Insect Meal: Blooming As Sustainable Alternative Animal Feed

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Introduction

The current world human population is 8.1 billion and it is predicted to increase to 9.7 billion in 2050 which would definitely face the formidable challenge of feeding with the finite available sources. Commodity inflation in recent past and availability of limited land for soya and maize production, demands for the alternative protein sources. Alternative protein sources have emerged as one of the critical research topics aiming at alleviating food shortage. Insects are one of the alternative protein sources along with other nutrients.

Entomophagy, which means the consumption of insects, is promoted as an alternative sustainable source of protein for both humans and animals. Edible insects are considered excellent sources of proteins, lipids, minerals, and vitamins. Moreover, they contain essential amino acids, polyunsaturated fatty acids and antioxidant compounds. Insects can be consumed whole or used as ingredients to fortify food formulations and are more efficient in converting feed to protein probably due to their poikilothermic physiology. On a commercial scale, insect production is considered as a promising strategy for global feed security, because they can be reared on bio-waste streams and to convert waste biomass into high value feed resources, grow and reproduce rapidly and responsible for great environmental impacts due to little land demand and lower greenhouse gas and ammonia emission.

Although, more than 2000 edible insect species have been reported in the literature, main insects used are black soldier fly, housefly, silkworms, bees, beetles, mealworms, crickets, locusts, grasshoppers and cicadas due to their great potential as feed on an industrial scale. The ideal insect species would have high productivity (i.e. high conversion rate and high potential of biomass increase per day), high egg production, high egg hatch, a short larval stage, low feed costs, low vulnerability to diseases, ability to live in high densities and a high-quality protein content.

Insect Farming

Insect farming has similar characteristics to that of livestock farming in that insects need feed (substrate) and water to supply energy and nutrients for maintenance, growth, reproduction and excrete intestinal contents (frass). The production is influenced by the scale off operation, level of technology used, level of biosecurity to prevent contamination, waste management units, etc. Some insect species justify the concept of circular economy and zero waste as they can efficiently convert low value organic substrate (wastes from industry or agriculture) into high value feed or product. Usually, biocides are used for disinfection of the production environment in between batches of insects. Eggs are introduced on to the substrate either manually, mechanically or by natural oviposition from adult flies and are maintained on it for 1-2 weeks depending upon species and also temperature. In case of mealworms it takes 8-10 weeks at temperature of 28-30°C and 60% relative humidity to reach the stage of harvest. Whereas, black soldier fly takes approximately 12 days. Black soldier flies are naturally found in cattle, poultry and pig manure but can also be reared on organic waste such as vegetables, coffee bean pulp and fish offal. Housefly larvae (maggots) can also be grown on cattle, pig and poultry manure along with Municipal organic waste. A single female fly can ovulate 750-1000 eggs per week which will then hatch into larvae. Larvae undergo three life stages in 72 h period and are harvested just before becoming pupae, dried, milled and packed. Yellow mealworms are also able to convert low nutritive organic waste products into high quality protein. 1 kg of mealworm biomass is produced from 2 kg of feed biomass. Thus, utilising bio-waste sources, particularly food waste, has been proved as ideal substrate for insect farming.

Nutritional Composition

Most insect species dry matter content is around 40% with the exception of black soldier fly (26.8%). In processed insects (in dried and ground form) dry matter content is around 90%. Protein (30%-65% of DM) is a significant component of edible insects along with 46%-96% of all amino acids where lysine and tryptophan are most limiting amino acids. Essential amino acids levels in silkworm pupae meal and black soldier fly larvae are higher than in soybean meal. Insects are also considerable sources of fat (between <5 and >50%). Omega fatty acids are rich in silkworm pupae meal and lowest in black soldier fly larvae. Designing substrates with more omega-3-fatty acids is desirable for enriching the final biomass with overall high fat content. A study shows that levels of EPA and DHA (omega-3-fatty acids) can be increased in black soldier flies by feeding them fish offal. Bees have a lipid profile composed of oleic, linoleic, linolenic, myristic, palmitic, and stearic fatty acids in large amounts. Crude fibre content in different edible insects range from 0-86% on DM basis. Most carbohydrates in insects are in form of chitin which may decrease insect protein digestibility and is also considered to induce allergic inflammation. Most insects contain higher levels of phosphorus than calcium. The phosphorus availability from insects in non-ruminants is almost 100%. Most insects are good sources of the trace elements like iron, zinc, copper, manganese and selenium but not for calcium. The most deficient vitamins in the insects are vitamins A, D, E, B1 and B12 when they are used as food/feed.

Use of Insect meal in Animal Nutrition

- ***Pigs:*** Black soldier fly prepupae meal could successfully replace dried plasma meal in pigs at 50% level with slightly better performance with or without amino acid supplementation. The peptides produced by black soldier fly and house fly larvae thriving on manure or organic waste having antimicrobial properties which might be functional in monogastric and livestock (especially pig and poultry).
- ***Poultry:*** In various research trials, it has been found that soybean meal can be partially replaced by black soldier fly up to 50% in poultry (broiler/layer) diets. Moreover, live insect larvae can be used as environmental and nutritional enhancers in poultry (broiler chickens or laying hens) in order to reduce feather pecking. Non insect chitin or chitin derivatives can enhance immune response by acting act as antibiotic/probiotic in rats and chicken along with hypolipidaemic properties in broilers.
- ***Ruminants:*** Use of insects in feed for cattle is not currently practised due to lower interest and acceptance of milk, dairy products and beef from insect fed cattle among farmers, stakeholders and consumers. However, a study on silkworm pupae meal indicated that it could replace 33% groundnut cake safely and economically (on weight basis) in fattening Jersey calf diets.

Processing technologies for edible insects

Processing is a critical step to develop insect meal for both animals and humans. Different pre-treatments lead to different effects on the insect's proximate composition. Heat treatments such as boiling and blanching show a negative effect on insect nutrition by causing Maillard and non-enzymatic browning reactions, but essential to assure food safety. Solar drying and oven drying are usually used to process whole insect bodies, while freeze drying, microwave drying, and some other novel drying technologies are mainly used in manufacturing insect flour and powders.

The extraction and production of protein isolates from insects is usually carried out using wet fractionation techniques. The most common method for solubilizing and recovering insect proteins is the alkaline method. But, current research on protein extraction under acidic conditions and alkaline conditions show conflicting results which demands for the further research. Insects with high-fat content requires defatting (using ethanol and hexane) before protein extraction. Studies indicate that Folch method and Soxhlet extraction methods have the highest lipid yield from insects, whereas aqueous methods have the lowest extraction efficiency but with the highest resultant ω-3 fatty acids concentration. Soxhlet extraction is considered as more suitable for industrial, large-scale production in insect industry. Thus, in terms of extraction technology, supercritical carbon dioxide extraction and ultrasound-assisted technology can improve the extraction efficiency of insect proteins and lipids, enhance the production of composite insect-fortified foods, which will ultimately facilitate the development of the insect feed and food industry.

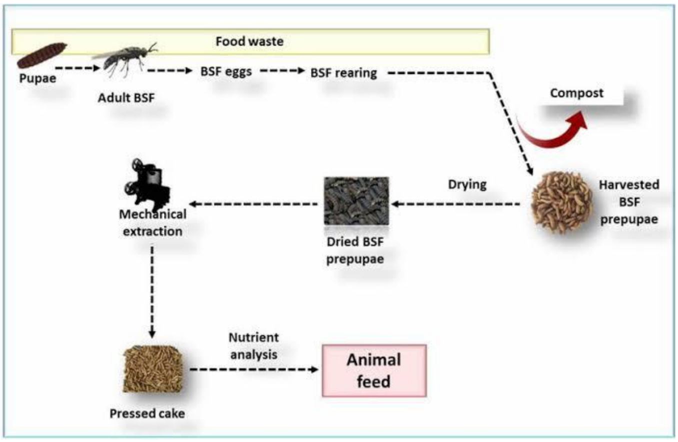

Fig 1 Schematic presentation of food waste bioconversion into animal feed via insect farming (Elgammal *et al.*, 2020)

Major Concerns

Antinutrient properties: Chitin has potential negative effects on protein digestibility. Mealworms and crickets contain spore forming bacteria and also many insects induce allergic reactions in susceptible individuals, due to the presence of tropomyosin, arginine kinase, glyceraldehyde 3-phosphate dehydrogenase and hemocyanin.

- **Risk assessment:** Evaluation of nutrient digestibility and toxic principles of insects (both processed/non-processed) for animals is important from a safety point of view.
- **Expensive processing methods:** Larvae of insects need to be processed from safety point of view and also to improve shelf life which is much costlier.
- **More awareness:** Cultural barriers and safety issues regarding insects as food are still quite strong which need to be addressed.
- **Legislative and regulatory issues:** Proper set of standards for insect meal and regulations for safe use of substrates such as vegetable and organic waste for insect farming is required.
- **Scaling up:** The quantity of insects required to replace 5% feed in poultry (both broilers and layers) will be around 1.1 million tons on 88% DM basis. In such case 3000 small scale insect producing units (capacity 365 t/year) are required in India.

Future Research

To include insects as feed ingredient in the pig and poultry diets on a large scale the scale of production of insects needs to be increased providing continuous quantity and quality. To make use of insects as a feed ingredient in the monogastric livestock feed chain, additional research on substrate needs per unit of insect biomass production in different species, feeding value with cost economics, functional properties of insects as feed ingredient, inclusion levels in animals' diet, safety and sanitary measures when using bio waste as substrate for rearing insects, extraction of nutrients to add value, shelf life, environmental footprint of insects in comparison to common protein feed resources and insect waste management need to be investigated.

Conclusion

Insect meal has a great potential to decrease the dependence on conventional protein sources for animal feed particularly, the most imported ones such as oilseed meal, soybean and sunflower meal. The global edible insects market presented in 2018 had a value close to USD 400 million, whereas, mass production of edible insects predicted to approximately 1.20 billion tons in 2025. Considering these facts, the development of a technological prospection is important to identify trends and potential investments in the insect industry. To be competitive, the cost of insect production needs to be more economical than currently used protein supplements. Establishing legal regulatory framework for use of insects/insect meals as animal feed and improved risk assessment methodologies are also very important for attracting investment in commercial insect farming. In addition, development of insect value chain by sharing knowledge and creating awareness among stakeholders of the insect industry will help to grow insect farming quickly on commercial scale which in turn contribute to global food security.

Order & species of insect	Stage at which harvested for feed/food	Protein (g/100g)	Fat (g/100g)	Fiber (g/100g)	NFE (g/100g)	Ash (g/100g)	Energy (Kcal/100g)
Coleoptera (Mealworm)	Larvae	40.69	33.40	10.74	13.20	5.07	490.30
Diptera (Black soldier fly and Housefly)	Larvae / Pupae	49.48	22.75	13.56	6.01	10.31	409.78
Lepidoptera (Silkworm)	Pupae	45.38	27.66	6.60	18.76	4.51	508.89
Orthoptera (Grasshopper and House cricket)	Adult	61.32	13.41	9.55	12.98	3.85	426.25

(Liang Z *et al.*, 2024; Borroso et al., 2014)

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