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A REVIEW: EVALUATION OF BLACK SOLDIER FLY (*Hermetia illucens*) LARVAE MEAL AS A PROTEIN SOURCE IN POULTRY DIETS

REVIEW: EVALUASI TEPUNG LARVA LALAT TENTARA HITAM (Hermetia illucens) SEBAGAI SUMBER PROTEIN PAKAN UNGGAS

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ABSTRACT

The increasing global population poses a problem in achieving food security. Poultry is one of the major animal protein sources for humans and the main difficulty of the poultry industry is seeking a suitable protein alternative to be integrated into poultry feed. Black soldier fly larvae (BSF) (Hermetia illucens) are one of the edible insects that are a great solution to this problem since they have various advantages, which include bioconversion of different organic wastes and the absence of competition for human resources. Several studies have already examined the effects of the addition of BSF larvae in the poultry diet, and most suggested that it is a promising alternative protein source that can replace soy or fish meal. The BSF larvae can also be used in different species of poultry, such as ducks, turkeys, and quails. However, there are several barriers to using BSF larvae as a feed ingredient in poultry feed, such as safety, price, and consumer acceptance. Despite these obstacles, BSF larvae production is still a promising industry due to the numerous benefits it brings.

Keywords: *Black Soldier Fly Larvae, poultry, protein*

ABSTRAK

Permasalahan pencapaian ketahanan pangan disebabkan meningkatnya populasi global. Daging ungags merupakan salah satu sumber protein hewani utama manusia. Permasalahan utama industri perunggasan adalah pakan sumber protein yang mahal sehingga perlu mencari alternatif protein yang cocok untuk diintegrasikan ke dalam pakan unggas. Serangga, khususnya larva lalat tentara hitam (Hermetia illucens), merupakan salah satu solusi untuk masalah ini karena mereka memiliki berbagai keuntungan yang meliputi biokonversi limbah organik yang berbeda dan tidak adanya persaingan untuk sumber daya manusia. Beberapa penelitian telah mengevaluasi efek dari pemberian pakan larva lalat tentara hitam pada ternak unggas, dan sebagian besar menyarankan bahwa itu adalah sumber protein alternatif yang menjanjikan untuk dapat menggantikan tepung kedelai atau tepung ikan. Larva lalat tentara hitam juga dapat digunakan pada berbagai jenis unggas seperti bebek, kalkun, dan burung puyuh. Namun, terdapat beberapa kendala dalam penggunaan larva black soldier fly sebagai bahan pakan dalam pakan unggas seperti keamanan, harga, dan penerimaan konsumen. Terlepas dari kendala tersebut, produksi larva lalat prajurit hitam masih merupakan industri yang menjanjikan karena memiliki banyak manfaat.

Kata kunci: *Larva Lalat Tentara Hitam, protein, unggas*

INTRODUCTION

The world population in 2050 will increase to 9 billion, and the global food demand will consequently increase, resulting in the rise of animal feed and human food production by approximately 60% [1]. In addition, increasing incomes have led to an increased preference for animal protein, thus intensifying the demand for animal feed [2]. The intensive utilization of agricultural land has resulted in the damage of ecosystems globally and can no longer augment the increasing worldwide demand for proteins [3]. Animal-based proteins contain a balanced amount of vitamins and essential amino acids that are essentially more favourable than plant-based proteins [4]. The poultry industry is considered one of the most vital sources of animal protein for human consumption. The poultry industry has the biggest challenge in finding a sustainable protein feed source for future demand [5].

Feed is an important factor in poultry production, comprising 70% of production cost. A lot of studies are now being conducted to discover new alternative and novel protein sources for poultry. One of the promising sustainable alternative protein sources for monogastric, which is high in nutrient content (essential amino acids and fat) is insect [6, 7], a bioconversion agent of waste, do not compete with human resources and has little environmental effect [8]. The benefits of insect production include a good feed conversion rate, few water and soil requirements, and minimal greenhouse gas and ammonia production. The concentration of nutrients varies depending on their rearing conditions, life stage, and the components of the growth media utilized for the production of insects [9].

Moreover, insects are a great alternative protein source for poultry since they are naturally and primarily the source of protein in the wild. Mealworms, houseflies, and grasshoppers are insects that have been incorporated into poultry feed [4]. Insects were observed to be promising since it has an approximately 70% consumer acceptance rate. The feed from insects is recognized as more sustainable with better nutritive composition [10]. The aim of this review is to evaluate the different research conducted on BSFL as a potential protein source in poultry diets, especially in the Philippines.

RESULTS AND DISCUSSION

Black soldier fly larvae (BSFL) as a protein source. *Hermetia illucens* also known as the black soldier fly belongs to the Order Diptera, *Stratiomyidae* Family, and *Hermetiinae* subfamily [11]. The adult BSF appears black with white legs, and its body is slender and approximately 2 cm long. This insect's larvae form is polyphagous, which allows them to feed on various types of food sources due to the effective enzyme activity present in their gastrointestinal system. The intestine of the larvae contains the majority of active enzymes such as amylases, lipases, proteases, and potent enzymes including arylamidase, mannosidase, and galactosidase, which are weakly active in *Musca domestica* [12]. The adult flies lack mouthparts for stinging, chewing, or sucking so, were not regarded as a vector of disease. BSFL stifle the production of other insect species that feed on the same waste materials [13]. The larvae can be utilized in various forms such as live, chopped, dried, or grounded [14] and in different applications such as animal feed, antimicrobial peptides, the substrate for biodiesel production, and biofertilizer [15]. Farming of BSF has the potential to be a source of animal feed (protein). It can be grown in high densities and in small spaces, waste streams, manure, and reduce negative environmental impact [16, 17].

Life cycle and rearing requirements. BSFL commonly grows on organic wastes (vegetables, animal feed leftovers, manure, and food/kitchen waste) [18]. Naturally, the manure of laying hens is the ideal rearing substrate for BSFL. BSF is endemic in tropical and subtropical areas, has a brief life cycle, and can produce a great number of eggs from 500 to 1000 [3]. The tropical climate must be mimicked in rearing BSF, and relatively high humidity and a temperature of 30°C are suggested for fly reproductivity and egg hatching [13]. The days, cycle of BSF: embryo, larva, pupa, and adult for 40 days however this may vary depending on external factors such as temperature, humidity, environment, and feed. Adult flies only require water and rely on fat deposited during their larval stage as a source of nutrients and are not considered pests [1]. Figure 1 are the *Hermetia illucens* (BSF) life cycle.

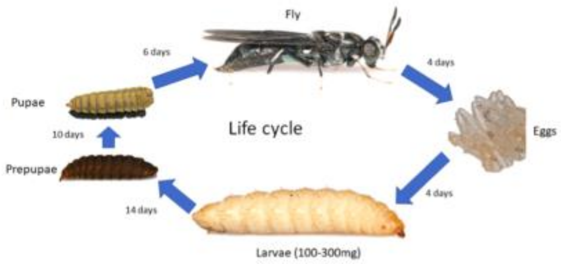

Figure 1. *Hermetia illucens* life cycle [13]

Two days after emerging from their pupa, the flies mate then the female fly lays eggs in tiny slits or cavities above a food source. These eggs hatch after four days thus starting the larval stage. Larvae will consume substrate and their weight can double or triple each day during this phase. Prepupae will emerge after 18 days, and its colour will darken. They start to find a quiet dark location to pupate and stop feeding. Pupae are sedentary and will remain so for about two weeks. The pupae enwrap themselves and the cycle repeats. The cycle may be finished after several months under unfavourable conditions [13].

Processing. A whole wet BSF larva's pH is near neutral, indicating that the commodity is perishable and needs to process the larvae in order to prolong its shelf life [19]. BSFL processing involves euthanizing or devitalizing or killing of biomass. Several devitalization techniques used are grinding, desiccation at 60°C for 30 minutes, blanching/boiling in water for 40 seconds, freezing in liquid nitrogen for 40 seconds, and asphyxiation [20]. It is recommended to dry the larvae to a water composition below 10% if they are not processed immediately after harvest [21].

The drying of insects possesses several benefits because it enhances preservation through the reduction of microbial development and the activity of spoilage-causing enzymes. Some studies intend to optimize the most common drying methods in insect processing such as oven-drying, microwave-drying, freeze-drying, and sun-drying [19, 82]. There are different techniques for drying insects, and these have varying effects such as color, proximate content, water activity, protein solubility, and lipid oxidation on the final dry insect product [82].

The nutrient availability of the larvae can be improved through processing. Defattening of larvae can increase the crude protein content, while mechanical compressing and solvent extraction can substantially lessen the crude fat content [22]. Conversion of BSFL biomass into biomolecules to acquire excellent marketable products requires appropriate fractionation processes such as insoluble and soluble protein, chitin, and lipid fractions [23]. Protein extraction is normally done with alkali or sonication on defatted insects. The extraction of chitin involves several steps, such as product deproteination and mineralization. It can be executed using chemicals or lactic acid bacteria [19].

Nutritional and chemical value. BSFL were one of the species of insects that reached the prerequisites to be considered an alternative source of protein source in feeds. A study conducted by [24] aimed to attain the production of excellent quality feed. The study concludes that the longer rearing period of BSFL influences the nutrition, increases crude fat, dry matter, and crude fibre levels, and causes a minor decrease in crude protein content. BSFL are usually composed of approximately 42% protein, 30% fat [3], 5,279 kcal/kg gross energy 15-33% ether extract, 7% crude fibre, and 14.5-28.5% ash [14]. The nutritional content of BSFL will differ depending on what they were fed [27, 28, 29]. Organic materials with high protein have high BSFL protein. However, the fat percentage of the feed consumed is not associated with fat percentage of larvae [30].

The amino acids quantity of BSF differs during their lifespan, and every development phase of this insect contains a diverse set of synthesized essential amino acids. The greatest quantity of amino acid contents was seen in the 4th to 6th day of life, which are during the early larval development stages, gradually decreases as the BSFL mature, followed by a steady stage of amino acid levels in the prepupa and pupa stages of the life cycle. The adult phase of the larvae was considered the stage with the highest content of amino acids on a dry matter basis [18].

Chitin which is present in the exoskeleton of some insects including BSF, has a negative impact on the nutrient digestibility of crude protein [31]. Józefiak et al. [9] suggest that chitin present in insects can stimulate the innate immune system since it has fungistatic and immunoadjuvant properties. Chitin and its derivatives are used in a variety of industries, such as food, agriculture, cosmetics, pharmaceuticals, waste management, and textiles. Moreover, chitin can also be used as a feed supplement due to its reported antifungal, antibacterial, and antiviral properties [7]. Furthermore, supplementing with chitosan oligosaccharide has been shown to improve growth performance by promoting immune response and intestinal development [18].

Chemical properties. Antimicrobial peptides found in BSFL can act on Gram-negative and Gram-positive bacteria as antimicrobial peptides and growth promoters with regulating properties on the gastrointestinal microbiome, making them useful in livestock production [9, 32]. *Hermetia illucens* larvae feed on diverse sources of decaying organic substances, which are commonly populated by bacteria and fungi. Since strong resistance to microorganisms is needed for survival in these environments, BSFLs are likely to express antimicrobial properties as well as other antibiotic-like compounds. Antimicrobial properties are produced in the body fat, which is then excreted into the hemolymph [25].

The BSF was discovered to have high levels of fatty acid (lauric acid), with substantial antimicrobial properties. Moreover, they also contain other antimicrobial agents, allowing food components made from them to have a longer shelf life [26]. Other than antimicrobial substances, BSF also contains different enzymes, such as cellulose and lignin-degrading enzymes. However, the protein-degrading enzyme activities of BSFL were unaffected by biochemical processing [25].

Chitin, a natural biopolymer, can be extracted from BSF and can be deacetylated to yield chitosan as marketable goods in agriculture, health care, cosmetics, and textiles [33]. Chitosan has antimicrobial and biological properties that could be useful in treating diseases (cancer, obesity, Alzheimer's disease), anti-inflammatory activity, and stimulating tissue regeneration [25].

Dietary BSFL in broiler chicken. Many studies presented that the addition of BSFL resulted in a desirable effect on growth parameters. The mere absence of adverse effects of dietary inclusion of BSFL makes it a promising alternative energy and protein source for broiler feed. The provision of BSFL to chickens is very suitable in poultry production with traditional systems. The study of BSFL on the growth performance of broiler chickens is shown in Table 1. More research is required, however, to determine the optimal level of BSF inclusion that will not negatively impact production parameters. The study of BSFL on the clinical parameters of broiler chicken is shown in Table 2. The studies showed that feeding BSFL to broiler chickens has no negative effects on their clinical parameters, making it a suitable protein component in their diet.

Table 1. Study of BSFL on growth performance of broiler chicken

Formula	Result	Reference
10% of BSFL	during the starter period the body weight and daily feed intake were improved	[31]
full-fat and defatted BSF meal	improved broilers' performance, carcass weight, and breast muscle percentage	[34, 35]
a long period of access to BSFL	improve the welfare of broilers since it enables natural behaviour as well as lessening anxiety without negatively affecting the health and productive performance	[36]
Substitution the fish meal with BSFL meal	had no negative effects on body weight gain, feed consumption, carcass consistency, or chicken breast taste and aroma	[37, 38]
8% commercial feed was replaced with whole de-frozen larvae	higher weekly weights	[39]

Table 2. Study of BSFL on clinical parameters of broiler chicken

Formula	Result	Reference
BSFL	beneficial to the cecal microbiota and rise in villi mucins	[40]
defatted BSFL meal	does not negatively influence the health of the chickens, blood parameters are well within the normal physiological ranges, and no effect on the development and severity of histopathologic changes	[31]
BSFL	no major variations in the relative quantity of most bacterial families found in the bird's ceca and the relative quantity of *Rhodobacteraceae* and *Bacillaceae* were lower	[41]
BSFL	no considerable dissimilarity in the crude protein digestibility, cellular immunity, and duodenum, jejunum, ileum, and caecum length and weight	[42]

Dietary BSFL in layer chicken. Several studies have already investigated the effects of using BSF in the diets of laying hens, with mixed results. The chitin present in the larvae led to poor feed utilization. BSF meal was examined on growth performance, gut health, and nutrient digestibility as the replacement of protein source. Due to favourable results such as the partial addition of BSFL meal layer chickens are believed to be promising. The presence of BSF meal in the diet may have influenced enzymatic events in the small intestine and the development of volatile fatty acids in the ceca. These changes have a positive effect on butyric acid production in the ceca but have a negative impact on ileum enzymatic events. An optimal level for the dietary inclusion of BSFL is needed to balance negative and positive effects through conducting more studies. More research is needed to decide the appropriate amount of BSFL to include in a layer's diet so that laying efficiency is not hampered. The study of BSFL on the laying performance of layer hens is shown in Table 3.

Alongside laying performance, egg quality must also be examined in determining the effects of the addition of BSFL in the layer. The diet of BSFL resulted in a significant improvement in the appearance, texture, and taste of eggs. The high glutamic acid content in BSFL meals may have remarkably affected the taste of eggs positively. The study of BSFL on the egg quality of layer hens is shown in Table 4. In general, the replacement of the conventional protein ingredient in hens' diet with BSFL had no negative impact on egg quality and other egg characteristics.

Future of BSF in poultry production. Other than chicken, BSFL can also be used as a protein ingredient in other poultry species' diets, such as quails, ducks, turkeys, and guinea fowls. BSFL has complete nutrients, and their live form is preferred by ducks. Table 5 shows the study of BSFL on other poultry animals.

Outlook on mass production of BSFL. The BSF is an excellent choice for large-scale production because of its low mortality, disease tolerance, high growth rate, and high protein content. More research must be performed in order to determine the maximum level of BSFL meal that can be included in the poultry diet with the absence of negative effects on palatability, nutritional content, growth performance, and taste of meat and eggs. Moreover, the chitin component of the BSFL and fatty acid content must be considered alongside necessary health standards for birds and consumers. Also, the effect of the BSFL meal on the good bacteria in the gastrointestinal tract must be assessed further [18]. The mass production of insects is moderately new, and there is still

Table 3. Study of BSFL on laying performance of layer hens

Formula	Result	Reference
defatted BSFL meal	maintain egg production by improving the immune status of birds and health	[43]
BSFL	the feed conversion ratio was remarkably increased in birds fed	[4]
full-fatted BSF meal	enhanced crude protein and ether extract digestibility and increased sIgA levels in the ileum mucosa	[44]
replacing soy with BSFL	no negative impact on the layer hens' production or egg quality	[45]
substitution of soybean cake with moderately defatted BSFL meal	no significant changes in laying performance, feed intake and feed efficiency	[46]
choice feeding of BSFL	satisfactory level of acceptance and had no impact on performance parameters	[47]
soybean meal was fully replaced with BSFL meal	feed intake and digestibility of nutrients especially protein decreased which resulted in a decrease in the birds' live weight at the end of the experiment	[48]
BSFL	lessening fat content in the blood of hens	[49]

Table 4. Study of BSFL on egg quality of layer hens

Formula	Result	Reference
BSFL	Egg odor is not significantly affected	[4]
dried BSFL	similar fatty acid content, egg quality characteristics, and sensory properties to the control eggs	[50]
BSFL	did not affect egg quality parameters such as Haugh unit, shell strength, and elasticity	[45]
BSFL meal	yolks have higher carotenoid levels and lessened cholesterol	[51]
BSF pre-pupae	did not affect feed intake and rate of egg-laying, higher values in terms of eggshell thickness, and cecum microbiota diversity	[52]

Table 5. Study of BSFL on other poultry animals

Formula	Animal	Result	Reference
replace soya bean meals with BSFL meals up to 15%	broiler quails	productive performance, nutrient digestibility, carcass, and meat quality were generally satisfactory.	[53]
BSFL	Jumbo quail	chitinase may permit higher-level addition of BSFL in the feed	[54]
BSFL	laying quails	the productive performance of the birds had no negative effects and the eggs generally have satisfactory sensory, physical, chemical traits	[55]
12% BSFL	turkey pullets	has a better growth rate, feed conversion ratio, and body weight at five weeks of age. Furthermore, less skin and feather damage and less aggressive behaviour	[56]
defatted BSFL meal (up to 9%)	ducks	did not affect the growth performance and digestibility and maintained physiological gastrointestinal development	[57]
live BSFL at a 10% level	ducks	significant impact on the carcass percentage and weight although there was no effect on the abdominal fat percentage and visceral weight	[58]
BSFL meal	Muscovy ducks	did not negatively affect the growth parameters and haematological traits	[59]
BSFL meal	guinea fowls	feed intake is higher among the groups, improved weight gains, higher live weight, and did not cause physiopathological irregularities	[60]
substitution of fishmeal with 60-100% BSFL meal	guinea fowls	the weight increased significantly, had no physio-pathological anomalies and reduced feed costs	[61]

significant potential for optimization of the different factors of rearing and feed conversion efficiency [62].

Incorporating insects as a protein source in poultry feed will help to solve and achieve food security. However, safety measures are needed to prevent toxic substances from accumulating in insect biomass. Supplying organic wastes to insects and feeding the insects to poultry may result in the actual sustainability of economics in the poultry industry. Furthermore, by adding biological value to organic waste from restaurants and households, the negative environmental effects can be reduced [18]. Though it can help with food security issues, insect production must be improved in order to be more sustainable. Bioconversion efficiencies must be better understood and improved in order to ensure the sustainability of BSFL production. Greater conversion efficiency indicates better sustainability of system performance. In addition to enhancing bioconversion efficiencies, another important factor for the sustainable production of BSFL is lessening gas emissions produced during rearing, such as methane, carbon dioxide, ammonia, and nitrous oxide [63].

The development of BSF is influenced by the organic waste composition. Furthermore, the negative effect on reproduction may be due to the small pupa size. The negative impact of low-quality feed on the developmental period can be surmounted by providing a large amount of feed [64]. Food waste reduction can be resolved by the commercialization of bioconversion using BSFL. Moreover, the industrialized production of this insect needs huge amounts of inexpensive and consistent feedstock. This is very suitable since global food waste is assessed to be 1.3 billion tons and to increase, and the need for protein, biofuels, and fertilizers is rising [65]. One substrate which can be used to rear BSFL is restaurant waste which consists of starch, protein, and fat [18]. This type of waste is abundant and broadly accessible, but it is considered an environmental pollutant if not properly disposed of.

Potential production of BSFL in the Philippines. The poultry industry of the Philippines comprises several sectors, such as broiler chickens, layer chickens, and ducks, thus making it quite diverse [66]. Data from the Philippine Statistics Authority show that the poultry industry in 1990 was valued at sixty-nine billion pesos and has increased to 123 billion pesos in 2016 thus having a growth of 78%. Hence, it is the swiftest growing animal industry sector in the Philippines [67]. The poultry industry must increase its efforts in finding ways to make production more efficient and competitive.

Since no specific solution for organic waste, it has yet been found continues to be a major source of concern in low and middle-income countries [68]. Post-consumer food waste has developed into a policy and societal problem in the Philippines, particularly in cities like Metro Manila. Food waste from households, restaurants, hotels and wet markets accounts for about half of the organic waste spread across the city. This fraction of organic waste can be converted into alternative value chains, allowing for its reduction and value addition [69].

The use of BSFL generates some advantages if the waste treatment system is expanded successfully from experimental to full-scale. Developing countries can become accustomed to this system when it is developed, applied, and managed at minimal expense through lessening infrastructure, maintenance, and operation expenses. Furthermore, establishing further value and making more income through selling larvae and utilizing them in the livestock industry can significantly boost the income of farmers [70].

A study about the effects of BSF on broiler chicken was already conducted in the Philippines, specifically in Musuan, Bukidnon. In the study by Villar [71], supplementation of BSFL indicated that there is a significant change in the average feed intake and ingestion while presenting a promising profit due to a return above feed cost and improved growth performance in terms of total weight gained, average daily gain, and final weight.

Safety use of BSFL as feed ingredients in poultry. The sanitation industry can utilize this insect to convert waste while producing cost-efficient protein for feeds [40]. Furthermore, when a BSF is actively feeding, it repels other species of flies by secreting a chemical, warding off disease vectors and pests like *Musca domestica* [72]. BSFL can solve waste problems associated with manure and organic leftovers by lessening moisture content and manure mass, as well as reducing offensive odours [4].

However, the microorganism found in or on the larvae of the BSF poses a risk to animal feed safety as well as public and environmental health [73]. A sanitary system is essential in handling organic waste and animal feed. Growing BSFL on non-defined waste which are likely to contain infectious pathogens might increase the risk of disease transmission. It is essential to supervise the quality of the feed. In some studies, BSFLs were utilized in treating wastes since they can eliminate some species of bacteria, such as Enterobacteriaceae, *Salmonella*, *Enteritidis*, and *Escherichia coli*. Moreover, the study also showed that viruses were remarkably lessened [3].

One of the matters regarding the production of BSFL is the transmission and collection of contaminants through the feed and food chain. Animal and human manures might possibly include drug residuals, mycotoxins, pesticides used for fruit and vegetables, heavy metals from municipal solid wastes, and other toxins [7]. Studies have suggested that certain pesticides, pharmaceuticals, mycotoxins, and dioxins do not build up in BSFL. However, some substances from biowaste, such as lead, cadmium, arsenic, and zinc, can be absorbed by BSF, and it may surpass the maximum limit allowed in animal feed regulations [74].

Price and legislation. The goal of replacing protein sources such as fishmeal and soybean meal with insects would entail a demand to produce a huge quantity of insect biomass. The cost of insect meals cannot compete with other common protein sources, which is a result of the scarce number of large-scale commercial production of insect meals and is presently too high [18]. Due to the inadequate number of produced insects, there is a substantial barrier in the utilization of insects as animal feed ingredients, thus not assuring a consistent supply. BSFL must be cost-efficient when produced at an industrial scale. In order to achieve mass production, automated process technologies for the process of rearing, harvesting, and post-harvest as well as regulating the safety and quality of products, must be established [75].

The economic feasibility of a BSF production system is influenced by several factors, the most important of which is the larval biomass or waste-to-biomass conversion ratio generated by a given amount of waste. This is affected by the type of materials included in the substrate [6]. In addition, infrastructure expenses such as space and containers are part of the cost of producing fly larvae. Other expenses include water, electricity, fly larvae feed, and labour [76].

Growing the size of the companies in the insect-producing industry will enhance efficiency and lessen the price of insects. The various ways to reduce the cost are intensifying bioconversion efficiency to lessen feed costs, increasing the size of insect-producing companies and proficient use of infrastructures to reduce housing costs. This can be done by enhancing heat exchange and ventilation to lessen energy usage. Moreover, improving breeding and rearing techniques to increase productivity and bettering the extraction efficiency of protein and fat are also more ways to reduce costs. Also, enhancing product value is also a great means to increase the competitiveness of insects [77]. The production expenses of these insects are expected to reduce after some time due to the characterization of effective methodologies for mass rearing. Moreover, the processes involved in BSF production are favourably well-suited for automation [26].

Consumer acceptance. The most considered barrier to the addition of insects in animal diets is general acceptance. The food preference of consumers is not only based on palatability, nutritional content, and environmental gain, but it is also affected by emotional and cultural factors such as experience, cultural associations, and adaptations [78]. BSFL as protein is achieving fast recognition as a high-value protein component in the diets of animals, especially pets and aquaculture [79].

Insect protein contains enough amino acids to meet the needs of humans and animals. While social barriers still exist in Western countries, consumers may be willing to consider insects as ingredients in livestock feed, starting with hybrid foods such as meat products containing insect meals, protein, or fat. To achieve this goal, it is critical to concentrate on food technology research and targeted advertising, which can include highlighting its benefits and focusing on early adopters [80]. The benefits of using insects in animal feed, such as improved livestock sustainability, reduced reliance on imported protein, and fewer negative environmental consequences, outweigh the drawbacks, which include unfavourable chemical residues in the food chain, microbial contamination, and decreased animal products acceptance by the consumer [75].

In a study conducted in Belgium, it was revealed that the utilization of insects as animal feed mostly for fish and poultry, was largely favourable. Food that was sourced from animals given insect-based feed was broadly accepted [81]. The use of insects as feed is presumed to be beneficial, as a study found that it has a 70 percent consumer acceptance rate. Furthermore, it was determined that there would be less dependency on protein imports and more waste valorization. The consumers believe that the benefits offset the risks associated. Better education of the public regarding the use of insects as feed ingredients is needed. A report by the European Food Safety Authority (EFSA) exhibited that insects that were fed solely on vegetable substrates in feed do not present biological or chemical hazards to consumers [10].

CONCLUSION

The use of BSFL as a protein ingredient in the diets of poultry is promising since there are no significant negative effects on growth and laying performance in meat and egg products. Moreover, the inclusion of BSFL is considered safe and economical when the production process is optimized. Production and utilization of BSFL are feasible in the Philippines since there are tons of unused organic waste streams as well as a large market due to the vast poultry industry.

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