TECHNICAL BULLETIN

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Issue	**Safety of Black Soldier Fly as an Alternative Source of Protein for Feeds**
Background	The production of insects and their use for feed is a rapidly growing sector. The increasing cost of imported raw materials and the environmental concerns attributed to cropland used for feed versus food [1] were reasons for its growing popularity [2]. Over the years, facilities in Europe, North America, China, South Africa, and Thailand have increased significantly. However, relative to other sectors in the global feed and food industry, insects for food and feed are still niche markets [3]. As an animal feed ingredient, insects are used as an alternative source of dietary protein for monogastric animals because they contain high amounts of quality protein characterized by a high feed-to-protein conversion rate [4]. Among the different insect species, Black soldier fly larvae (BSFL) meal (*Hermetia illucens* L.) is widely used as a feed source for animals such as chickens, fish, and pigs. Its use in ruminants as feedstuff was observed to be less successful due to high chitin and fat content leading to a negative effect on fermentation and digestibility [5]. In response to the growing practice in the Philippines, the Department of Agriculture carried out several initiatives using BSFL. In 2020, the Agricultural Training Institute (ATI) and Kahariam Farms entered into a partnership to formally launch the use of BSFL as an alternate source of proteins for pigs [6]. Meanwhile, ATI Region 2 developed a farming guide brochure related to BSF [6]. Other private-led initiatives were also documented. This Technical Bulletin aims to provide information on the safety issue of BSFL as an alternative source of protein in feeds. It also lists the recommended practices when considering BSFL for feeds.
General Description	**Black Soldier Fly** (*Hermetia illucens*)

Image 1. Image of black soldier fly, (Ref. istockphoto.com)

The Black Soldier Fly (BSF) is a species now common throughout all (sub)tropical regions worldwide. However, it is originally from America's (sub)tropical and warm climate. As shown in Image 1, BSF is wasp-like and about 13-20 mm in length, while their larvae can be larger and grow up to 27 mm with a width of 6 mm [7] at an environmental temperature of 20-30 °C [8] —. Its life cycle happens within 45 days (eggs, four days; larva, 18 days; pupa, 14 days; and adult, nine days) [9] as shown in Figure 1.

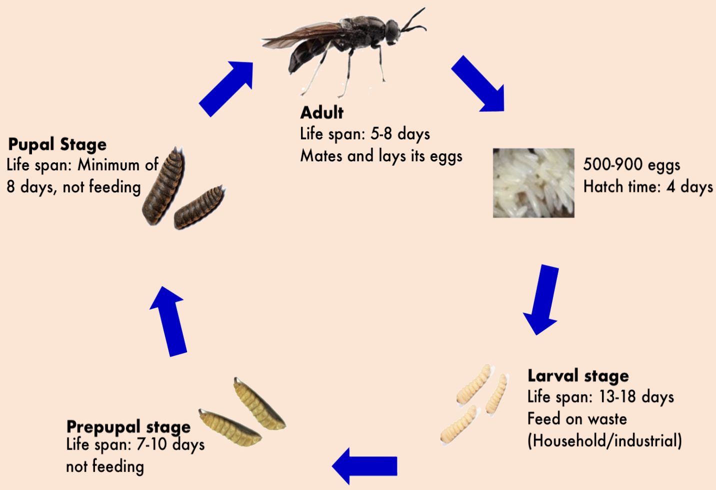

Figure 1. Life cycle of a Black Soldier Fly [10]
(Ref. Fleurdeliza M. et al., 2021)

BSF is widely farmed due to its ability to convert a wide variety of organic materials into quality nutrients such as proteins, fats, and minerals. The insect's gut enzymes allow it to consume many substrates, helping reduce agricultural waste streams by feeding on these substrates and converting them into nutrients [5]. The BSF larvae also can significantly reduce pathogenic bacteria such as Enterobacteriaceae colonies and *Salmonella* spp. in different materials such as manure and fecal matter. This ability is attributed to the high pH of their gut (9.3), gut enzymatic reactions, and competitive gut bacteria that bacterial species such as *E. coli* and *Salmonella* spp. from the feed cannot survive [11]. Due to these facts, BSF is not considered a pest or vector of diseases and does not constitute a nuisance, thus, making it an attractive insect species for mass production as a sustainable and affordable feed ingredient [12].

BSF in feeds

The BSF is one of the most common insect species used for animal feed due to its ease of rearing, high yield, rich nutritional value, and the ability to utilize organic wastes [6]. They are known to feed and develop in a broader range of raw materials such as kitchen waste, manure, fecal sludge, and distillers' by-products [13]. The BSF larvae can also be grown in various rearing substrates such as mixed organic wastes, palm oil meal, brewer's spent grains, brewer's yeast, and cane molasses, among other agro-industrial by-products.

The BSFL is known for its high nutritional content, which shows great potential as an alternative protein source in feeds [4]. The pre-pupal stage comprises 42% protein and 35% fat, including essential amino and fatty acids [9]. Meanwhile, the dry weight of BSFL contains up to 50% crude protein (CP), up to 35% lipids, and has an amino acid profile similar to that of fishmeal [14].

The protein quality of BSFL is identical to soybean protein with higher Methionine and Tyrosine components. BSFL is used as a partial replacement for soybean meal and fishmeal in pig, broiler, and fish diets [13]. The pupae of BSF can immediately be fed to chickens and fish and processed into dry feed as a protein source [6].

Aside from being a good substitute for protein, some studies have also shown that BSFL has potential as an ingredient for milk replacer, creep feed, fattening ration, and source of lactic acid bacteria (LAB) probiotics [1].

Figure 2 below, lifted from the FAO Manual on Edible Insects, summarizes the use of insects in the animal feed chain.

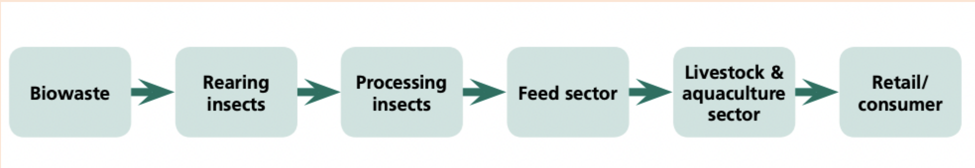

Figure 2. Use of insects in the animal feed chain (Ref. FAO, 2013)

Figure 3, on the other hand, shows a much more detailed chain provided by the ATI Region 2 in their BSF brochure.

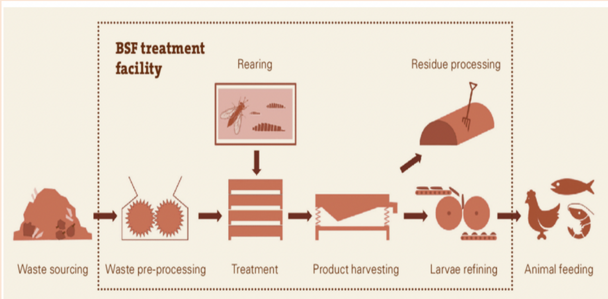

Figure 3. BSF rearing and use in animal feeds
(Ref. Agricultural Training Institute, 2021)

BSF Nutritional component [15]

The primary nutritional components of BSF larvae include crude protein, fat, amino acids, minerals, and ash. Below is an overview of its mineral, amino acids, and fat composition.

Mineral composition
The BSF larvae have the following minerals: Calcium (Ca), Phosphorus (P), Potassium (K), Sulfur (S), and Magnesium (Mg), with Ca as the most abundant mineral. The following minerals are also present in low concentrations: Sodium (Na), Iron (Fe), Manganese (Mn), and Zinc (Zn).

Amino Acids
Total of 17 amino acids (AA) are recorded in BSF larvae (nine essential and eight non-essential). The most prevalent essential AA are Lysine, Histidine, Arginine, Methionine, Phenylalanine, Isoleucine, and Leucine. For the non-essential AA, Tyrosine was the most abundant, followed by Proline, Glycine, and Alanine. While Aspartic acid, Cystine, Glutamic acid, and Serine are in smaller concentrations.

Fatty acids
Total of 10 fatty acids are identified from the BSF larvae - seven are saturated fatty acids while three are unsaturated. Saturated fatty acids include Lauric acid, Palmitic acid, Stearic acid, Myristic acid, Capric acid, Margaric acid, and Arachidic acid, while unsaturated fatty acids are Linoleic acid, Palmitoleic acid, and Oleic acid.

Hazard Presence in Feeds

As the BSF is grown in various wastes, feeds and food are associated with microbiological and chemical hazards.

Microbiological Hazard

The European Food Safety Authority (EFSA) Risk Profile related to the production and consumption of insects as food and used as feed reported that although pathogens are found in the substrate used to grow insects, active replication of the pathogens in the intestinal tract does not seem to occur in insects. In addition, the risk of transmission of bacteria could be mitigated through effective processing [16].

BSFL has been noted to reduce the microbial load of substrates with processed composts showing lower concentrations of bacteriophages and bacteria such as *Salmonella enteritidis* and *Enterococcus coli*. Recent studies showed BSF gut enzymatic reactions significantly reduce pathogenic bacteria in the organic matter and convert them into a nutritional component. However, the larvae can become contaminated with these bacteria if kept on a contaminated substrate for too long [17].

	Chemical Hazard To use BSFL as a feed ingredient, its chemical safety must be guaranteed. As the composition of the rearing substrate may pose risk to the safety of BSFL due to bioaccumulation of different (in)organic compounds, such as pesticides, toxic metals, and mycotoxins, the quality of the rearing substrate is considered one of the most critical safety factors. While bioaccumulation was observed in heavy metals, the level observed is within the safe limits of the national authority (i.e., European Commission limits). For pesticides and toxins, bioaccumulation was not observed due to the BSF's detoxification process. However, the use of several organic waste streams as rearing substrates is prohibited due to a lack of adequate safety information [8]. *Heavy Metals Concentration* Studies have shown that BSFL bioaccumulates certain heavy metals from their feed, including Cadmium (highly accumulative), Copper, Lead, and Mercury, which is a concern due to the severe health risks associated with their consumption [11]. These heavy metals are known to affect human health when consumed excessively [18]. Thus, it is essential to monitor the possible presence of such heavy metals in the substrates [11] to mitigate the toxic risks of these components to humans [5]. Rearing BSFL for livestock feed use necessitates thorough monitoring of the heavy metal contents, especially Cadmium and Lead, to ensure feed and food safety along the value chain [18]. *Mycotoxins and Pesticides* Although substrates in which the BSFL is grown may contain mycotoxins and pesticides; the BSFL does not accumulate these [18] due to their natural detoxification processes [5]. Additionally, the presence of mycotoxins and pesticides in the raising substrate did not affect the growth performance of BSFL [18]. *Allergens* While allergens from BSFL are safety concerns and need further studies, cross-reactive allergens were noted. These are tropomyosin, arginine kinase, and myosin. Cross-reactive allergens would increase the likelihood of allergic reactions in consumers allergic to other species containing the same BSFL allergens. Some documented cross-reactivity includes tropomyosin being cross-reactive in both mites and shrimp and arginine kinase in prawn species and silkworms. Thus, further investigation needs to be done on BSFL before its inclusion as an ingredient in commercial food [11].
Adverse Health Effect in Human	Referring to the animal feed chain in Figure 2, below could be considered as the possible food pathway of BSFL:

	BSF/L (as feed ingredient) → feeds → food producing animal → human consumption Given the mechanism of BSF in relation to reduction of microbiological hazards, bioaccumulation within safe limits of heavy metals and non-bioaccumulation of pesticides and toxins, possible adverse health effects to humans is considered minimal. However, the authors did not find direct literature on this, as such further research and studies is recommended.
Regulatory Framework	**Standards** Currently, there is no regional or international standard for the utilization of insects for feed. While Codex discusses appropriate requirements for edible insects, FAO recommended criteria and parameters when farming insects for food use. The recommendation includes species and strain collection, household production, training in insect farming, choice, cost and reliability of feedstock, safety, health, and environmental issues, and strategic issues for industrial-scale insect farmers [1]. **Regulations** While the discussions of international and regional standards for edible insects are ongoing; there are initiatives done regarding the review and compilation of national regulations deemed relevant for the edible insects. Though not specific, some regulations covered feed and food safety concerns. European Union and East Africa, as well as countries like Canada, United States, Australia, New Zealand, Netherlands, Belgium, Germany, Switzerland, and the United Kingdom, have respective regulations for feeds and food that consider insects as part of the raw materials or ingredients. As part of the precautionary principles, these regulations consider the following hazards related to edible insects [3]: a. heavy metals b. mycotoxins c. pesticide residues d. pathogens e. natural toxins f. allergens g. processing contaminates h. veterinary residues
Mitigating Measures	**Farming insects** 1. *Species and strain collection* ● for tropical countries employ local species for minimal climate control and culture acceptance ● set selection criteria that include ease of rearing, taste, color, and whether they can be used as feed. 2. *Feed* ● feed insects with organic wastes that have been assessed for safety parameters such as chemical and

	microbiological hazards (feed grade or food-grade, especially for insects that are not to be gutted) • carefully select the rearing substrate to limit the possible bioaccumulation of different (in)organic compounds in BSFL, such as pesticides, toxic metals, and mycotoxins. 3. *Household production* • maximize the productivity of traditional management systems • develop kits for home use to start small-scale rearing facilities • use locally obtained organic waste as feeds for insects 4. *Industrial-scale insect farming* • develop of code of practice and quality parameters • harmonize of terminologies • document of best practices available • develop of marketing strategy **Training** 1. attend a farmer field school to increase awareness that insects can be farmed like other livestock **Processing** 1. As a preprocessing method for BSFL, blanching is recommended to reduce microbial load 2. Dry insects to extend shelf life 3. Store in a refrigerated environment (0-4C)
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