Insects as Nutrition and Enrichment:

The Benefits of Feeding Whole Dried Black Soldier Fly Larvae to Animals

Insects offer unique advantages across animal species including livestock, pets (cats and dogs), specialty pets (reptiles, amphibians, small mammals, fish), and exotics as dietary items. Insects can provide both nutritional benefits and behavioral enrichment. Feeding whole dried black soldier fly (*Hermetia illucens*) larvae (BSFL) to animals provides the nutritional values of high protein, lower fat than traditionally fed worms and larvae, and a positive calcium:phosphorus ratio that is unobtainable by other insect species, as well as the opportunity for animals to practice natural behaviors (e.g., foraging) which may help reduce unwanted behaviors (e.g., feather plucking).

NATURAL BENEFITS

While in the agriculture industry the term 'natural' has meaning in relation to regulatory standards, here what is meant by natural is something that an animal would eat in its native environment. Insects are a common natural dietary component of mammals, birds, fish, reptiles, amphibians, and other invertebrates. They are ingested both actively (as a purposeful part of the diet) and passively (as a by-product of the intended food item). Insects are a natural dietary item of many omnivorous fish species, as well as juvenile fish (Henry et al., 2015; Tran et al., 2015). Poultry and wild birds voluntarily eat insects throughout their different life stages (Józefiak et al., 2016; Zuidhof et al., 2003). Insects have been identified in the diets of wild wolves and both feral and domestic cats (Bosch & Swanson, 2020; Plantinga et al., 2011; Woolley et al., 2020). And lastly, insects are ingested by numerous wild animals, and a regularly provided diet item for many exotic animals. Koutsos et al. (2019) report that U.S. zoological institutions have offered invertebrates (which include insects) to mammals consecutively for more than 45 years, and to amphibians, reptiles, and spiders for over 10 years.

NUTRITIONAL BENEFITS

Protein

BSFL are a high protein food item with crude protein ranging from 37% to 63% (DMB) of whole dried larvae (Barragan-Fonseca et al., 2017). This range is an example of the effects of feed inputs on the nutritional composition of BSFL, with higher protein diets typically resulting in higher protein

larvae. In addition to high protein content, the protein is also high quality with a similar amino acid profile to traditional high-quality protein sources (Table 1).

Table 1. Comparison of essential amino acid profiles and digestibility (in parentheses) among black soldier fly larvae (BSFL) meal and two traditional high-quality protein sources.

	BSFL meal[1]	Soybean meal[2]	Menhaden Fishmeal[2]
Crude Protein	54.4	45.3	61.3
Arg	2.64 (92)	3.36 (94)	3.68 (92)
His	1.72 (87)	1.20 (91)	1.42 89
Ile	2.50 (90)	2.09 (90)	2.28 (92)
Leu	3.77 (90)	3.34 (89)	4.16 (92)
Lys	4.00 (87)	2.78 (90)	4.51 (88)
Met	0.90 (93)	0.64 (92)	1.63 (92)
Phe	2.36 (91)	2.28 (91)	2.21 (91)
Thr	2.18 (88)	1.77 (91)	2.46 (89)
Trp	0.79 (97)	0.59	0.49
Val	5.10 (74)	2.18 (88)	2.77 (91)
Cys	0.62 (72)	0.67 (86)	0.57 (73)
Tyr	3.34 (91)	1.25	1.80

[1] n=4 dried BSFL sources, 12-20% fat content. n=1 dried cricket meal source, 19% fat content. n=2 dried mealworm meal sources, 30% fat content. Data represent amino acid concentration and (digestibility) determined using cecectomized rooster model (Matin, 2019). Evaluation of the Nutritional Values of Seven Insect Meals for Inclusion in Poultry Diets. MS Thesis. U. Illinois.; [2] NRC, 1994.

Fat

These larvae are also a great source of energy due to their fat content. A unique component of the fatty acid profile of BSFL is the high level of lauric acid averaging 40% of the fat composition (Benzertiha et al., 2020; Borelli et al., 2021), which is comparable to coconut and palm kernel oils. When whole dried BSFL are included in animal feed and pet foods, the entirety of the lauric acid content is included; conversely, when ground BSFL products are used, only a portion of lauric acid is included as most will have been pressed out and remain within the oil product. The benefits of lauric acid have been demonstrated in a variety of species such as poultry (Wu et al., 2021), fish (Ullah et al., 2022), and swine (Spranghers et al., 2018). Some of these benefits include: 1) improved animal growth attributed to enhanced nutrient absorption from

positive modulation of gut microbial communities (Wu et al., 2021), 2) lower gram-positive bacterial infections (Spranghers et al., 2018), and 3) improved protein metabolism (Ullah et al., 2022).

Minerals

Lastly, whole dried BSFL are a good source of minerals. BSFL provide a positive ratio of calcium:phosphorous when fed a high calcium (3%) diet (Spranghers et al., 2017). This makes BSFL a particularly great food item for young and growing animals, poultry raised for egg production, and reptiles.

Feeding Programs

It is important to keep in mind that some nutrients of BSFL can be susceptible to influence by diet or age of larvae at harvest. Examples include calcium, manganese, zinc, Vitamin E, and some fatty acids (Boykin et al., 2020; Koutsos et al., 2019; Veldkamp et al., 2021). Although larvae can be fed on a range of feedstocks, their susceptibility to dietary changes can result in nutritional inconsistencies of whole dried BSFL. Therefore, attention should be paid to the feed inputs provided to growing larvae. Two common types of feed inputs include pre- and post-consumer food wastes.

Pre-consumer food wastes are last handled by an entity responsible for safe food production, and post-consumer food wastes are last handled by the consumer. Each of these food waste types can lead to inconsistent nutritional inputs. For example, leftover produce from grocery stores (considered pre-consumer) will vary with every batch. However, pre-consumer food waste in the form of food by-products, which are remnants from making a specific food product in a food manufacturing facility, provides very consistent nutritional inputs. This allows control over the nutrient profile of the final feed provided to growing larvae, and results in a controlled and consistent nutrient profile of whole dried BSFL.

ENRICHMENT BENEFITS

The term enrichment is commonly used in zoological settings but is becoming increasingly common within the livestock and pet industries (Morris et al., 2011). Enrichment is the process of engaging an animal with its environment and can occur in several ways including physical enrichment, social enrichment, feeding enrichment, and more (Laule, 2003). This discussion will focus on feeding enrichment as a method of environmental engagement. Supplying whole dried BSFL in treat toys for companion animals, in

substrates for livestock, and in both ways for exotic animals are just a few examples of how a natural, nutritious, and sustainable food item can be used.

Pets

Whole dried BSFL can be a great food enrichment item for pets, particularly when provided as a treat. Dog owners regularly provide treats to their pets (Morelli et al., 2020), and studies have demonstrated that providing treats in toys increases overall levels of activity in dogs (Schipper et al., 2008; Su et al., 2019). Food has also been used as motivation and reward for overweight cats participating in physical play to lose weight (Clarke et al., 2005). By encouraging physical activity through food enrichment balanced with daily meals, cats lost more weight than those who did not receive food enrichment and activity (Clarke et al., 2005). Whole dried BSFL are highly palatable, nutritious, and leave minimal environmental impacts, making them appealing to both pets and owners.

Livestock

Providing enrichment to pigs is known to redirect aggressive behaviors. Beattie et al. (2000) provided pigs with a control environment (traditional pens), partially enriched environment (added straw), or completely enriched environment (five distinct areas including defecating area, feeding area, rooting area, straw area, and sleeping area). Pigs in enriched environments spent more time interacting with the areas and substrates, while pigs in the control environment spent more time displaying "harmful social behavior". During the finishing phase, pigs in enriched environments had significantly higher growth rates and weighed significantly more. Additionally, meat from pigs in enriched environments demonstrated significantly lower cook loss, and significantly lower shear force, both of which indicate greater meat tenderness (Beattie et al., 2000). Livestock enrichment has the potential to benefit the animal, the producer, and the end consumer.

Exotics

In zoos, enrichment is regularly used to promote natural behaviors and reduce (negative) stereotypical behaviors (Laule, 2003; Morris et al., 2011). It also often increases animal activity, just as it does for pets and livestock. Iske et al. (2018) demonstrated a 50% increase in the activity of lions and tigers provided with feeding enrichment on enrichment days compared to pre-enrichment days, and a nearly 30% activity increase three weeks post-enrichment compared to

pre-enrichment (Iske et al., 2018). Another important point of enrichment for exotic animals is that it is appropriate to the species' natural biology (Swiasgood & Shepherdson, 2005). Considering the range of animals in zoological settings, the previously described benefit of insects as a natural food item to so many species make them an extremely versatile item for feeding enrichment programs.

PROCESSING BENEFITS

Although meals and oils are traditional ingredient forms, whole dried BSFL provide the benefit of both meal and oil in one ingredient. This reduces the amount of storage space needed, eases inventory management, and helps simplify formulations. Additionally, whole dried BSFL can be co-ground with other dry ingredients before the extruding or pelleting process as an easy way to incorporate the high fat ingredient.

SUSTAINABILITY BENEFITS

One of the most common ways in which insect production and processing can be highly sustainable is the lower resource requirement to raise insects as compared to traditional animal-based ingredients. By using less land, feed, water, and energy inputs, insect production and processing also releases less greenhouse gases into the atmosphere (Shah et al., 2022; Valdés et al., 2022). Additionally, whole dried insects are the most sustainable type of insect ingredient. Whole dried BSFL require less processing since they do not need to go through the pressing and grinding steps. This further reduces energy use and greenhouse gas emissions. As the global human population continues to grow, it is critical that there are sustainable ingredient options available to feed the livestock needed to feed people. Józefiak et al. (2016) report that although poultry production is less resource-intensive than other livestock species, the growing demand for protein to feed people is increasing the need for protein to feed poultry. BSFL ingredients are a viable sustainable solution to include in poultry and other animal diets.

CONCLUSION

As the first U.S. commercial scale black soldier fly larvae production facility, EnviroFlight prides itself on using the best processes and procedures to yield our whole dried BSFL (EnviroBug) and additional products (EnviroMeal, EnviroOil, EnviroFeed, and EnviroFrass). EnviroFlight uses locally sourced pre-consumer food by-products to feed our BSFL to ensure a consistent and quality larvae

product. Additionally, we frequently evaluate and improve the efficiencies of our equipment and processes to continually minimize the environmental impact of our BSFL products. We want insects to be a long-term sustainable solution to the growing demand for animal feed and pet foods!

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