



Effect of Dietary Selenium Conjugated Protein Black Soldier Fly Larvae Meal on Carcass Characteristics and Meat Fatty Acid Profiles in Broiler Duck

DAVID KURNIAWAN^{1,2}, EKO WIDODO², AGUS SUSILO², OSFAR SJOJFAN^{2*}

¹Department of Poultry Product Processing, Community College State of Putra Sang Fajar, Blitar, Indonesia; ²Faculty of Animal Science, University of Brawijaya, Malang, Indonesia.

Abstract | The study evaluated the effects of Se-conjugated protein black soldier fly larvae meal (Se-BSFL) on carcass characteristics and meat fatty acid profiles in broiler ducks. This study used a total of 200 one-day-old hybrid broiler ducks which were randomly divided into 4 treatment groups with 5 replicates, each replicate consisting of 10 ducks. The broiler ducks were fed with basal diet without Se-BSFL meal (0%), basal diet with 5% Se-BSFL meal, basal diet with 7.5% Se-BSFL meal, and basal diet with 10 mg/kg Se yeast. The results showed that feeding Se-BSFL with 7.5% and 10 mg/kg Se-Yeast significantly ($p < 0.05$) decreased slaughter weight, carcass weight, breast yield, breast yield, breast percentage, thigh yield, and thigh percentage, but showed no significant difference in carcass percentage. The monounsaturated fatty acid profile of meat increased significantly ($p < 0.05$) in line with the increase in Se-BSFL feeding level, but in contrast, the polyunsaturated fatty acid profile decreased significantly ($p < 0.05$). In conclusion, feeding 5% Se-BSFL is recommended because it does not show a negative impact on carcass characteristics, especially a decrease in slaughter weight and carcass weight and shows the highest carcass percentage. Feeding Se-BSFL also had an impact on the monounsaturated and polyunsaturated fatty acid of broiler duck meat. These results indicate the potential use of Se-BSFL as a feed ingredient in poultry production although the use of high levels will reduce slaughter weight and carcass yield.

Keywords | Meat quality, Organic selenium, MUFA, Feed additive

Received | August 15, 2024; **Accepted** | September 16, 2024; **Published** | December 27, 2024

***Correspondence** | Osfar Sjojfan, Faculty of Animal Science, University of Brawijaya, Malang, Indonesia; **Email:** osfar@ub.ac.id

Citation | Kurniawan D, Widodo E, Susilo A, Sjojfan O (2025). Effect of dietary selenium conjugated protein black soldier fly larvae meal on carcass characteristics and meat fatty acid profiles in broiler duck. *Adv. Anim. Vet. Sci.* 13(1): 108-114.

DOI | <https://dx.doi.org/10.17582/journal.aavs/2025/13.1.108.114>

ISSN (Online) | 2307-8316; **ISSN (Print)** | 2309-3331



Copyright: 2025 by the authors. Licensee ResearchersLinks Ltd, England, UK.

This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

INTRODUCTION

The demand for livestock-derived food has increased along with the increase in human population growth and public awareness to consume animal protein. By 2050, animal food production will increase by 60%-70% to meet global food demand (FAO, 2022).

Livestock production will gradually increase in response

to increasing demand for animal food, requiring more resources such as land and feed. Feed in the livestock industry accounts for about 60-75% of overall production costs with the need for feed ingredients containing protein sources reaching more than 15% (Khan *et al.* 2016). Insects are one of the new, alternative and sustainable feed sources that address important challenges in the animal feed industry. The advantage of insects is that they can be cultivated in organic side streams and thus contribute to

Hermetia illucen L., commonly known as the black soldier fly (BSF), is being investigated for its potential to feed a variety of livestock, control certain harmful bacteria and insect pests, turn organic waste into high-quality protein, and supply possible chemical precursors to produce biodiesel (Barragan-Fonseca *et al.*, 2017). Higher percentages of protein (37–63%) as well as other macro- and micronutrients that are necessary for animal feed are present in BSF larvae. According to studies already conducted, using BSF larvae in fish, pig, and poultry feed can only partially substitute traditional feed ingredients (Cullere *et al.*, 2016).

Hermetia illucen L., also known as the black soldier fly (BSF), has been investigated for its potential to feed various livestock, control harmful bacteria and insect pests, and convert organic waste into high-quality protein source material (Barragan-Fonseca *et al.*, 2017). BSF larvae have a high protein content (37–63%) and contain other macro- and micro-food substances needed for animal feed. Based on previous research studies, the use of BSF larvae in fish, pig and poultry feed can partially replace traditional feed ingredients (Cullere *et al.* 2016). The utilization of BSF larvae as a source of poultry feed ingredients has led to efforts to enrich certain nutritional values to produce high quality and economic value livestock products. A number of studies have examined the biofortification potential of insects with selenium as an organic selenium source (Ferrari *et al* 2022; Zhang *et al* 2024). This new type of organic selenium source called selenium conjugated insect protein (SCIP) is made through two biotransformation processes: microbial fermentation and insect larval synthesis. SCIP provides excellent bioavailability, biosafety, and high biological value to livestock (Qiu *et al* 2021).

Selenium is an essential mineral involved in metabolism, immune response, antioxidant activity, and animal growth (Gu and Gao, 2022). Selenium plays a role in the formation of the enzyme glutathione peroxidase which functions to remove peroxides, protecting cells and membranes from oxidative damage (Silva *et al.*, 2019).

The poultry industry has challenges in reducing the impact of lipid oxidation of unsaturated fatty acids in meat and egg products when stored, resulting in various rancid flavors and aromas (Nemati *et al* 2021). Wang *et al.* (2021) reported that selenium supplementation in feed can improve growth performance, selenium content in muscle, antioxidant activity and meat quality of broilers. The use of selenium doses in livestock needs to be considered because there are toxicity effects at high levels. Kim and Kil (2020) reported that feed supplementation with inorganic Se showed a decrease in body weight gain and greater feed

intake compared to poultry given feed containing organic Se at the same dose of 15 mg/kg feed.

Broiler ducks are one of the poultry animals that are utilized for meat production. Duck meat has high nutritional value because it contains essential amino acids and has a healthy fatty acid profile (Ismoyowati and Sumarmono, 2019). Consumers prefer duck meat for its delicate flavor and texture, as well as its high content of easily digestible protein, polyunsaturated fatty acids, and vitamins (Cao *et al.*, 2021). The content and composition of fatty acids in meat is one of the main factors that determine meat quality, including meat color, freshness, flavor, and nutritional value (Kamal *et al.*, 2022). The worldwide population of ducks (*Anas* spp.) reaches 1.15 billion and about 1.0 billion (89%) are in Asia (FAO, 2022). Duck meat production in Indonesia has averaged 37.8 thousand tons/year over the past 5 years, contributing less than 1% of national meat production from all livestock species (Directorate General of Animal Husbandry and Animal Health Indonesia, 2021). Many previous studies have reported the effects of selenium supplementation on growth, production performance, and meat quality of poultry, especially chicken, but very limited on broiler ducks. Therefore, the objective of this study was to investigate the potential of Se-conjugated protein black soldier fly larvae meal (Se-BSFL) as a feed ingredient on carcass characteristics and meat fatty acid profile in broiler duck.

MATERIALS AND METHODS

ETHICAL CLEARANCE

Under the ethical number (No. 004-KEP-UB-2024), this experiment methodology was conducted according to the Animal Care and Research Ethics Committee's guidelines at the Institut Biosains Universitas Brawijaya, Indonesia.

BIRDS, DIETS AND HOUSING

A total of 200 (one-day-old) hybrid broiler ducks were randomly allocated into four dietary treatments in five replicates, with 10 ducklings per replicate and 50 ducklings per group. All experiment ducklings were raised in the communal cages (100 cm width × 200 cm length × 60 cm height). The birds were housed at an initial ambient temperature of approximately 32°C, which was gradually reduced to 22°C under routine management practices. Relative humidity was maintained at 50–70%. A continuous lighting schedule was used for the first 7 days, followed by 23 hours of lighting for the remainder of the experiment. The experimental compartment was equipped with water fountains and feeders. Throughout the rearing period, fresh water and feed were given on a continuous basis. There were two phases to the feeding plan during the trial period: starter (day 1:21) and finisher (day 22:42). Four experimental diets were formulated as starter-finisher

diets as recommended by the NRC (1994). The diets provided included basal diet without Se-BSFL meal (0%), basal diet with 5% of Se-BSFL meal, basal diet with 7.5% of Se-BSFL meal, and basal diet with 10 mg/kg Se-yeast as control diet. The nutritional composition of the Se-BSFL meal and BSFL meal utilized in the study is detailed in Table 1. Table 2 presents the chemical composition of the basal diet. The selenium conjugated BSF protein (Se-BSFL) meal was supplied from the Department of Poultry Product Processing, Community College State of Putra Sang Fajar Blitar, Indonesia. The procedure for preparing Se-BSFL meal by enriching sodium selenite through two biotransformation steps refers to the research of Qui *et al* (2021). First, fermentation of larval growth media enriched with sodium selenite using *Saccharomyces cerevisiae* yeast at optimal conditions by Faramarzi *et al* (2020). The growth media consisted of bran and soybean meal as raw materials for 400 mg of sodium selenite, according to previous research (Kurniawan *et al.*, 2024). Second, the fermented growth medium was fed to the larvae. Finally, the selenium-enriched larvae were dried and ground.

Table 1: Nutritional and selenium content of BSFL and Se-BSFL meal.

Nutritional Content	BSFL meal	Se-BSFL meal
Dry Matter Content (%)	94.85	94.65
Ash (%)	6.15	6.58
Crude Protein (%)	41.71	41.81
Crude Lipid (%)	36.90	36.80
Gross Energy (cal/kg)	5900	6140
Selenium Content (mg/kg)	1.26	223.61

Note: Result of laboratory nutrition and feed technology, university of brawijaya.

CHARACTERISTICS CARCASS PERFORMANCE MEASUREMENT

At the end of the rearing period on day 49, one bird per replicate per treatment was randomly selected, weighed, and slaughtered by cutting the jugular vein in a professional slaughtering room. The birds are fasted for 12 hours before being slaughtered, bled, scalded and their feathers mechanically plucked. The process of collecting and transporting the ducks is done with proper handling so as to ensure minimal stress and injury. Bleeding slaughter is done effectively by ensuring thorough removal of blood. Scalding at the right temperature and duration loosens feathers for easier plucking and to avoid skin damage. Rapid cooling to 4°C or lower to prevent bacterial growth. The broiler duck carcass characteristics were then established by weighing the carcass, the muscles in the breast and legs, and determining the relative weight as a percentage of the live body weight.

Table 2: The composition and nutritional content of the basal diet.

Ingrediens (%)	0-21 Day	22-49 Day
Corn	10,05	19,03
Soybean meal	29,05	20,07
Rice bran	45,00	45,00
Fish meal	7,00	7,00
Palm oil	2,00	2,00
Premix	1,50	1,50
Salt	0,10	0,10
L-Lysine	0,10	0,10
DL-Methionine	0,20	0,20
BSFL meal	5,00	5,00
Calculation results		
Energi Metabolis (kcal/kg)	2.860	2.945
Crude Protein (%)	23,00	18,00
Crude Lipid (%)	7,96	9,08
Crude Fiber (%)	3,00	2,92
Calcium (%)	0,60	0,55
Phosphorus (%)	0,33	0,28
Lysine (%)	1,58	1,38
Methionine (%)	0,65	0,60
Test results*		
Gross Energy (cal/kg)	3.906	4.163
Crude Protein (%)	22,68	18.50

Note: *Result of laboratory nutrition and feed technology, university of brawijaya.

MEAT FATTY ACID PROFILE

The pectoralis major muscle was examined to determine the meat's fatty acid (FA) content. These methods were developed considering Vilela *et al.* (2021) as a basis. The FA profile was determined using gas chromatography (GC). FAME, or fatty acid methyl esters, are produced by converting fatty acids. The associated fatty acids' FAME was determined using gas chromatography. To identify fatty acid methyl esters, individual standards' retention durations were examined. They were discovered by comparing the fatty acids' retention lengths to the assigned standards. The chromatographic peak regions were utilized to calculate the relative amounts of fatty acids.

STATISTICAL ANALYSIS

All data were presented as means, which were compared using the SPSS program and one-way ANOVA in a completely randomized design. The LSD test mean differences were estimated based on the least significant difference. All tests were considered significant when the p-value was less than 0.05.

Table 3: The effect of dietary Se-BSFL meal on carcass characteristics of broiler ducks at 49 days of age.

Parameter	Se-BSFL meal (%)			Se-yeast 10 mg/kg
	0	5	7,5	
Slaughter weight (g)	2,277 ± 90 ^b	2,299 ± 166 ^b	1,909 ± 132 ^a	1,866 ± 221 ^a
Carcass (g)	1,443 ± 75 ^b	1,495 ± 110 ^b	1,206 ± 80 ^a	1,250 ± 118 ^a
Breast (g)	199±33 ^a	168±26 ^{ab}	106±23 ^b	103±47 ^b
Thigh (g)	206±18 ^a	207±7 ^a	177±23 ^b	174±23 ^b
Heart (g)	12.24±0.3 ^a	12.60±2.1 ^a	11.00±0.7 ^{ab}	10.20±1.5 ^b
Liver (g)	51.6±3.0	58.2±9.7	53.2±11.2	56.7±4.0
Gizart (g)	59.6±8.4	62.3±5.6	50.5±8.4	57.2±8.0
Abdominal Fat (g)	31.2±13	35.9±6.6	26.8±6.4	30.2±12
Percentage				
Carcass (%)	63.37 ± 2.86	65.04 ± 1.29	63.18 ± 2.83	62.74 ± 4.63
Breast (%)	18.93 ± 1.16	18.58 ± 2.48	16.95 ± 1.00	16.31 ± 1.08
Thigh (%)	12.71 ± 0.67 ^a	13.92 ± 0.48 ^{ab}	14.42 ± 1.08 ^b	14.13 ± 0.95 ^b
Heart (%)	2,26 ± 0,18 ^a	2,53 ± 0,40 ^{ab}	2,78 ± 0,52 ^{ab}	3,09 ± 0,62 ^b
Liver (%)	0,53 ± 0,03	0,55 ± 0,11	0,57 ± 0,03	0,54 ± 0,03
Gizart (%)	2,63 ± 0,47	2,71 ± 0,20	2,65 ± 0,53	3,10 ± 0,54
Abdominal Fat (%)	1,36 ± 0,56	1,55 ± 0,22	1,40 ± 0,33	1,57 ± 0,49

Note: Means within a row with different superscripts are different (P <0.05).

RESULTS AND DISCUSSION

EFFECT OF SE-BSFL ON THE CARCASS CHARACTERISTICS

The effects of dietary Se-BSFL supplementation on the carcass characteristics of the broiler ducks are presented in Table 3. The dietary 7.5% Se-BSFL meal and 10 mg/kg Se-yeast significantly decreased (p <0.05) between all treatments in slaughter weight, carcass yield, breast yield, breast percentage, thigh yield and thigh percentage. There were no significant differences in dietary Se-BSFL of carcass percentage the broiler ducks. The dietary Se-BSFL significantly (p<0.05) affected liver weight and percentage, but not significantly different heart and abdominal fat in broiler ducks.

EFFECT OF SE-BSFL ON THE FATTY ACID PROFILES

The fatty acid composition of of broiler duck breast samples in each dietary treatment is shown in Table 4. The dietary Se-BSFL had a significant impact (p<0.05) on some fatty acid composition of breast meat such as palmitic acid, stearic acid, oleic acid, linoleic acid in broiler ducks. The dietary Se-BSFL had a significant increase (p<0.05) in monounsaturated fatty acid and polyunsaturated fatty acid compared to dietary Se-yeast.

The monounsaturated fatty acid profile of meat increased significantly (p<0.05) in line with the increase in Se-BSFL feeding level, but in contrast, the polyunsaturated fatty acid profile decreased significantly (p<0.05). The dietary Se-BSFL had a significant increase(p<0.05) in oleic acid

resulting in higher total MUFA in broiler duck breast muscle whereas dietary Se-BSF significantly decreased linoleic acid, which was the main cause of PUFA decrease (p <0.05).

The carcass characteristics are essential markers in poultry production because they help to evaluate meat production metrics and explain the amount of nutrients deposited in the body. The body mass or weight, as well as the size of the non-carcass components (head, feet, organs, intestines, feathers, and internal fat), have an impact on the carcass features (Bai *et al.*, 2022). The dietary Se-BSFL meal had a significant effect on all carcass characteristics except the proportion of the carcass, the heart, and the quantity of abdominal fat. This confirms previous findings. According to Al-Quwaie (2023), adding selenium nanoparticles to the broiler diet significantly reduced fat and enhanced breast muscle, while the carcass parameters remained constant. Ahmadi *et al.* (2018) discovered that when compared to control birds, NS-supplemented Male Ross 308 chicks had higher percentages of breast and drumstick tissue and less fat. According to Elkhateeb *et al.* (2022), broilers fed a diet supplemented with various kinds of selenium had a higher proportion of the abdomen and dressing, but internal organs did not differ within treatments. Abdel-Moneim *et al.* (2022) found that supplementing the diet with Spirulina platensis and selenium nanoparticles improved the dressing percentage and carcass yield while decreasing abdominal fat in heat-stressed broiler chickens at market age as compared to a control diet. Se-chitosan, Na selenite, vitamin E, or any combination of these nutrients had no effect on the relative weights of the carcass, breast, legs, gizzard, pancreas, and

abdomen in broiler chickens at 21 and 42 days (Bami *et al.*, 2021). According to Bakhshalinejad *et al.* (2019), carcass characteristics were unchanged by selenium source, inclusion rate, or combination. Furthermore, Mohamed *et al.* (2020) showed that neither bacterial selenoprotein nor sodium selenite had any effect on carcass characteristics in broiler chickens fed 0.30 mg Se/kg of feed. Markovic *et al.*, (2018) reported that breast percentage in carcasses was higher with high selenium (Se) yeast supplementation. The increase in breast percentage in the groups receiving the highest Se content may reflect better protein assimilation and improved growth through Se-enhanced metabolism of thyroid hormones that regulate animal growth. In this study, carcass characteristics decreased with higher Se-BSFL levels. This is thought to be because high selenium levels can reduce feed intake and final body weight. This is consistent with the findings of Kim and Kil (2020), that increasing organic or inorganic Se levels in feed to 15 mg/kg can reduce feed intake and body weight of broilers. Park *et al.* (2021) suggested that carcass yield is closely related to live weight or slaughter weight. Broilers with low live weight will produce low carcass weight.

The fatty acid content of the feed has an impact on the fatty acid profiles of broiler meat. This has led several studies aimed at developing animal products by altering the fatty acid composition of meat in the diet to include bioactive fatty acids that are better for human nutrition (Saleh *et al.*, 2021; Verge-Merida *et al.*, 2022). The current study investigated the effects of Se-BSFL supplementation on broiler ducks' fatty acid profiles. The available literature reported the similar observation in broiler chicks (Cullere *et al.*, 2019; Kim *et al.*, 2020; Kieronczyk *et al.*, 2023). Se-BSFL significantly increased the levels of MUFA and medium chain fatty acids (palmitic) in meat. This study also confirmed an unfavourable association between the overall concentration of polyunsaturated fatty acids (PUFAs) in broiler chicken meat and the diet. Juniper *et al.* (2022) reported that addition of Se caused relatively small and inconsistent changes in meat fatty acid profiles. An increase in long-chain PUFA concentrations has been observed in meat tissues after selenium supplementation. Dietary selenium is thought to affect tissue PUFAs indirectly by decreasing the rate of peroxidation, thereby affecting the action/expression of elongases and desaturases involved in their synthesis. On the other hand, Kim *et al.* (2020) found that the addition of Se-BSFL lowered the concentration of PUFA. Cullere *et al.*, (2019) found that adding BSFL oil to chicken diets improved broiler meat's n-6/n-3 content. The increased content of n-6 PUFA and lower concentration of n-3 PUFA are responsible for these effects. Daszkiewicz *et al.* (2022), discovered higher SFAs in the muscles of chickens fed a BSFL diet. Schiavone *et al.* (2019), discovered no significant rise in SFAs in the breast muscles of chickens fed a BSFL diet. The current study found that

Se-BSFL meal had a significant effect on the proportion of MUFAs in the breast muscle of broiler ducks, which is consistent with the findings of Schiavone *et al.* (2019) and Cullere *et al.* (2018), who found that the proportion of MUFAs increased in the thigh muscles of birds fed BSFL meal when compared to the control group. After being fed a defatted BSFL diet, broiler quails and chickens' breast muscles contain a higher percentage of MUFAs.

Table 4: The effect of dietary Se-BSFL meal on fatty acid profiles of broiler ducks at 49 days of age.

Fatty acid profile (%)	Se-BSFL meal (%)			Se-yeast 10 mg/kg
	0	5	10	
Caproic (C6:0)	0.00 ^a	0.00 ^a	0.00 ^a	1.06 ^b
Caprylic (C8:0)	0.00 ^a	0.07 ^a	0.00 ^a	14.19 ^b
Decanoic (C10:0)	0.04 ^a	0.00 ^a	0.00 ^a	9.53 ^b
Lauric (C12:0)	0.00 ^a	0.25 ^a	2.50 ^b	19.57 ^c
Tridecanoic (C13:0)	0.02	0.00	0.00	0.00
Myristic (C14:0)	0.71 ^a	0.10 ^a	2.61 ^b	8.14 ^c
Pentadecanoic (C15:0)	0.07	0.00	0.00	0.00
Palmitic (C16:0)	16.89 ^b	12.72 ^a	17.21 ^b	11.68 ^a
Heptadecanoic (C17:0)	0.00	0.17	0.15	0.15
Stearic (C18:0)	4.66 ^a	7.26 ^b	9.97 ^c	6.63 ^b
Arachidic (C20:0)	0.39	0.00	0.00	0.00
Heneicosanoic (C21:0)	0.21	0.00	0.00	0.00
Docosanoic (C22:0)	0.40	0.00	0.00	0.00
Myristoleic (C14:1)	0.10	0.00	0.00	0.00
Palmitoleic (C16:1)	1.94	0.38	0.62	0.58
Heptadecenoic (C17:1)	0.00	0.08	0.13	0.00
Oleic (C18:1ω9)	38.38 ^b	44.64 ^c	46.62 ^c	29.36 ^a
Eicosenoic (C20:1ω9)	0.16	0.37	0.00	0.27
Erucic (C22:1ω9)	4.29	1.37	0.00	0.00
Nervonic (C24:1ω9)	0.29	0.00	0.00	0.00
Linoleic cc (C18:2ω6)	31.72 ^c	30.40 ^c	21.90 ^b	11.41 ^a
Alfa Linolenic ccc (C18:3ω3)	0.39	0.56	0.00	0.26
Gamma Linolenic ccc (C18:3ω6)	0.43	0.83	0.00	0.43
Eicosadienoic (C20:2ω6)	0.09	0.00	0.00	0.00
EPA (C20:5ω3)	0.92	1.10	0.00	0.00
DHA (C22:6ω3)	0.69	0.00	0.00	0.00
SFA	23.39 ^b	20.57 ^a	32.43 ^c	70.94 ^d
MUFA	45.16 ^b	46.83 ^c	47.37 ^c	30.21 ^a
PUFA	34.24 ^c	32.88 ^c	21.90 ^b	12.10 ^a
n9	43.12 ^b	46.37 ^b	46.62 ^b	29.63 ^a
n6	32.24 ^c	31.23 ^c	21.90 ^b	11.84 ^a
n3	2.00 ^d	1.66 ^c	0.00 ^a	0.26 ^b

Note: Means within a row with different superscripts are different (P < 0.05).

In conclusion, the dietary high levels of Se-BSFL meal supplementation could decrease carcass characteristics of broiler duck. The dietary 5% Se-BSFL is recommended because it does not show a decrease in slaughter weight and carcass weight and shows the highest carcass percentage. .

ACKNOWLEDGMENTS

The authors acknowledge the Higher Education Financing Center, Ministry of Education, Culture, Research, and Technology (Balai Pembiayaan Pendidikan Tinggi), and the Indonesia Endowment Fund for Education, Ministry of Finance of the Republic of Indonesia (Lembaga Pengelola Dana Pendidikan) for providing funding. Dietary Se-BSFL also had an impact on the monounsaturated and polyunsaturated fatty acid of broiler duck meat. These results indicate the potential use of Se-BSFL as a feed ingredient in poultry production although the use of high levels will reduce slaughter weight and carcass yield.

NOVELTY STATEMENT

This study aimed to evaluate the effects of Se-conjugated protein black soldier fly larvae meal (Se-BSFL) meal supplementation on carcass characteristics and meat fatty acid profiles in broiler ducks. These results point to the potential advantages of incorporating Se-BSFL as a feed ingredient in poultry production by indicating that feeding it to broiler ducks improves their fatty acid content. However, the use of high levels will reduce slaughter weight and carcass yield.

AUTHOR'S CONTRIBUTIONS

DK designed the study, contributed to material preparation, sampling, laboratory analysis, data collection, and interpreted the data. AS, EW, and OS supervised the study. The first draft of the manuscript was written by DK and OS. All authors reviewed and approved the final manuscript.

CONFLICT OF INTERESTS

The author should declare any conflict of interest.

REFERENCES

- Abdel-Moneim AE, Shehata AM, Mohamed NG, Elbaz AM, Ibrahim NS (2022). Synergistic effect of *Spirulina platensis* and selenium nanoparticles on growth performance, serum metabolites, immune responses, and antioxidant capacity of heat-stressed broiler chickens. *Biol. Trace Elem. Res.* 200(2):

- 768-779. <https://doi.org/10.1007/s12011-021-02662-w>
- Ahmadi, Ahmadian A, Seidavi A (2018). Effect of Different Levels of Nano-selenium on Performance, Blood Parameters, Immunity and Carcass Characteristics of Broiler Chickens. *Poult. Sci. J.*, 6(1); 99-108. <https://doi.org/10.22069/psj.2018.13815.1276>
- Al-Quwaie DA (2023). The influence of bacterial selenium nanoparticles biosynthesized by *Bacillus subtilis* DA20 on blood constituents, growth performance, carcass traits, and gut microbiota of broiler chickens. *Poult. Sci.*, 102(9): 102848. <https://doi.org/10.1016/j.psj.2023.102848>
- Bai H, B Yang, Z Dong, X Li, Q Song, Y Jiang, G Chang, G Chen (2022). Research Note: Effects of cage and floor rearing systems on growth performance, carcass traits, and meat quality in small-sized meat ducks. *Poult. Sci.*, 101: 101520. <https://doi.org/10.1016/j.psj.2021.101520>
- Bakhshalinejad, Bakhshalinejad R, Hassanabadi A, Swick RA (2019). Dietary sources and levels of selenium supplements affect growth performance, carcass yield, meat quality and tissue selenium deposition in broilers. *Anim. Nutr.*, 5(3): 256-263. <https://doi.org/10.1016/j.aninu.2019.03.003>
- Bami MK, Afsharmanesh M, Salmorini M, Ebrahimnejad H (2021). Effects of selenium-chitosan on growth performance, carcass traits, meat quality, and blood indices of broiler chickens. *Livest Sci.*, 250: 104562. <https://doi.org/10.1016/j.livsci.2021.104562>
- Barragan-Fonseca KB, Dicke M, van Loon JJA (2017). Nutritional value of the black soldier fly (*Hermetia illucens* L.) and its suitability as animal feed - a review. *J Insects as Food Feed.* 3(2), 105-120. <https://doi.org/10.3920/JIFF2016.0055>
- Cao Z, Gao W, Zhang Y, Huo W, Weng K, Zhang Y, Li B, Chen G, Xu Q (2021). Effect of marketable age on proximate composition and nutritional profile of breast meat from Cherry Valley broiler ducks. *Poult. Sci.*, 100(11):101425.
- Cullere M, Tasoniero G, Giaccone V, Miotti-Scapin R, Claeys E, De Smet S, Dalle Zotte A (2016). Black soldiers 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. <https://doi.org/10.1017/S1751731116001270>
- Cullere M, Schiavone A, Dabbou S, Gasco L, Zotte AD (2019). Meat quality and sensory traits of finisher broiler chickens fed with black soldier fly (*Hermetia illucens* L.) larvae fat as alternative fat source. *Animals*, 9: 140. <https://doi.org/10.3390%2Fani9040140>
- Cullere M, Tasoniero G, Giaccone V, Acuti G, Marangon A, Zotte AD (2018). Black soldiers fly as dietary protein source for broiler quails: Meat proximate composition, fatty acid and amino acid profile, oxidative status and sensory traits. *Animal*, 12: 640-647. <https://doi.org/10.1017/s1751731117001860>
- Daszkiewicz T, Murawska D, Kubiak D, Han J (2022). Chemical Composition and Fatty Acid Profile of the Pectoralis major Muscle in Broiler Chickens Fed Diets with Full-Fat Black Soldier Fly (*Hermetia illucens*) Larvae Meal. *Animals*, 12. <https://doi.org/10.3390/ani12040464>
- Directorate General of Animal Husbandry and Animal Health (2021). Ministry of Agriculture. Livestock and Animal Health Statistics 2021. Availabel at: <https://repository.pertanian.go.id/handle/123456789/15553>
- Elkhateeb F, Ghazalah A, Abdel-Wareth A (2022). Effect of selenium sources on growth performance, carcass criteria and physical meat quality of broiler chickens. *SVU-Int. J. Agric. Sci.*, 4(4): 207-217. <https://doi.org/10.21608/svuijas.2023.186986.1265>

- FAO (2022). Food and Agriculture Organisation (FAO). Gateway to poultry production and products. Available at: <https://www.fao.org/poultry-production-products/production/poultry-species/ducks/en/>
- Faramarzi S, Anzabi Y, Jafarizadeh-Malmiri H (2020). Nanobiotechnology approach in intracellular selenium nanoparticle synthesis using *Saccharomyces cerevisiae*—fabrication and characterization. *Arch. Microbiol.*, 202: 1203-1209. <https://doi.org/10.1007/s00203-020-01831-0>
- Ferrari L, Sele V, Silva M, Bonilauri P, De Filippo F, Selmin F, Ørnsrud R, Pinotti L, Ottoboni M (2022). Biofortification of selenium in black soldier fly (*Hermetia illucens*) prepupae reared on seaweed or selenium enriched substrates. *J. Insects Food Feed.* 8(8): 887-899. <https://doi.org/10.3920/jiff2021.0153>
- Gu X, Gao C (2022). New horizons for selenium in animal nutrition and functional foods. *Anim. Nutr.*, 11: 80-86. <https://doi.org/10.1016/j.aninu.2022.06.013>
- Ismoyowati and Sumarmono (2019). Duck Production for Food Security Duck Production for Food Security. 1st Anim. Sci. Food Technol. Conf., <http://dx.doi.org/10.1088/1755-1315/372/1/012070>
- Juniper DT, Kliem KE, Lee A, Rymer C (2022). The effect of stocking rate and supplementary selenium on the fatty acid composition and subsequent peroxidisability of poultry muscle tissues. *Animal*, 16(3):100459. <https://doi.org/10.1016/j.animal.2022.100459>
- Kamal R, Chandran PC, Dey A, Sarma K, Padhi MK, Giri SC, Bhatt BP (2022). Status of Indigenous duck and duck production system of India - a review. *Trop. Anim. Health Prod.*, 551:15. <https://doi.org/10.1007/s11250-022-03401-6>
- Khan S, Khan RU, Sultan A, Khan M, Hayat SU, Shahid MS (2016). Evaluating the suitability of maggot flour as a partial substitute of soya bean on the productive traits, digestibility indices and organoleptic properties of broiler meat. *J. Anim. Physiol. Anim. Nutr.*, 100: 649-656. <https://doi.org/10.1111/jpn.12419>
- Kieronczyk B, Rawski M, Mikolajczak Z, Szymkowiak P, Stuper-Szablewska K, Jozefiak D (2023). Black soldier fly larva fat in broiler chicken diets affects breast meat quality. *Animals*. 13: 1137. <https://doi.org/10.3390/ani13071137>
- Kim YB, Kim DH, Jeong SB, Lee JW, Kim TH, Lee HG, Lee KW (2020). Black soldier fly larvae oil as an alternative fat source in broiler nutrition. *Poult. Sci.*, 99: 3133-3143. <https://doi.org/10.1016/j.psj.2020.01.018>
- Kim JH, Kil DY (2020). Comparison of toxic effects of dietary organic or inorganic selenium and prediction of selenium intake and tissue selenium concentrations in broiler chickens using feather selenium concentrations. *Poult. Sci.*, [Internet]. 99(12): 6462-6473. <https://doi.org/10.1016/j.psj.2020.08.061>
- Kurniawan D, Widodo E, Susilo A, and Sjoefjan O (2024). Synthesis of selenium conjugated insects' protein in *Hermetia illucens* larvae as poultry feed. *BIO Web Conf.*, 88: 00004. <https://doi.org/10.1051/bioconf/20248800004>
- Marković R, Ćirić J, Drljačić A, Šefer D, Jovanović I, Jovanović D, Milanović S, Trbović D, Radulović S, Baltić MZ, Starčević M (2018). The effects of dietary Selenium-yeast level on glutathione peroxidase activity, tissue Selenium content, growth performance, and carcass and meat quality of broilers. *Poult. Sci.*, 97(8): 2861-2870. <http://dx.doi.org/10.3382/ps/pey117>
- Mohamed DA, Sazili AQ, Teck Chwen L, Samsudin AA (2020). Effect of microbiota- selenoprotein on meat selenium content and meat quality of broiler chickens. *Animals*. 10: 981. <https://doi.org/10.3390/ani10060981>
- National research council (NRC) (1994). Nutrient Requirements of Poultry. 9th rev. ed. National Academy Press, Washington DC.
- Nemati Z, Alirezalu K, Besharati M, Holman B, Hajipour M, Bohrer BM (2021). The effect of dietary supplementation with inorganic or organic selenium on the nutritional quality and shelf life of goose meat and liver. *Animals (Basel)*. 11: 261. <http://dx.doi.org/10.3390/ani11020261>
- Park SY, Byeon DS, Kim GW, Kim HY (2021). Carcass and retail meat cuts quality properties of broiler chicken meat based on the slaughter age. *J. Anim. Sci. Technol.*, 63:180-190.
- Qiu K, Ma Y, Obianwuna UE, Wang J, Zhang H, Qi G, Wu S (2021). Application of selenium conjugated to animal protein in laying hens' diet for the production of selenium-enriched eggs. *Foods*. 10(6): 1224. <https://doi.org/10.3390/foods10061224>
- Saleh AA, Alharthi AS, Alhotan RA, Atta MS, Abdel-moneim AME (2021). Soybean oil replacement by poultry fat in broiler diets: performance, nutrient digestibility, plasma lipid profile and muscle fatty acids content. *Animals*. 11: 2609. <https://doi.org/10.3390%2Fani11092609>
- Schiavone, Dabbou A, Petracci S, Zampiga M, Sirri M, Biasato F, Gai IF, Gasco L (2019). Black soldiers fly defatted meal as a dietary protein source for broiler chickens: Effects on carcass traits, breast meat quality and safety. *Animal*, 13: 2397-2405. <https://doi.org/10.1186/s40104-018-0266-9>
- Silva VA, Clemente AHS, Nogueira BRF, De Carvalho AC, De Freitas LFVB, Ramos ADLS, Bertechini AG (2019). Supplementation of selenomethionine at different ages and levels on meat quality, tissue deposition, and selenium retention in broiler chickens. *Poult. Sci.*, 98(5): 2150-2159. <https://doi.org/10.3382/ps/pey569>
- Sogari G, Oddon SB, Gasco L, Huis A Van, Spranghers T, Mancini S (2023). Review: Recent advances in insect-based feeds: from animal farming to the acceptance of consumers and stakeholders. *Animals*, 17: 100904. <https://doi.org/10.1016/j.animal.2023.100904>
- Verge-Merida G, Sola-Oriol D, Tres A, Verd u M, Farre G, Garcés-Narro C, Barroeta AC (2022). Olive pomace oil and acid oil as alternative fat sources in growing-finishing broiler chicken diets. *Poult. Sci.*, 101:102079. <http://dx.doi.org/10.3390/ani12091198>
- Vilela J de Souza, Alvarenga TIRC, Andrew NR, McPhee M, Kolakshyapati M, Hopkins DL, Ruhnke I (2021). Technological quality, amino acid and fatty acid profile of broiler meat enhanced by dietary inclusion of black soldier fly larvae. *Foods*. 10(2). <https://doi.org/10.3390/foods10020297>
- Wang CL, Xing GZ, Wang LS, Li SF, Zhang LY, Lu L, Luo XG, Liao XD (2021). Effects of selenium source and level on growth performance, antioxidative ability and meat quality of broilers. *J. Integr. Agric.*, 20(1): 227-235. [http://dx.doi.org/10.1016/S2095-3119\(20\)63432-3](http://dx.doi.org/10.1016/S2095-3119(20)63432-3)
- Zhang Y, Li C, Zhou Y, Lu Z, Wen A, Wu X (2024). Selenium-Rich Black Soldier Fly Supplementation Enriches Serum Indexes and Egg Selenium Content in Laying Hens. *Biol. Trace Elem. Res.*, <https://doi.org/10.1007/s12011-024-04078-8>