTEIN SUPPLIES

Animal protein source	Organic matter	Nitrogen	References
Insect meal			
Black solider fly pupae	68·1	77·7	Bosch et al. (2014)
Black solider fly larvae	84·3	89·7	
Housefly pupae	83·2	84·3	
Yellow mealworm	91·5	91·3	
House cricket	88·0	91·7	
Argentinean cockroach.female	84·0	83·8	
Death's head cockroach.	79·4	78·4	
Morio worm	91·1	92·0	
Lesser mealworm	90·2	91·5	
Six spot roach	77·8	76·4	
Animal protein meal			
Fish meal	82·1	85·7	Bosch et al. (2014)
Soyabean meal	80·6	94·7	
Poultry meat meal	85·8	87·9	

1-4. The optimum level of insect meal in poultry diets.

In general, the level of insect meal recommended for feeding poultry is shown in table (6). The result suggested that the level of BSF meal in laying hen's nutrition ranged from 2-8 % in laying hen diets and 2.5-28% in broiler diets. This wide range reflected the types of 'insects' meals and chickens. Therefore, it is acceptable that insect meals can be fed to chickens at 5% without harmful effects on performance and product quality, and consumer acceptance (Bovera et al., 2016; Isabella Cutrignellia et al., 2018; Abd El-Hack et al., 2020; Hatab et al., 2020; Kovitvadhi et al., 2020; Maryam et al., 2021; Traksele et al., 2021).

TABLE (6). LEVEL OF INSECT MEAL IN POULTRY DIETS

Series Number	Common name	Laying diets	Refernces	Broiler diets	References
1	Black soldier Fly	7.3%	6	5%	Makker et al. (2014).
2	House Fly	5%	3	>10%	
3	Meal Worm	3%	15	10-25%	https://www.technologynetworks.com/applied-sciences/articles/why-insect-meal-will-be-the-new-feed-for-animals-in-aquaculture-316569; https://www.idrc.ca/en/project/integrating-insects-poultry-and-fish-feeds-kenya-and-uganda.
4	Locusts	2%	19	>2.5	Adeyemo et al. (2008); Halder et al. (2012), Ojewola et al. (2005).
5	Silk Worm	6-8%	9,20	5-6	Makker et al. (2014).
6	House Cricket			5-15%	Khatun et al. (2005); Rao et al. (2011).

1-4-1 The Optimum Level of Black Soldier Fly-in Laying Hen Diets

The level of BSF meal used in the feeding trial for chickens is shown in table (7). The result suggested that the level of BSF meal in laying hen's nutrition ranged from 5- 100 % substation of soybean meal or fish meal (Khan, 2018; Moula and Detilleux, 2019).

TABLE (7). THE OPTIMUM LEVEL OF BLACK SOLDIERS FLY IN LAYING HEN DIETS.

Series Number	Laying diets	Replacement	Reference
1	50-100	Soybean	Jozefiak and Enbery (2015)
2	5-50%	Fish	Khan (2018).
3	50%	Soybean	Kawasaki et al. (2019).
4	1-5%	Ingredient composition	Al-Qazzaz et al. (2016).
5	12-24%	Soybean	Maurer et al. (2015).
6	5-10%	Inclusion rate	Moula and Detilleux (2019).
7	5-7.5%	Inclusion rate	Moula and Detilleux (2019)
8	100%	Fish meal	Moula and Detilleux (2019)
9	15-25%	Inclusion rate	Moula and Detilleux (2019)
10	7.3-14.5%	Soybean	Secci et al. (2020)
11	100%	Soybean	Star et al. (2020)
12	5-7.5%	Soybean	https://www.allaboutfeed.net/New-Proteins/Articles/2019/7/Insect-meal-Good-for-bird-and-eggs-448478E/.

1-5. The impact of insect meal on meat and egg quality, and acceptance of poultry products.

1.5.1 Egg Quality on Black soldier fly

The quality of eggs of laying hens fed on BSFL and BSFP are presented in Table 8. Although egg weight and albumen weight were considerably higher within the BSFP diets than within the BSFL no vital changes in eggshell thickness were noticed between BSFL and BSFP. However, the eggshell thickness was improved due to feeding BSF, which may be due to high calcium availability in the animal protein source (Al-Qazzaz et al., 2016; Star et al., 2020). It was observed that insect meals had no adverse impact on egg quality when fed at 7.3% (5,6,18) and meat quality (Khan, 2018; Makker et al., 2014; Sogari et al., 2019). In addition, silkworms did not significantly affect the egg quality of laying hens (Schiavone et al.,2014), and muscle mass (Khan, 2018), and carcass characteristics (Spranghers et al., 2016). n addition, the results indicate that insect meals had no negative impact on the organoleptic of poultry products (Jozefiak and Enbery., 2015; Khatun et al., 2005; Rao et al., 2011). Furthermore, silkworms did not significantly affect the taste of poultry products (Khan, 2018), and did not cause a fishy taint in the meat (Ssepuuya et al., 2017).

TABLE (8). EGG QUALITY OF LAYING HENS FED BLACK MORE SOLID LARVA DIET AND BLACK SOLDIER PRE-PUPA DIET.

Trait	BSFL	BSFP
Egg weight (g)	45.6±0.88	49.9±0.60
Egg yolk weight (g)	12.03±0.25	12.6±0.24
Albumen weight (g)	26.8±0.63	30.0±0.46
Eggshell weight (g)	6.49±0.29	7.32±0.23
Eggshell thickness (mm)	0.37±0.02	0.43±0.01
Eggshell strength (kgf\cm2)	3.64±0.30	4.44+_0.17
Egg yolk color score	6.28±0.22	5.92±0.36
Albumen height (mm)	7.64±0.14	8.08±0.18
Haugh unit	91.7±0.69	92.7±0.93
Reference	Kawasaki et al. (2019)	Kawasaki et al. (2019).

1-5-1 The impact of black soldier fly on feed intake production

There has been no critical variation in feed intake, egg production rate, the average weight of the egg, feed conversion rate, body weight, liver weight (Table 9). Additionally, no differences in mortality were observed (Kawasaki et al., 2019; Maurer et al., 2015), as illustrated in the table (8), indicating no negative immune and health issues.

TABLE (9). FEED INTAKE AND PRODUCTION TRAITS OF LAYING HENS FED BLACK SOLDIER FLY LARVA AND PRE-PUPA DIET.

Trait	BSFL	BSFP	BSF12%	BSF24%
Feed intake (g\day)	77.5±1.3	76.2±4.9	131±5.3	107±9.4
Egg-production rate (%)	70.6±6.3	70.7±3.1	84.4±8.4	83.4±3.2
Egg weight (g)	49±0.7	51.1±0.3	67.3±0.66	64.8±1.07
Feed conversion rate (kg feed/kg eggs)	2.3±0.2	2.2±0.1	2.38±0.25	2.03±0.13
Body weight (g\bird)	1235±124.4	1329±98.1	-	-
Liver weight (% of BW)	1.8±0.1	1.8±0.1	-	-

1-6. The impact of insect meal on economic efficiency

Researchers have reported that black soldier leavers, house fly, crickets, and silkworms improved economic efficiency and net profits when substituting up to 100% of fish meal (Jozefiak and Enbery ., 2015; https://www.idrc.ca/en/project/integrating-insects-poultry-and-fish-feeds-kenya-and-uganda.). This may be due to the low price of insect meals compared to fish meals. Besides, BSF improved economic efficiency and net profit when substituting up to 10% of fish meal (Jozefiak and Enbery, 2015; Spranghers et al., 2016).

DISCUSSION

These updated reviews indicate that insect meal is a valuable animal protein supplement in Poultry diets that can replace 25-50% of fish meal. The percentage recommended for laying hens, and broiler chickens ranged from 5-7% based on insect species and strain of chickens (Makker et al. 2014; Secci et al., 2018; Secci et al., 2020; Shumo et al., 2019; Khatun et al., 2005). The high inclusion rate above 10% of insect meal in poultry nutrition may hindered poultry performance because of the increase in the chitin content, which has a negative impact on organic matter and protein digestibility (Bosch et al., 2014; Marono et al., 2015; Abd El-Hack et al., 2020; Traksele et al., 2021).

The literature also revealed that insect meals did not adversely affect the quality of poultry products and the organoleptic and taste properties of poultry meat and egg (Makker et al., 2014; Secci et al., 2018; Secci et al., 2020; Khatun et al., 2005; Liu and Lian ., 2003). In addition, insect meals can improve economic efficiency for egg and meat production (Jozefiak and Enbery., 2015; Khatun et al., 2005) while reducing environmental pollution due to organic waste use in insect breeding and production of insect meals (Jozefiak and Enbery., 2015; Shumo et al., 2019; Khatun et al., 2005). According to the expected increase in the global population and the competition between humans and animals for feed resources, insect meal may be helpful, valuable, and economical protein supplements for animal feeding. The result indicates that black soldier fly meal is an available animal protein supplement in feeding laying hens that can substitute about 25-50 % of fish meal (Makker et al. 2014). It is also recommended that 5-100% of soybean meal be replaced by BSFL or BSFP based on the strain of chickens (Makker et al., 2014; Khan ., 2018; Secci et al., 2018; Secci et al., 2020; Kawasaki et al., 2019; Al-Qazzaz et al., 2016; https://www.idrc.ca/en/project/integrating-insects-poultry-and-fish-feeds-kenya-and-uganda.; Star et al. 2020). Obviously, BSF meal did not negatively affect poultry product quality, taste, and organoleptic characteristics of table eggs (Makker et al. 2014; Secci et al., 2018; Secci et al., 2020 ;). In addition, BSF meal IS an affordable animal protein that can enhance farming profits for laying hens (Makker et al., 2014; Shumo et al., 2019; Sparnghers et al., 2016; Tarkaseie et al. 2021).

The BSF also has a positive environmental impact due to the use of organic waste for the production cycle of BSF (Makker et al. 2014; Shumo et al., 2019). The results showed that BSF had an excellent amino acid profile and thus protein quality and energy. Also, BSF is a suitable source of Macro-minerals such as Ca and P. In addition, BSF is a beneficial source of bioactive substances e.g., antimicrobial peptides, lauric acid, and chitin, that have immune-supporting influences (Makker et al., 2014; Shumo et al., 2019; Kawasaki et al., 2019). These substances can enhance immunity and thus gut health (Borrelli et al., 2017). According to the expected increase in the global population and the competition between humans and animals for the same feed resources. BSF may be a valuable, useful, and affordable protein source for poultry and aquaculture nutrition without negatively influencing eggs' production, quality, and sensory evaluation.

Processed insect protein in farmed animals was recently addressed and investigated as potential processed animal protein. According to EU Regulation, No 2017/893 (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32017R0893) "studies have shown that farmed insects could represent an alternative and sustainable solution to conventional sources of animal proteins destined for feed for non-ruminant farmed animals." The EU Regulation No 2017/893 conceded that "as regards the risks related to the presence of prions, EFSA concludes that, compared to the occurrence of hazards in currently authorized protein sources of animal origin. The occurrence of hazards in non-processed insects is expected to be equal or lower, as long as the insects are fed on substrates that do not provide harbor material of ruminant or human (manure) origin." Also, it is reported that as the processing of insects may further reduce the occurrence of biological hazards, that statement is also valid when it comes to processed animal proteins derived from insects".

The EU Regulation No 2017/893 indicated that "the insects bred to produce processed animal protein derived from insects are to be considered as farmed animals and are therefore subject to the feed ban rules laid down in Article 7 and Annex IV to Regulation (EC) No 999/2001 and the rules of animal feeding laid down in Regulation (EC) No 1069/2009. Thus, the use of ruminant proteins, catering waste, meat-and-bone meal, and manure as a feed for insects is prohibited. Furthermore, following Annex III to Regulation (EC) No 767/2009 of the European Parliament and the Council, the use of feces for animal nutritional purposes is prohibited". "The processed animal protein derived from insects should be produced in plants dedicated exclusively to the production of products derived from farmed insects." In addition, the Regulation stated that there is increasing investment in the use of insects in monogastric animal animals and aquaculture feeding. The EU declared that these should not be pathogenic or have other adverse effects on plant, animal, or human health; they should not be recognized as vectors of human, animal, or plant pathogens, and they should not be protected or defined as invasive alien species. Thus, farmed insects to produce processed animal protein may be promising animal protein for feed use. According to Regulation No 2017/893 "processed animal protein derived from insects, the following insect species can fulfill the safety conditions for insect production of authorizing processed animal protein for feed use: Black Soldier Fly (*Hermetia illucens*), Common Housefly (*Musca domestica*), Yellow Mealworm (*Tenebrio molitor*), Lesser Mealworm (*Alphitobius diaperinus*), House cricket (*Acheta domesticus*), Banded cricket (*Gryllodes sigillatus*) and Field Cricket (*Gryllus assimilis*). Last January 13, 2021 the EFSA did a favorable opinion about Tenebrio molitor, considering the meal safe for human food (https://efsa.onlinelibrary.wiley.com/doi/10.2903/j.efsa.2021.6343).

In the last ten years, there are increasing interest in using BSF in animal feed and the commercialization of BSF larvae for biowaste treatment and agricultural practice. However, using proceeded protein from BSF larvae in animal feeding practice has to be proved by authority for waste treatment and farming industry and animal feed particularly in the Islamic worlds after approval of 7 insects by the EU Regulation No 2017/893 (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32017R0893) and Tenebrio Molitor, for human food (https://efsa.onlinelibrary.wiley.com/doi/10.2903/j.efsa.2021.6343). However, insufficient research in the Islamic and academic scholarship is found, although its ubiquity in food production and consumption demonstrates the necessity to increase the research and improve coordination between the technical fields and jurisprudence until then a debit among scientists will continue (Maryam et al., 2021). Furthermore, insects were recently extended to other poultry species such as ducks (Kovitvadhi et al., 2020) and Japanese quails (Hatab et al., 2020).

Conclusion and Recommendation

The different available insect meals are an excellent feed resource for poultry, and the BSF resulted from the most common species. Overall, insect meal can be included in poultry feed between 5-10%. Moreover, insect meal had no adverse effects on the consumers' quality and sensory characteristics, organoleptic parameters, and acceptance of meat and egg. Therefore, black soldier fly is the most suitable animal protein resource in broilers and layers' diets that could be between 5-10% without adverse effects on the production, quality and sensory traits, organoleptic characteristics of eggs, and eggs' acceptance by consumers. A nother consideration is that due to the low inclusion levels, insect cannot could be considered now a real alternative to protein sorces. New techniques must be devoleped to separate the chitin from the rest of insect body, so they can be considered as protein source. an increase of cos This means to production but probably, when the insect industry will grow, these costs could be reduced

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استخدام الحشرات كأعلاف واعدة في تغذية الدواجن مع التركيز على ذبابة الجندي الأسود "*Hermetia illucens*"، دراسة مرجعية

علي خالد احمد، خالد علي عسيري، عادل ضيف الله القرشي، نجيب المسعودي،
مجدي علي موسي، عمر إبراهيم، يوسف عبد الوهاب عطية وماجد سليم الرفاعي
قسم الزراعة-كلية العلوم البيئية-
جامعة الملك عبد العزيز –جدة- المملكة العربية السعودية

مستخلص. هدفت هذه المراجعة العلمية الي الوقوف على التطورات الحديثة في استخدام الحشرات في تغذية الدواجن بعد ان سمح الاتحاد الأوربي ب استخدام سبعة منها في اعلاف الحيوانات لتقييم الأنواع المناسبة، ومستوى احتواء الغذاء، ومحتواها من العناصر الغذائية، والمزايا، والعيوب أيضًا. تم الحصول على أكثر من ٥٠ مقالة بحثية ومقالات مراجعة واتصالات قصيرة وفصول كتب من قواعد بيانات مختلفة على الإنترنت مثل Google Scholarو PubMed وScopus ، باستخدام الكلمات الدالة التالية: تربية الحشرات والحشرات في تغذية الدواجن، ذبابة الجندي الأسود Hermetia illucens (BSF) . تعتمد يرقات ذبابة الجندي الأسود المختارة(BSFL) ، والخادرة (BSFP) على الاهتمام المتزايد بسبب سهولة التكاثر، ومحتواه القيم من البروتين، والقيمة الاقتصادية. حيث زادت الاحتياجات من موارد الأعلاف البديلة والمتاحة محليًا بشكل كبير بعد أزمة كوفيد- ١٩ والحرب الأكرانية الروسية الحالية لأسباب مختلفة مثل التغييرات في سلاسل الامداد نتيجة إغلاق الحدود وإغلاق الموانئ والمطارات والموانئ البحرية وحيث تعتمد معظم البلدان النامية على الأعلاف المستوردة لتغذية الحيوانات والتي تأثرت بشكل كبير خلال الفترة الحالية، مما أثر على سلسلة توريد الأعلاف الحيوانية. وقد أدى ذلك إلى زيادة الحاجة إلى مصادر بروتينية محلية بديلة / غير تقليدية للحفاظ على إنتاج البروتين الحيواني. يُعد حشرة الجندي الاسود موردًا واعدًا ومرشحًا للأعلاف استنادًا إلى دراسات دجاج التسمين والدجاج البياض والسمان الياباني والبط التي تم نشرها مؤخرً علاوة على دورها في الحفاظ على البيئة من المخلفات العضوية.

الكلمات المفتاحية: حشرات؛ دواجن، أعلاف، بروتينات حيوانية، الطاقة القابلة للتمثيل الغذائي، الأحماض الأمينية