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Nutritional Benefits of Black Soldier Fly Larvae Oil in Animal Feed

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Abstract *– Black Soldier Fly Larvae (BSFL) oil is currently an insect oil that potentially replaces fish oils in animal feed. However, there are limited information on its benefits and nutritional comparison of BSLF oil to fish oil. Present study was to evaluate the benefits of BSFL oil in animal feed and compare the BSFL to Fish oil. Collected data of BSFL oil in the animal feed and its physiological effects was obtained from several articles of reputable journal and compiled into a table. Meanwhile, BSFL was reared and extract their oil to determine the fatty acid composition and compare to fish oil. The current study indicated that BSFL oil can be used in various animal feeds, such as aquafeed, broiler feed, and pets. The BSFL oil which is included in the feed showed an improvement in growth and other physiological responses of animals. Meanwhile, in comparison to fish oil, BSFL oil has a similar composition of fatty acids such as Omega 3 and Omega 6. Eicosapentaenoic acid (EPA; 20:5n3) is detected in the BSFL oil, though the quantity is much lower than in fish oil. Further, the BSFL oil also contains lauric acid. In conclusion, BSFL oil can be an alternative feed ingredient to substitute fish oil and has beneficial to the growth and physiological responses of the animal*

Keywords: *BSFL, Feed, Feish, Oil*

INTRODUCTION

Insects have been utilized both as a substitute for traditional oil sources, such as fish oil (FO) and soybean oil (SBO) as a source of protein (Devi et al., 2022; Kipkoech et al., 2023; Nugroho & Nur, 2018), but they are also becoming value-added feed resources for the animal feed diets (Heuel et al., 2021; Kierończyk et al., 2022; Y. B. Kim et al., 2020). During their development, black soldier fly larvae, also known as BSFL (*Hermetia illucens* L.), are able to transform the huge amounts of organic substrates found in food or animal wastes into edible protein and fats/oil (Gligorescu et al., 2020; Lim et al., 2019; Liu et al., 2018). This makes them a popular bio recycling organism. According to Patterson et al. (2021); Wang and Shelomi (2017) the BSFL has more than forty percent protein that is abundant in essential amino acids and more than twenty-eight percent lipids. Meanwhile, the BSFL oil has a high concentration of medium-chain fatty acids, such as palmitic acid (C16:0), which is analogous to coconut oil (Abduh et al., 2017; Ushakova et al., 2016). The coconut oil is the only plant-origin oil where about 50% of the fatty acid composition is lauric acid (C12:0) (Nasir et al., 2018) which is also found in the BSFL oil (Lumanlan et al., 2022).

Due to their preference for energy consumption, Wang et al. (2015) found that medium-chain fatty acids may be advantageous in reducing abdominal fat. This is because medium-chain fatty acids consume less energy than long-chain saturated or unsaturated fatty acids. In addition, studies have demonstrated that lauric acid and other medium-chain fatty acids, like it, have antibacterial effects on the bacteria that live in the gut (Schiavone et al., 2017; Zeitz et al., 2015). Therefore, insect oils that are rich in lauric acid may have an influence on the growth performance and intestinal health of broiler chickens, who are known for their rapid rate of development (A Schiavone et al., 2018).

According to Khatun et al. (2018); Taulescu et al. (2010), the amount of fatty acids found in grill feed has an effect on the levels of those

acids found in meats and internal organs. This has direct implications for fat accumulation and metabolism. Meanwhile, Schiavone et al. (2017) discovered that substituting BSFL oil for SBO affected the fatty acid profile of broiler chicks. It was suggested by Kierończyk et al. (2018) that insect oil, such as that extracted from *Tenebrio molitor* and *Zophobas morio*, might be utilized as a replacement for soybean oil in the feed of broiler chickens without affecting either the growth performance or the nutritional digestibility of the chickens. In addition, Li et al. (2017) discovered that consumption of BSFL oil increased the amount of omega-3 fatty acid deposition in the muscles of juvenile carp while simultaneously reducing the amount of intraperitoneal fat buildup.

On the other hand, FO is also a pivotal part of the animal diet. Fish oil is a rich source of omega-3 fatty acids, which are essential nutrients that cannot be produced by animals themselves and must be obtained from their diet. Omega-3 fatty acids play a vital role in many physiological processes in animals, including brain function, immune system regulation, and cardiovascular health. In addition, these fatty acids are important for the development and maintenance of healthy skin and coat in animals. Therefore, including FO in the diet of animals can provide important growth and health benefits.

Though some researchs have been performed in the effects of the BSFL oil and FO in animal diet, However, recent data about the BSFL oil as a partial or total FO/SBO replacement and its physiological effects is still limited. Current research is to compile the physiological effects of the BSFL oil in the diet of fish and poultry animals. The comparison between the BSFL oil and FO are also evaluated in order to understand the potential use in the future feed preparation.

MATERIALS AND METHODS

1. Data comparison for BSFL oil in animal feed

All data regarding the use of BSFL oil in animal feed and their physiological effects was collected from the recent published articles (2018-2023), from various publisher. The information of the BSFL oil in the animal feed and its physiological effects was compiled into a table.

2. BSF rearing.

To compare the fatty acid content of BSFL oil versus FO, several steps were prepared, from BSFL rearing to BSFL oil analysis. In BSFL rearing, a number of BSFL (Average initial weight of 0.05 ± 0.004 g; Initial lenght of 12.43 ± 0.25 mm was purchased from a BSF farmer, Samarinda City, East Kalimantan, Indonesia. The BSFL were reared from third-generation flies fed with fermented Palm Kernel Meal (PKM). The BSFL were reared in a plastic box and maintained at temperature of 28.5 °C, for 17 days.

3. BSFL oil preparation

At the day 17th, the BSF was in the prepupal stage. All prepupal BSF were collected and dried (60 °C) for 48 h, and crushed, to make a meal. The BSFL meal and its oil were separated using an oil extractor (RG-307, Jiangsu, China). The BSFL oil was analyzed with GCMS for fatty acid composition and compared to fish oil.

RESULTS AND DISCUSSION

1. BSFL oil in animal feed

The black soldier fly larvae, often known as BSFL, are a highly sustainable insect candidate species because of their potential for use as a component in animal feed and their capacity to generate revenue. The introduction of insect meals into animal diets has been shown in a number of studies to

have the potential to improve animal survival rates, antioxidant capacities, and immunological responses. Present study found that various inclusion of BSFL oil in the diet of several animals and its physiological effects (Table 1).

Table 1. Partial and total inclusion/substitution of black soldier fly larvae (BSFL) oil in the diet of several animals and its physiological effects

Species	Suggested Inclusion/substitution	Physiological effects	References
Rainbow trout (*Oncorhynchus mykiss*)	Potentially be superior to 10%	Posterior intestine did not affect Blood glucose and BSFL oil addition concentration has a negative correlation Several antihyperglycemic effects in fasted rainbow trout. The digestibility of hydroxyproline was higher in feed with BSFL oil compare to reference feed	Dumas et al. (2018)
Rainbow trout (*Oncorhynchus mykiss*)	16% in the diet	Some immunological benefits Hepar or gut histology did not affect by BSFL oil. Upregulated of kidney interluekin-8, 41 tumor necrosis factor and IRF-1 Significantly higher serum peroxidase activity A substantial increase in lysozyme activity	Kumar et al. (2021)
Siberian sturgeon	30% inclusion	Positive effects on growth performance	Rawski et al. (2020)
Broilers	50% and 100% (Part and full replacement of Soybean oil)	No negative effect on the cecal microbiota of broilers. No minor affected on the Growth statues	B. Kim et al. (2020) B. Kim et al. (2020)
Broiler	25; 50; 75; 100% of BSFL fat (Part and full replacement of Soybean oil)	Several growth performances, length and weight of organ, nutritional absorption coefficients in the ileum did not influence by BSFL oil inclusion	Kierończyk et al. (2020)
Hens	20 g/kg of diet	The quality of the eggs was not affected significantly in terms of shell strength, egg composition, albumen percentage, or any of the major characteristics of the yolk.	Heuel et al. (2021)

Species	Suggested Inclusion/substitution	Physiological effects	References
Hens	Up to 4.5% of soybean oil substitution	Body weight, production of egg, Neither the feed conversion ratio nor the egg weight were affected by the BSFL oil. Eggs produced by hens given BSFL oil had a deeper yellow yolk colour than eggs laid by hens used as controls.	Patterson et al. (2021)
Turkey	50% and 100% (Part and full replacement of Soybean oil)	Growth performance was not influence, nutrient digestibility, gastro-intestinal tractus morphology, or the quality of the muscles of the chest and thighs. Reduced trypsin activity (Total replacement), but this had no effect on digestibility. full change of soybean oil reduced proliferation of potentially pathogenic bacteria (*Enterobacteriaceae* spp). Decreased levels of IL-6 (Total replacement), while part change reduced the TNF-α concentration.	Sypniewski et al. (2020)
Turkey	50% and 100% (Partial and total replacement of Soybean oil)	Lipase and amylase activity was improved. Liver health status was enhanced by decreased cholesterol and triglyceride concentration. Positively inhibited Bacteroides-Prevotella growth in the cecal digesta. Modulates the immune system by decreasing the level of IL6	Kierończyk et al. (2022)

As can be seen that the BSFL oil has been included and used as inclusion/substitution in various animal diet and has several physiological effects. In fish diet, the BSFL oil inclusion/substitution affected on the growth and immune parameters of the fish. In contrast, Li et al. (2017) observed that no change in growth parameter of the fish when SBO was substituted with BSFL oil from 0 to 100% in *Cyprinus carpio* diets, but did discover a rise in intraperitoneal fat, possibly owing to a considerable elevation of peroxisome proliferator-activated receptor alpha expression. Meanwhile, Dumas et al. (2018) found no deleterious effects of dietary BSFL oil incorporation levels of 2.5, 5.0, or 10.0% on rainbow trout growth, feeding efficiency, or gut histomorphology, and felt that greater inclusion levels were achievable. Furthermore, the BSFL oil had no impact on the expression of genes involved for inflammation in the gut or any signs of increased fat accumulation in the liver of fish (Kumar et al., 2021). In addition, the BSFL oil may totally replace fish oil or soybean oil in rainbow trout diets while also offering some health advantages, such as enhance the

oxidative state and diminish the expression of pro-inflammatory genes in in fish.

Meanwhile, the BSFL oil has a valuable physiological effect on some poultry animals such as hens and turkeys. It is revealed that replacement either partially or totally had positive effects on the health statues of those animals, but no growth effects. The BSFL oil has a genuine position as nutritional supplements for commercial poultry animals. According to Patterson et al. (2021), the oil extracted from BSFL has enough energy (7840 kcal/kg) and linoleic acid (15.29%) to easily replace soybean oil in poultry animal diet. With higher levels of dietary inclusion, for example in hens, both hen performance and egg quality were maintained, and melanin-lauric acid complexes in the amber hue of the BSFL oil are likely transferred to boost egg yolk color.

Furthermore, it is generally understood that the liver's quality, as the organ involved in lipid metabolism, is critical in determining the feasibility of fat/oil source adoption in animal diets. The BSFL oil may be used safely for partial or entire replacement of soybean oil with no changes in biochemical blood characteristics such as AST and ALT levels (Kierończyk et al., 2022). Previous findings of Schiavone et al. (2017); A. Schiavone et al. (2018), in which partial (50%) or entire inclusion of BSFL oil also mentioned that BSFL oil had no effect on AST and ALT blood concentrations in broilers compared to the soybean oil group (SO). Nonetheless, the partial substitution of BSFL oil, as opposed to the total replacement, had the lowest AST score, indicating that partial replacement is more helpful than whole replacement in terms of liver function.

It is hypothesized that changing the kind of oil used in turkey meals from soybean oil to BSFL oil would have a major impact on the selected microbiota populations in the ceca, which would have led to a reduction in the growth of the Bacteroides-Prevotella cluster in the digesta. It is also widely recognized that dietary fats that include high amounts of SFAs from both plant and animal sources, such as palm kernel fatty acid distillers (PKFD) and bovine tallow, may enhance the abundance of potentially harmful bacteria, such as Bacteroides and Clostridium perfringens. This is because SFAs are a kind of saturated fatty acid that may come from either plants or animals. (Józefiak et al., 2016; Knarreborg et al., 2002). On the other hand, oils that are high in fatty acids (FAs), such as oleic (C18:1), linoleic (C18:2), and linolenic (C18:3) acids, have antibacterial properties (Yoon et al., 2018). The relatively large amount of lauric acid in BSFL oil may have an effect on the microbiota composition, despite the fact that SFAs are the primary components of the FA profile in this oil. The antibacterial, antiviral, and antiparasitic effects that lauric acid has are well known and generally recognized (Dayrit, 2015; Ushakova et al., 2016; Zeitz et al., 2015).

2. BSFL oil versus Fish oil (FO)

Black soldier fly larvae oil and FO are both sources of omega-3 fatty acids, which are essential for good health for animal and abundance with some important fatty acid ingredients (Table 2). The BSFL oil is a relatively new and emerging source of oil that is gaining interest for its potential health benefits.

Table 2. Fatty acid comparison between black soldier fly larvae oil and fish oil

Fatty Acid	BSFL oil	Fish oil
Lauric acid (C12:0)	42.42	nd
Myristoleic Acid (C14:1)	0.23	1.97
cis-10-Pentadecenoic Acid (C15:1)	3.92	0.28
Palmitoleic Acid (C16:1)	0.14	2.45
Heptadecanoic Acid (C17:0)	0.03	6.46
Linoneic Acid (C18:2n6c)	7.15	1.61
Linoleladic Acid (C18:2n6t)	0.77	0.84
γ-Linolenic Acid (C18:3n6)	0.09	0.80
α-Linolenic Acid (C18:3n3)	0.07	2.64
Arachidie Acid (C20:0)	0.96	43.70
cis-11-Eicosanoic Acid (C20:1n9)	0.01	3.84
cis-5,8,11,14,17-Eicosapentaeonic Acid (C20:5n3)	0.04	1.34
Heneicosanoic Acid (C21:0)	0.00	2.52
Behenic Acid (C22:0)	0.01	1.66
Eruchic Acid (C22:1n9)	0.01	22.75
Tricosanoic Acid (C23:0)	0.23	1.97

Noted: W/W%= grams per 100 grams of sample. Results are expressed on a dry weight basis. nd = not detected.

There are some characteristics of the BSFL oil. The BSFL oil is a good source of omega-3 fatty acids, particularly alpha-linolenic acid (ALA). The ALA from BSFL oil is a precursor to other forms of omega-3s that are important for brain and heart health, such as EPA and DHA. Meanwhile, the BSFL oil is also high in lauric acid, which is a medium-chain fatty acid that has been linked to numerous health benefits, including improved cholesterol levels. The BSFL oil contains antioxidants such as tocopherols, which may help protect against oxidative stress and inflammation in the body. The high amount of lauric acid (C12:0) in the BSFL oil is one of its distinguishing characteristics (Oonincx et al., 2015). When animals eat lauric acid, it is promptly oxidized rather than retained in the liver, resulting in decreased feed intake (Belghit et al., 2019).

However, there are some differences between the BSFL oil and FO. Fish oil typically contains more omega-3 fatty acids than black soldier fly larvae oil (St-Hilaire et al., 2007). This is because fish accumulate omega-3s by consuming algae, which is rich in these fatty acids. The BSFL oil, on the other hand, contains a different type of omega-3 called alpha-linolenic acid (ALA), which is converted by the body into other forms of omega-3s such as EPA and DHA (Lozica et al., 2022). The EPA and DHA are more easily absorbed by the body than ALA, which means that fish oil may be more effective at increasing levels of these important omega-3s in the body. Fish oil contains other important nutrients such as vitamin D and astaxanthin, which have additional health benefits. The BSFL oil contains some antioxidants and vitamins (Lu et al., 2022), but not at the same levels as FO. Further, the BSFL oil is considered more sustainable than FO, as it can be produced using food waste and does not require wild fish populations to be harvested (Hossain et al., 2023). The BSFL oil is also considered to

be a sustainable source of oil because it can be produced using food waste and does not require the harvesting of wild fish populations. In addition, the BSFL oil has been shown to be stable at room temperature for up to six months, which is longer than some other vegetable oils.

CONCLUSION

There are various physiological effects of animal, such as in fish and poultry when the BSFL oil is included either partially or totally replacement in animal diet. Both FO and BSFL oil can be good sources of omega-3 fatty acids. The BSFL oil is a promising new source of oil that is rich in omega-3s, lauric acid, and antioxidants. Further research is needed to fully understand its health benefits and potential uses of BSFL oil in various animal feed and its gene regulation.

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