Insect Ingredients in Poultry Feed:

Benefits of Black Soldier Fly Larvae in Diets for Broilers and Layers

Insects have been reared commercially for over 70 years as fishing bait and for use in live feedings (e.g., to reptiles), but only recently have insects been included in commercial poultry diets. Researchers have examined black soldier fly larvae (BSFL; *Hermetia illucens*), house fly larvae (*Musca domestica*), and mealworms (*Tenebrio molitor*) (De Marco et al., 2015; Dörper et al., 2021) as feed ingredients for poultry. Among these, BSFL have many advantages. This insect is an incredibly sustainable source of nutrition, providing over one million pounds of protein per acre of production per year due to breeding efficiency, growth efficiency, and vertical farming methods (Koutsos et al., 2019. Larvae of the black soldier fly are high in protein with comparable amino acid digestibility to traditional protein sources (e.g., chicken meal and fishmeal), an excellent source of fat with a high concentration of lauric acid and consist of a positive calcium:phosphorus ratio (Koutsos et al., 2019).

Nutritional Benefits

Broilers

Carcass composition and meat quality are important impacts to consider when adding novel ingredients to broiler diets. Adding full-fat BSFL meal (0%, 5%, 10%, 15% and 20% inclusion rates; de Souza Vilela et al., 2021) or BSFL oil (50% or 100% replacement of soybean oil; Schiavone et al., 2017) to Ross 308 broiler diets did not negatively affect overall carcass composition (cut weights) or meat quality (pH, color, lipid oxidation, cook loss, and shear force) (Table 1). Despite comparable amino acid (AA) profiles of the diets, meat from broilers fed the 5, 10, or 15% BSFL meal diet showed significant increases in aspartic acid, glutamine, and lysine and a significant decrease in serine compared to broilers fed the control diet (differences between BSFL meal diets were not significant). Arginine was also numerically lower across BSFL meal diets compared to the control. Fatty acid (FA) composition of the meat from broilers fed the 20% BSFL meal diet demonstrated modifications of 23 of the identified 47 FAs. The FA composition of the BSFL diets more closely mirrored that of the larvae themselves with increases in EPA, myristic acid, and lauric acid (de Souza Vilela et al., 2021). Broilers fed either BSFL oil inclusion level maintained growth parameters (body weight gain [BWG], feed conversion ratio [FCR], and feed intake [FI]) compared to broilers fed soybean oil (Schiavone et al., 2017).

In another study, Kim et al. (2020) investigated Ross 308 broiler performance when fed diets containing 5% BSFL oil, coconut oil or corn oil. Body weight gain and FI were not affected by dietary

treatment, but FCR was significantly higher for broilers fed the corn oil diet (Table 1). Additionally, most carcass and meat quality parameters were similar across treatments (Kim et al., 2020).

EnviroFlight's BSFL ingredients, EnviroMeal and EnviroOil, have also been included in broiler diets at up to 15% and 3% inclusions, respectively, replacing soybean meal and poultry fat. Across the 37-day feeding trial, FI was not affected by dietary treatment, and differences in FCR were only observed between the control and highest EnviroMeal inclusion rate (15%). Body weight gain was highest or most comparable to the control with the inclusion of 5% EnviroMeal while no differences in BWG were observed across EnviroOil diets. All carcass parameters (fat pad weight, fat pad color, surface color, cross section color) were comparable across all EnviroOil diets. Most carcass parameters were also comparable across EnviroMeal diets except for slightly different color scores detectable when using spectrophotometry.

Layers

Similar to the importance of carcass and meat quality for broilers, egg quality is important for layers. Al-Qazzaz et al. (2016) demonstrated significantly improved egg production, egg and shell weights, shell thickness, egg yolk color and more when Arabian hens were fed diets including BSFL meal. Furthermore, appearance, taste, texture and consumer acceptance of eggs from hens fed the highest BSFL meal inclusion rate of 5% were significantly improved (Al-Qazzaz et al., 2016). These data align with Bejaei and Cheng's (2020) study in which odor, taste, and texture of eggs from Novogen Brown layers fed chopped dried BSFL partially or completely replacing soybean meal in layer hen diets were similar to eggs from hens fed soybean meal.

Furthermore, Mwaniki et al. (2020) also demonstrated improved or maintained egg quality (yolk color, haugh unit, shell breaking strength, and shell thickness) when soybean meal was replaced by BSFL meal at either 50% or 100% in the diets of Shaver White hens. In another study replacing soybean meal with either defatted or full-fat BSFL meal inclusions of 5%, Petkov et al. (2022) significantly increased not only egg production (% total and per hen), but significantly decreased FI (g/bird/d) resulting in improved feed efficiency (g feed/egg).

When Patterson et al. (2021) fed diets using EnviroFlight's EnviroMeal at up to 16% inclusion in place of soybean meal and oil, and EnviroOil at up to 4.5% inclusion replacing soybean oil, Hyline layers maintained egg production and quality with an improvement in egg yolk color (darker pigmentation) from the natural source of carotenoid pigments provided by EnviroMeal and EnviroOil. When fed diets containing whole dried BSFL (EnviroBug) at up to 18% of the diet, replacing calcium sources,

soybean meal and soybean oil, hens also maintained egg production (number laid and mean egg weight) and quality (albumen ht, egg specific gravity, haugh unit, and yolk color).

Turkeys

Table 1. Selected growth and carcass traits of different poultry types fed diets of varying BSFL meal and oil inclusion levels.

Poultry Type	Diet	BW, g	FCR	Breast Meat Yield, %	Breast pH	TG, mg/dL[5]
Broiler[a]	Control	3085[1]	--	10.6[3]	--	--
	5% BSFL meal	3034	--	10.6	--	--
	10% BSFL meal	3100	--	10.2	--	--
	15% BSFL meal	3202	--	10.4	--	--
	20% BSFL meal	3282	--	10.4	--	--
Broiler[b]	Control	1747[1]	1.48	24.3[4]	5.95	48.2
	BSFL oil as 50% soybean oil replacement	1763	1.51	24.7	5.91	56.2
	BSFL oil as 100% soybean oil replacement	1796	1.52	27.8	5.99	49.5
Broiler[c]	100% BSFL oil	1454[1]	1.49	7.2[3]	5.73	117.4
	100% coconut oil	1479	1.46	6.9	5.64	123.5
	100% corn oil	1384	1.58	7.1	5.70	138.4
Turkey[d]	Control	1398[2]	1.56	--	--	112.2
	BSFL oil as 50% soybean oil replacement	1396	1.56	--	--	122.9
	BSFL oil as 100% soybean oil replacement	1372	1.58	--	--	124.1
Quail[e]	Control	194[1]	2.83	30.7[3]	5.76	--
	10% BSFL meal	189	2.90	30.8	5.68	--
	15% BSFL meal	187	2.86	30.7	5.67	--

[a]de Souza Vilela et al., 2021; [b]Schiavone et al., 2017; [c]Kim et al., 2020; [d]Sypniewski et al., 2020; [e]Cullere et al., 2016; [1]final BW; [2]BWG; [3]% body weight; [4]% carcass weight; [5]Blood TG

Sypniewski et al. (2020) partially (50%) and completely replaced soybean oil with BSFL oil in the diets of female turkey poults (B.U.T. 6) and found similar performance as compared to soybean oil for growth performance (BWG, FCR, and FI), gut morphology, nutrient digestibility or muscle composition (triglycerides and cholesterol) (Table 1).

Quail

BSFL meal has also been successfully included in the diets of broiler quail (*Coturnix coturnix japonica*) as a partial replacement for soybean meal and oil. Cullere et al. (2016) fed two treatment diets where BSFL meal replaced approximately: (a) 28% of soybean meal and 16% of soybean oil in treatment one, and (b) 25% of soybean meal and 100% of soybean oil in treatment two. Overall, performance parameters (BWG, FCR, and FI), carcass characteristics (dressing %, breast muscle weight, yield, pHu, color, and cooking loss) and mortality were similar to hens fed the soybean oil diets when BSFL oil was included (Table 1) (Cullere et al., 2016).

Value Added Benefits

Broilers

BSFL oil and whole dried larvae have also been investigated in Ross 308 broiler diets. Kim et al. (2020) tested a single inclusion level of coconut, corn, or BSFL oil and found the BSFL oil diet to increase serum antioxidant capacity while also improving FCR and increasing medium-chain fatty acid incorporation into the broiler abdominal fat pad. When whole dried BSFL were included at 0%, 1%, 2% or 3% of the diets of *Salmonella* Gallinarum-challenged Ross broilers, broilers fed the BSFL diets showed enhanced immune responses and greater survival (Fig. 1; Lee et al., 2018).

Layers

Considering the natural foraging behavior of hens, Star et al. (2020) investigated the effects of providing live BSFL to Dekalb White layers to improve stereotypy behaviors. Layers were fed a control diet or soy-free treatment diet top-dressed with live BSFL. Performance (BWG, FCR, egg production, and egg quality) was similar among both groups, but layers provided with live larvae had significantly better feather condition due to reduced feather picking behavior.

Turkeys

When BSFL oil was included in the diets of female turkey poults (as 50% or 100% soybean oil replacement), the total number of bacteria in the jejunum were significantly increased while Enterobacteriaceae counts were significantly decreased (Fig. 1; Sypniewski et al., 2020). The authors attributed the increase of healthy bacteria and simultaneous decrease in pathogenic bacteria to the high lauric acid content of BSFL which averages 40%. Furthermore, a significant decrease in crop pH associated with poults fed the BSFL oil diets is considered another positive effect of the lauric acid

content, and likely contributed to the lower Enterobacteriaceae count since these bacteria proliferate in higher pH environments (Sypniewski et al., 2020).

Quail

Broiler quail (*C. japonica*) fed one of two treatment diets with BSFL meal partially replacing soybean meal, and partially or completely replacing soybean oil, maintained fecal microbial compositions similar to those reported for healthy quails in other published literature (Cullere et al., 2016). The authors considered these results in relation to the high lauric acid content and known antimicrobial peptides present in BSFL ingredients.

Conclusion

BSFL products are a natural, nutritious, and sustainable option for poultry diets that include value-added components, all in one ingredient! Multiple product options, including whole dried BSFL (EnviroBug), BSFL defatted meal (EnviroMeal), and mechanically separated BFSL oil (EnviroOil) provide opportunities for diet formulation to fit poultry production needs. Additionally, unique characteristics of BSFL, such as high lauric acid content, may provide benefits beyond nutrition, including modulation of gut bacteria. EnviroFlight's BSFL are raised and processed in the USA with a focus on sustainable production using AAFCO-defined by-products as feedstock, vertical farming methods, and energy efficient processes.

References

Al-Qazzaz, M. F. A., D. Ismail, H. Akit, and L. H. Idris. 2016. Effect of using insect larvae meal as a complete protein source on quality and productivity characteristics of laying hens. R. Bras. Zootec. 45(9):518-523. doi:1590/S1806-92902016000900003

Bejaei, M. and K. M. Cheng. 2020. The effect of including full-fat dried black soldier fly larvae in laying hen diet on egg quality and sensory characteristics. J. Insects Food Feed. 6(3):305-314. doi:10.3920/JIFF2019.0045

Cullere, M., G. Tasoniero, V. Giaccone, R. Miotti-Scapin, E. Claeys, S. De Smet, and A. Dalle Zotte. 2016. Black soldier fly as dietary protein source for broiler quails: Apparent digestibility, excreta microbial load, feed choice, performance, carcass and meat traits. Animal. 10(12):1923-1930. doi:10.1017/S1751731116001270

De Marco, M., S. Martínez, F. Hernandez, J. Madrid, F. Gai, L. Rotolo, M. Belforti, D. Bergero, H. Katz, et al. 2015. Nutritional value of two insect larval meals (*Tenebrio molitor* and *Hermetia illucens*) for broiler chickens: Apparent nutrient digestibility, apparent ileal amino acid digestibility and apparent metabolizable energy. Anim. Feed Sci. Tech. 209:211-218. doi:10.1016/j.anifeedsci.2015.08.006

de Souza Vilela, J., T. I. R. C. Alvarenga, N. R. Andrew, M. McPhee, M. Kolakshyapati, D. L. Hopkins, and I. Ruhnke. 2021. Technological quality, amino acid and fatty acid profile of broiler meat enhanced by dietary inclusion of black soldier fly larvae. Foods. 10(297). doi:10.3390/foods10020297

Dörper, A., T. Veldkamp, and M. Dicke. 2021. Use of black soldier fly and house fly in feed to promote sustainable poultry production. J. Insects Feed Food. 7(5):761-780. doi:10.3920/JIFF2020.0064

Kim, Y. B., D-H. Kim, S.-B. Jeong, J.-W. Lee, T.-H. Kim, H.-G. Lee, and K.-W. Lee. 2020. Black soldier fly larvae oil as an alternative fat source in broiler nutrition. Poult. Sci. 99(6):3133-3143. doi:10.1016/j.psj.2020.01.018

Koutsos, L., A. McComb, and M. Finke. 2019. Insect composition and uses in animal feeding applications: A brief review. Ann. Entomol. Soc. Am. 112(6):544-551. doi:10.1093/aesa/saz033

Lee, J.-A., Y.-M. Kim, Y.-K. Park, Y.-C. Yang, B.-G. Jung, and B.-J. Lee. 2018. Black soldier fly (*Hermetia illucens*) larvae enhances immune activities and increases survivability of broiler chicks against experimental infection of *Salmonella* Gallinarum. J. Vet. Med. Sci. 80(5):736-740. doi:10.1292/jvms.17-0236

Mwaniki, Z., A. K. Shoveller, L.-A. Huber, and E. G Kiarie. 2020. Complete replacement of soybean meal with defatted black soldier fly larvae meal in Shaver White hens feeding program (28-34 wks of age): Impact on egg production, egg quality, organ weight, and apparent retention of components. Poult. Sci. 99:959-965. doi:10.1016/j.psj.2019.10.032

Patterson, P. H., N. Acar, A. D. Ferguson, L. D. Trimble, H. B. Sciubba, and E. A. Koutsos. 2021. The impact of dietary black soldier fly larvae oil and meal on laying hen performance and egg quality. Poult. Sci. 100:101272. doi:10.1016/j.psj.2021.101272

Petkov, E., M. Ignatova, and T. Popova. 2022. Layers' performance and egg hatchability as affected by the dietary inclusion of two meals of black soldier fly (*Hermetia illucens*). J. Insects Feed Food. 8(10):1077-1084. doi:10.3920/JIFF2021.0206

Schiavone, A., M. Cullere, M. De Marco, M. Meneguz, I. Biasato, S. Bergagna, D. Dezzutto, F. Gai, et al. 2016. Partial or total replacement of soybean oil by black soldier fly larvae (*Hermetia illucens L.*) fat in broiler diets: Effect on growth performances, feed-choice, blood traits carcass characteristics and meat quality. Italian J. Anim. Sci. 16(1):93-100. doi:10.1080/1828051X.2016.1249968

Star, L., T. Arsiwalla, F. Molist, R. Leushuis, M. Dalim, and A. Paul. 2020. Gradual provision of live black soldier fly (*Hermetia illucens*) larvae to older laying hens: Effect on production performance, egg quality, feather condition and behavior. Animals. 10(216). doi:10.3390/ani10020216

Sypniewski, J., B. Kierończyk, A. Benzertiha, Z. Mikołajczak, E. Pruszyńska-Oszmałek, P. Kołodziejski et al. 2020. Replacement of soybean oil by *Hermetia illucens* fat in turkey nutrition: Effect on performance, digestibility, microbial community, immune and physiological status and final product quality. Brit. Poult. Sci. 61(3):294-302. doi:10.1080/00071668.2020.1716302