

BLACK SOLDIER FLY FAT AS AN ALTERNATIVE LIPID SOURCE IN ANIMAL NUTRITION: COMPARATIVE FATTY ACID PROFILING AGAINST CONVENTIONAL FEED OILS AND FATS

Ester Vargová, Kristína Kolbaská, Michal Rolinec, Branislav Gálik,
Miroslav Juráček, Milan Šimko, Ondrej Hanušovský

*Institute of Nutrition and Genomics, Faculty of Agrobiology and Food
Resources, Slovak University of Agriculture in Nitra,
Tr. Andrea Hlinku 2 949 76 Nitra, Slovakia*

Corresponding email address: estervargova01@gmail.com

ABSTRACT

Black soldier fly (*Hermetia illucens*) fat has recently gained attention as a potential alternative lipid source in animal nutrition because of its distinctive fatty acid profile and sustainable production potential. The present study compared the fatty acid composition and selected lipid quality indices of black soldier fly (BSF) fat with representative conventional feed and edible lipid sources, including soybean oil, rapeseed oil, coconut oil, palm oil, chicken fat, pig fat/lard, and marine and freshwater fish-derived lipids. Four BSF fat samples were analysed using gas chromatography with flame ionisation detection (GC-FID), while comparative literature-derived datasets were harmonised for calculation of the atherogenicity index (AI), thrombogenicity index (TI), and hypocholesterolemic/hypercholesterolemic ratio (h/H). BSF fat was characterised by elevated proportions of saturated fatty acids, particularly lauric acid (C12:0), while still retaining moderate levels of monounsaturated and polyunsaturated fatty acids. Among the evaluated lipid sources, BSF fat showed the greatest similarity to coconut oil with respect to its medium-chain saturated fatty acid profile; however, its AI and TI values remained lower because of the higher proportion of unsaturated fatty acids. In contrast, soybean and rapeseed oils exhibited the most favourable lipid quality indices, whereas marine and freshwater fish-derived lipids were distinguished by higher polyunsaturated fatty acid content and lower n-6/n-3 ratios. Overall, the obtained results indicate that BSF fat occupies a unique compositional position among the evaluated lipid sources. Although its fatty acid profile is most similar to coconut oil because of the high proportion of saturated fatty acids, its lipid quality indices suggest an intermediate nutritional position between highly saturated tropical oils and more unsaturated lipid sources. These findings further support the growing interest in BSF-derived lipids as nutritionally relevant alternative lipid sources.



Keywords: *Hermetia illucens*; insect-derived lipids; fatty acid profiling; lipid quality indices; alternative feed fats; animal nutrition; gas chromatography

INTRODUCTION

Black soldier fly (*Hermetia illucens*) larvae have attracted increasing attention as a sustainable nutrient source for livestock production systems due to their efficient biomass conversion, ability to utilise diverse organic substrates, and favourable protein and lipid composition (Lu et al., 2022). In recent years, interest in black soldier fly-derived lipids has expanded considerably, particularly in relation to their possible use as alternative fat sources in animal feeding (Nekrasov et al., 2022; Quigley et al., 2025). Unlike many conventional vegetable oils, BSF fat is typically rich in medium-chain saturated fatty acids, especially lauric acid (C12:0), which is considered one of the characteristic features of insect lipid fraction (Suryati et al., 2023; Srisuksai et al., 2024). Owing to this distinct fatty acid profile, BSF lipids are increasingly being evaluated not only as energy sources, but also as nutritionally and functionally relevant feed ingredients with potential effects on gut health, lipid metabolism, and feed utilisation efficiency (Kim et al., 2020; Khan et al., 2024).

The nutritional and functional properties of dietary fats are strongly influenced by fatty acid composition, particularly by the relative proportions of saturated (SFA), monounsaturated (MUFA), and polyunsaturated fatty acids (PUFA). Differences in fatty acid distribution can substantially affect oxidative stability, physicochemical behaviour, digestibility, and overall nutritional evaluation of lipids used in feed and food systems (Maheshwari et al., 2025). In black soldier fly-derived lipids, fatty acid composition may additionally vary according to substrate composition, larval developmental stage, environmental conditions, and processing methodology, resulting in considerable heterogeneity among BSF lipid products (Ijdema et al., 2025; Srisuksai et al., 2024). Accurate compositional characterisation therefore represents an important prerequisite for evaluating the practical suitability of BSF-derived fats in animal nutrition. Conventional fat sources used in feed formulations differ markedly in both fatty acid distribution and functional characteristics. Vegetable oils such as soybean and rapeseed oil generally contain higher proportions of unsaturated fatty acids, whereas tropical oils including coconut and palm oil are characterised by substantially greater levels of saturated fatty acids (Kostik et al., 2013; Sabahannur and Alimuddin, 2022). Animal-derived fats and fish lipids further expand this compositional diversity because of differences in oleic acid content, long-chain polyunsaturated fatty acids, and n-6/n-3 fatty acid balance (Özogul et al., 2007; Zhang et al., 2023). Chicken fat, lard, and fish-derived lipids are also commonly used in feed and food systems and represent useful comparative reference materials when evaluating alternative fat sources (Marikkar et al., 2021; Dongmo et al., 2024). Taken together, these lipid

categories provide a broad compositional framework for assessing the relative positioning of BSF-derived fat among conventionally used dietary lipids.

In recent years, several lipid quality indices, including the atherogenicity index (AI), thrombogenicity index (TI), and hypocholesterolemic/hypercholesterolemic ratio (h/H), have increasingly been applied as complementary tools for comparative evaluation of fatty acid quality in edible oils, animal fats, fish lipids, and insect-derived lipid materials (Ulbricht and Southgate, 1991; Santos-Silva et al., 2002; Chen et al., 2020). These indices provide additional insight into the balance between saturated and unsaturated fatty acids and allow broader compositional interpretation beyond individual fatty acid proportions alone. Comparative application of such indices has become increasingly common in studies focused on both conventional and emerging lipid sources (Dongmo et al., 2024; Domiszewski et al., 2026).

Despite growing interest in black soldier fly larvae oils and lipid fractions, their compositional positioning relative to conventional feed and edible lipids remains insufficiently characterised, particularly when evaluated using harmonised fatty acid datasets and derived lipid quality indices. Comparative studies integrating plant oils, animal fats, fish-derived lipids, and other insect lipid fractions within a unified analytical framework are still relatively limited. Therefore, the aim of the present study was to characterise the fatty acid composition and selected lipid quality indices of black soldier fly fat and compare them with representative conventional lipid sources used in feed and food systems.

MATERIALS AND METHODS

BLACK SOLDIER FLY FAT SAMPLES

Four black soldier fly (*Hermetia illucens*) fat samples were included in the study. Three samples originated from a commercially obtained black soldier fly fat product that exhibited visible phase separation into two distinct layers. These fractions were analysed separately and designated as BSF_A and BSF_B, while an additional mixed sample (BSF_C) was prepared by combining both fractions. A fourth independent sample (BSF_D) originated from the same supplier but represented a separate batch obtained independently. Each BSF sample was analysed independently, and fatty acid composition was expressed as percentage of total fatty acid methyl esters (%FAME).

EXTRACTION OF FAT AND PREPARATION OF FATTY ACID METHYL-ESTERS

Black soldier fly lipid samples were processed according to modified STN ISO 5509 and STN ISO 5508 procedures for determination of fatty acid methyl esters (FAME) with minor laboratory-specific modifications related to sample preparation and transmethylation conditions. Lipids were obtained by Soxhlet extraction using petroleum ether as a non-polar extraction solvent following sample homogenisation and preparation according to the laboratory protocol for lipid analysis.

Approximately 200 mg of extracted lipid was dissolved in n-hexane and subjected to alkaline transmethylation using methanolic potassium hydroxide solution. The reaction mixture was intensively mixed and briefly incubated at 60 °C to facilitate cleavage of acylglycerols and formation of fatty acid methyl esters. Subsequently, hydrochloric acid solution was added to promote phase separation. After equilibration, the upper hexane layer containing FAME was collected, filtered through anhydrous sodium sulfate, diluted with n-hexane, and used for gas chromatographic analysis.

GAS CHROMATOGRAPHIC ANALYSIS

Fatty acid methyl esters (FAME) were analysed using gas chromatography with flame ionisation detection (GC-FID) on an Agilent 6890 GC system (Agilent Technologies, USA) equipped with a DB-23 capillary column (60 m × 250 µm × 0.15 µm; Agilent Technologies, USA). Helium was used as the carrier gas under a head pressure of approximately 239 kPa corresponding to a flow rate of 2.225 mL/min. The injector temperature was set to 250 °C and the detector temperature to 280 °C. Samples were injected in split mode (1:10) with an injection volume of 1 µL. Separation of FAME was achieved using the following temperature program: initial temperature 50 °C for 1 min, followed by heating at 25 °C/min to 175 °C and subsequently at 2 °C/min to 230 °C.

The flame ionisation detector was operated using hydrogen (35 mL/min), air (350 mL/min), and nitrogen as make-up gas (30 mL/min). Identification of fatty acids was performed by comparison of retention times with a commercial 37-component FAME standard mixture (Supelco, USA) containing C4–C24 fatty acid methyl esters. Fatty acid composition data for all BSF samples were expressed as percentage of total fatty acid methyl esters (%FAME).

LITERATURE-BASED LIPID DATASETS

Comparative lipid datasets representing conventionally used feed and edible fats were constructed from published studies reporting fatty acid methyl ester (FAME) composition determined by gas chromatography with flame ionisation detection (GC-FID). Only studies providing sufficiently detailed fatty acid composition data suitable for calculation of lipid quality indices were included in the comparative analysis.

Plant-derived lipid datasets included soybean oil, rapeseed oil, coconut oil, and palm oil. Soybean and rapeseed oil datasets were derived from the studies of Kostik et al. (2013) and Toishimanov et al. (2024), whereas coconut and palm oil datasets were obtained from Sabahannur and Alimuddin (2022).

Additional comparative datasets representing animal-derived fat sources included chicken fat, pig fat/lard, and fish-derived lipids. Chicken fat composition data were derived from Marikkar et al. (2021). Pig fat/lard datasets were constructed using fatty acid composition data reported by Zhang et al. (2023), where values were calculated as the mean across all adipose tissue depots reported in

the study in order to minimise depot-specific selection bias and better represent generalised pig fat composition. Fish-derived lipid datasets were constructed using the fatty acid composition data reported by Özogul et al. (2007). Marine and freshwater fish species were evaluated separately, generating two distinct comparative datasets representing mean fatty acid composition of marine fish-derived lipids (FISH_A) and freshwater fish-derived lipids (FISH_B), respectively.

Explicitly reported zero values were retained as analytical zeros, whereas fatty acids described as not detected (N/D) were treated as absent for lipid quality index calculations. Only datasets reporting fatty acid composition as relative percentages of total fatty acids (%FAME) were included in order to ensure methodological comparability among lipid sources. Fatty acids required for calculation of lipid quality indices were harmonised across all datasets prior to comparative evaluation. The construction strategy and origin of all comparative lipid datasets are summarised in Table 1.

Tab. 1: *Construction of comparative lipid datasets used for fatty acid composition and lipid quality index evaluation*

Dataset group	Origin/source	Construction strategy
BSF fat samples (BSF_A-D)	Experimental samples	Individually analysed black soldier fly lipid samples
Soybean oil (SOY_A-B)	Kostik et al. (2013); Toishimanov et al. (2024)	Literature-derived fatty acid profiles
Rapeseed oil (RAPESEED_A-B)	Kostik et al. (2013); Toishimanov et al. (2024)	Literature-derived fatty acid profiles
Coconut oil (COCONUT_A)	Sabahannur and Alimuddin (2022)	Literature-derived fatty acid profile
Palm oil (PALM_A)	Sabahannur and Alimuddin (2022)	Literature-derived fatty acid profile
Chicken fat (CHICK_A)	Marikkar et al. (2021)	Literature-derived chicken fat profile
Pig fat/lard (LARD_A)	Zhang et al. (2023)	Mean fatty acid profile calculated across six adipose tissue depots
Marine fish-derived lipids (FISH_A)	Özogul et al. (2007)	Mean fatty acid profile calculated across marine fish species
Freshwater fish-derived lipids (FISH_B)	Özogul et al. (2007)	Mean fatty acid profile calculated across freshwater fish species

Fatty acids not reported in individual studies weren't included unless biologically justified. The atherogenicity index (AI) and thrombogenicity index (TI) were calculated according to Ulbricht and Southgate (1991), whereas the hypocholesterolemic/hypercholesterolemic ratio (h/H) was calculated according to Santos-Silva et al. (2002).

$$AI = \frac{C12:0 + (4 \times C14:0) + C16:0}{\sum MUFA + \sum n-6 + \sum n-3}$$

$$TI = \frac{C14:0 + C16:0 + C18:0}{0.5(\sum MUFA) + 0.5(\sum n-6) + 3(\sum n-3) + \left(\frac{\sum n-3}{\sum n-6} \right)}$$

$$h/H = \frac{C18:1n9 + C18:2n6 + C20:4n6 + C18:3n3 + C20:5n3 + C22:5n3 + C22:6n3}{C14:0 + C16:0}$$

STATISTICAL ANALYSIS

Statistical processing of the data was performed using Microsoft Excel (Microsoft Corp., Redmond, WA, USA). The study was designed as a comparative evaluation of fatty acid composition and derived lipid quality indices across experimentally analysed BSF fat samples and literature-derived lipid datasets. Descriptive statistics, including mean values and standard deviations (SD), were calculated for fatty acid groups (SFA, MUFA, PUFA), n-6/n-3 ratio, and derived lipid quality indices (AI, TI, and h/H). For BSF fat, descriptive statistics were calculated from four independently analysed samples (BSF_A–D). For literature-derived lipid categories, statistics were calculated from the datasets constructed as described in Section 2.4.

Because the evaluated lipid categories originated from different biological materials and independent literature sources, no inferential statistical analyses (e.g., analysis of variance or significance testing) were performed. The results are therefore presented as descriptive comparative summaries intended to characterise compositional similarities and differences among the evaluated lipid sources rather than to establish statistically significant differences between categories. Categories represented by a single dataset are reported with SD = 0.00, indicating the absence of within-category variation rather than analytical replication.

RESULTS

FATTY ACID COMPOSITION OF BSF FAT AND SELECTED LIPID SOURCES

The fatty acid composition and derived lipid quality indices of black soldier fly (BSF) fat and comparative lipid sources are summarised in Table 2, whereas the distribution of saturated (SFA), monounsaturated (MUFA), and polyunsaturated fatty acids (PUFA) is illustrated in Figure 1. Overall, the evaluated lipids exhibited distinct compositional patterns associated with their relative proportions of saturated and unsaturated fatty acids.

Tab. 2: Summary lipid composition and lipid quality indices of BSF fat and comparative lipid sources

Lipid source	SFA (%)	MUFA (%)	PUFA (%)	n-6/n-3	AI	TI	h/H
BSF fat	68.88 ± 1.91	16.68 ± 3.25	13.22 ± 1.36	8.42 ± 0.74	3.09 ± 0.35	1.57 ± 0.04	0.42 ± 0.04
Coconut oil^a	87.00 ± 1.41	6.50 ± 0.71	2.00 ± 0.00	12.00 ± 0.00	14.56 ± 0.80	6.71 ± 0.06	0.12 ± 0.01
Palm oil^a	49.00 ± 1.41	39.50 ± 0.71	10.50 ± 0.71	30.00 ± 2.83	0.94 ± 0.05	1.96 ± 0.11	1.14 ± 0.07
Rapeseed oil^b	9.50 ± 2.12	55.00 ± 7.07	30.50 ± 0.71	2.31 ± 0.28	0.06 ± 0.01	0.14 ± 0.04	15.75 ± 3.18
Soybean oil^b	14.50 ± 1.41	25.50 ± 2.12	59.75 ± 1.06	7.52 ± 0.46	0.14 ± 0.01	0.24 ± 0.02	8.17 ± 0.80
Chicken fat^c	32.49 ± 0.00	49.26 ± 0.00	18.26 ± 0.00	18.26 ± 0.00	0.49 ± 0.00	0.88 ± 0.00	2.34 ± 0.00
Pig fat/lard^d	47.51 ± 0.00	42.80 ± 0.00	9.14 ± 0.00	25.33 ± 0.00	0.63 ± 0.00	1.36 ± 0.00	1.71 ± 0.00
Marine fish-derived lipids^e	31.42 ± 4.83	28.65 ± 3.71	39.11 ± 5.04	0.34 ± 0.05	0.54 ± 0.08	0.22 ± 0.04	3.94 ± 0.61
Freshwater fish-derived lipids^e	28.97 ± 3.92	36.44 ± 4.12	33.82 ± 4.57	1.21 ± 0.17	0.42 ± 0.05	0.31 ± 0.05	4.76 ± 0.58

^a Sabahannur and Alimuddin (2022);

^b Dataset constructed from fatty acid profiles reported by Kostik et al. (2013) and Toishimanov et al. (2024);

^c Marikkar et al. (2021);

^d Zhang et al. (2023);

^e Özogul et al. (2007).

Values are presented as descriptive mean ± standard deviation. For BSF fat, statistics were calculated from four independently analysed samples (BSF_A–D). Literature-derived lipid categories were represented either by individual literature profiles or by aggregated profiles constructed from multiple biological observations reported in the original studies (e.g., adipose tissue depots or fish species), as described in Section 2.4. The presented values represent descriptive comparative summaries and should not be interpreted as inferential statistical comparisons among lipid sources.

BSF fat was characterised by elevated SFA content ($68.88 \pm 1.91\%$), primarily due to the high proportion of lauric acid (C12:0), accompanied by moderate MUFA and relatively low PUFA levels. Among the evaluated lipids, coconut oil exhibited the highest SFA content ($87.00 \pm 1.41\%$) and showed the closest compositional similarity to BSF fat with respect to medium-chain saturated fatty acids. In contrast, soybean and rapeseed oils displayed markedly lower SFA proportions and substantially higher PUFA and MUFA contents, respectively (Figure 1).

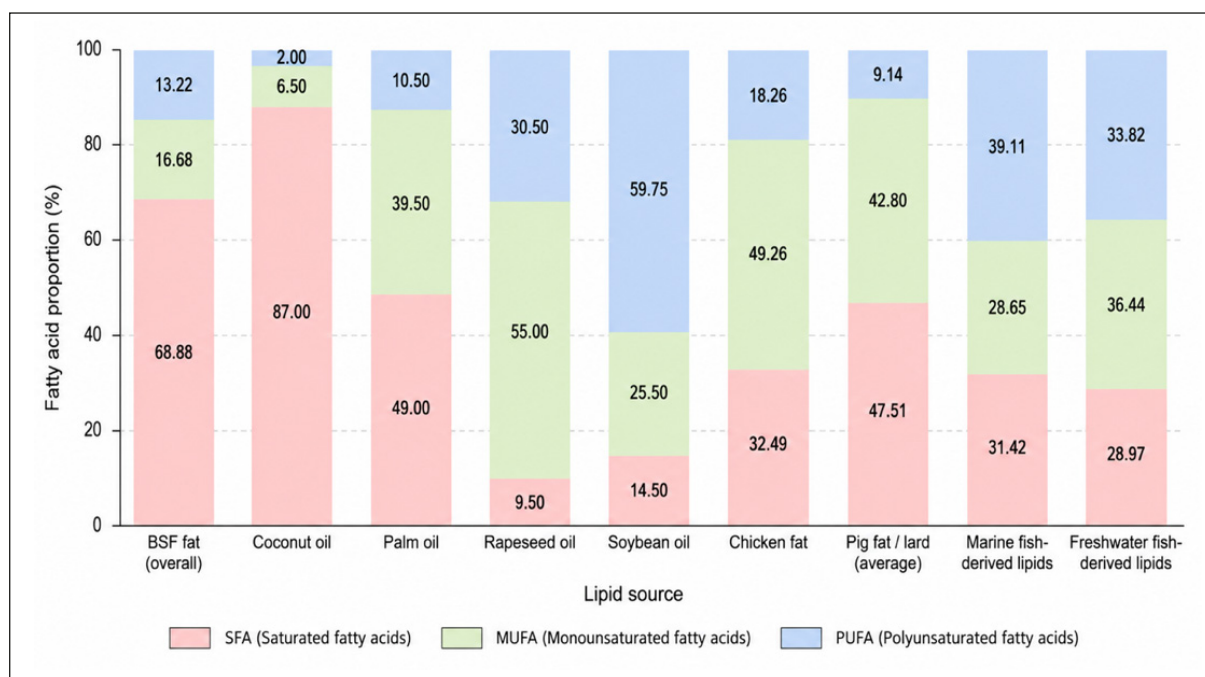


Fig. 1: Distribution of SFA, MUFA, and PUFA across evaluated lipid sources. (% of total FAME)

Chicken fat and pig fat/lard exhibited intermediate compositional characteristics between highly saturated lipids and unsaturated plant oils. Chicken fat was characterised by elevated MUFA content, whereas pig fat/lard contained higher SFA proportions accompanied by moderate MUFA levels. Marine and freshwater fish lipid fractions displayed comparatively higher PUFA content and lower n-6/n-3 ratios than the remaining lipids, reflecting the contribution of long-chain polyunsaturated fatty acids typical of fish-derived oils. Lauric acid (C12:0) predominated in BSF fat and coconut oil, whereas oleic acid (C18:1) represented the dominant fatty acid in rapeseed oil, chicken fat, and pig fat/lard. Soybean oil and fish lipid fractions were characterised by higher proportions of polyunsaturated fatty acids, particularly linoleic acid (C18:2 n-6) and long-chain n-3 fatty acids.

LIPID QUALITY INDICES

Calculated lipid quality indices reflected the marked compositional differences among the evaluated lipid sources (Table 2). Coconut oil exhibited the highest AI and TI values together with the lowest h/H ratio, corresponding to its predominance of saturated fatty acids, particularly medium-chain saturated fatty acids. In

contrast, soybean and rapeseed oil displayed the most favourable index values, characterised by low AI and TI values and elevated h/H ratios associated with their higher proportions of unsaturated fatty acids.

BSF fat exhibited intermediate lipid quality index values positioned between highly saturated tropical oils and more unsaturated plant-derived oils. Although BSF fat was characterised by elevated saturated fatty acid content, its AI and TI values remained substantially lower than those observed for coconut oil, reflecting the contribution of monounsaturated and polyunsaturated fatty acids within the BSF lipid fraction. Chicken fat, pig fat/lard, and fish lipid fractions likewise occupied intermediate positions, with marine and freshwater fish-derived lipids exhibiting comparatively lower TI values and reduced n-6/n-3 ratios associated with their higher long-chain polyunsaturated fatty acid content.

DISCUSSION

The evaluated BSF fat samples showed a fatty acid profile dominated by saturated fatty acids, particularly lauric acid (C12:0), which is commonly regarded as one of the characteristic fatty acids of black soldier fly-derived lipids (Lu et al., 2022; Suryati et al., 2023). Similar findings were reported by Srisuksai et al. (2024), who described BSF oil as a lauric acid-rich lipid source with certain physicochemical similarities to tropical oils. In the present study, BSF fat was compositionally closer to coconut oil than to soybean or rapeseed oil with respect to overall saturation profile and medium-chain fatty acid content. At the same time, however, BSF samples contained noticeably higher MUFA and PUFA proportions than coconut oil, which resulted in substantially lower AI and TI values despite the elevated saturated fatty acid fraction. This suggests that BSF lipids should not be viewed simply as another tropical saturated fat source, but rather as a separate lipid category occupying an intermediate position between highly saturated oils and more unsaturated vegetable oils.

The broader comparative analysis further demonstrated how diverse the fatty acid distribution of commonly used feed and edible fats can be. Rapeseed oil and chicken fat contained predominantly oleic acid and generally exhibited a more MUFA-rich profile than the remaining lipids, whereas soybean oil and fish lipid fractions were characterised by markedly higher PUFA levels. Pig fat/lard showed a more balanced distribution of SFA and MUFA, corresponding well with fatty acid patterns previously reported for porcine adipose tissue lipids (Zhang et al., 2023). Marine and freshwater fish-derived lipids differed from the remaining evaluated fats mainly because of their elevated long-chain polyunsaturated fatty acid content and substantially lower n-6/n-3 ratios, which is consistent with previously described fish lipid profiles (Özogul et al., 2007). Together, these observations illustrate that BSF fat occupies a distinct compositional position among conventional lipid sources rather than closely matching any single plant or animal-derived fat.

Some variability among BSF samples was observed even though all analysed materials originated from the same commercial supplier. In particular, the BSF_D sample contained relatively higher lauric acid and PUFA proportions together with lower MUFA levels compared with the remaining BSF samples. Similar differences in BSF lipid composition have previously been linked to substrate composition, larval developmental stage, environmental conditions, and extraction or processing methodology (Lu et al., 2022; Ijdema et al., 2025; Srisuksai et al., 2024). The observed variation therefore likely reflects the considerable metabolic flexibility of black soldier fly larvae and further supports the idea that substrate manipulation can significantly influence the final lipid profile of BSF-derived products. From a practical perspective, such variability also highlights the importance of compositional standardisation when BSF fat is considered for larger-scale feed applications.

The calculated lipid quality indices reflected the pronounced differences in saturation profile among the evaluated lipid sources. As expected, rapeseed and soybean oil displayed the lowest AI and TI values together with the highest h/H ratios because of their elevated unsaturated fatty acid content, while coconut oil exhibited the least favourable index values due to its predominance of saturated fatty acids (Dongmo et al., 2024). Similar relationships between fatty acid saturation patterns and derived lipid quality indices have been described previously for edible oils, fish lipids, and insect-derived fats (Maheshwari et al., 2025; Domiszewski et al., 2026). BSF fat consistently occupied an intermediate position between highly saturated coconut oil and more unsaturated plant-derived oils. Chicken fat, pig fat/lard, and fish-derived lipids likewise represented intermediate compositional categories, although fish-derived lipids differed because of their substantially lower n-6/n-3 ratios and higher proportions of long-chain omega-3 fatty acids. Nevertheless, AI, TI, and h/H values should be interpreted cautiously, since these indices primarily serve as comparative compositional tools rather than direct predictors of physiological or health-related effects in animals (Chen et al., 2020).

Interest in BSF larvae oil has recently expanded beyond compositional evaluation alone, particularly in relation to their practical use as alternative dietary fat sources in animal nutrition. Schiavone et al. (2017) and Kim et al. (2020) reported that partial or complete replacement of soybean oil with BSF larvae oil in broiler diets did not negatively affect growth performance or feed efficiency, whereas Khan et al. (2024) described acceptable serum biochemical and gut health responses following dietary inclusion of BSF-derived ingredients. Similar findings were reported by Somparn et al. (2024), who evaluated replacement of rice bran oil with BSF larvae oil in broiler diets. In young ruminant nutrition, Quigley et al. (2025) further suggested that BSF oil may represent a suitable alternative to conventional milk replacer oils such as palm or coconut oil. Although the present study was limited to compositional characterisation and literature-based comparison of lipids, the obtained results support the growing view that BSF-derived

lipids may represent a nutritionally relevant alternative fat source worthy of further investigation under practical feeding conditions.

Several limitations should nevertheless be considered when interpreting the present findings. The comparative datasets combined experimentally analysed BSF samples with literature-derived fatty acid profiles originating from studies that differed in biological material, analytical conditions, and sample origin. Although only datasets reporting fatty acid composition as relative percentages of total fatty acids (%FAME) determined by GC-FID were included in order to improve methodological comparability, some degree of inter-study variability remains unavoidable. In addition, the calculated AI, TI, and h/H indices should primarily be regarded as comparative compositional indicators rather than direct indicators of animal health or nutritional efficacy. Future studies should therefore combine compositional lipid characterisation with controlled *in vivo* experiments evaluating digestibility, metabolic responses, animal performance, and product quality following dietary inclusion of BSF or other insect-derived lipids.

ACKNOWLEDGEMENT

This work was supported by the Slovak Grant Agency for Education, VEGA (Vedecká grantová agentúra MŠVVaŠ SR) no. 1/0384/24

REFERENCES

- Chen, J. and Liu, H. (2020) 'Nutritional indices for assessing fatty acids: a mini-review', *International Journal of Molecular Sciences*, 21(16), 5695. <https://doi.org/10.3390/ijms21165695>
- Domiszewski, Z., Szpicer, A., Mierzejewska, S., Wojtasik-Kalinowska, I., Bińkowska, W., Maziarz, K. and Piepiórka-Stepuk, J. (2026) 'Comparative study of lipid quality from edible insect powders and selected cereal flours under storage conditions', *Applied Sciences*, 16(1), 13. <https://doi.org/10.3390/app16010013>
- Dongmo, F.F., Fogang, MBA, A.R., Njiké Ngamga, F.H., Asongni, W.D., Zokou, R., Simo Noutsu, B., Ngo Hagbe, D., Tchuenbou-Magaia, F.L., Ebelle Etame, R.M. *et al.* (2024) 'An overview of fatty acids-based nutritional quality indices of fish oils from Cameroon: impact of fish pre-treatment and preservation methods', *Journal of Food Composition and Analysis*, 134, 106366. <https://doi.org/10.1016/j.jfca.2024.106366>
- Ijdema, F., Lievens, S., Smets, R., Poma, G., Van Der Borgh, M., Lievens, B. and De Smet, J. (2025) 'Modulating the fatty acid composition of black soldier fly larvae via substrate fermentation', *Animal*, 19(1), 101383. <https://doi.org/10.1016/j.animal.2024.101383>
- Khan, S., Shi, X., Cai, R., Shuai, Z., Mao, W., Khan, I.M., Swelum, A.A. and Guo, J. (2024) 'Effect of black soldier fly (*Hermetia illucens*) larvae meal and oil on the performance, biochemical profile, intestinal health and gut microbial dynamics in laying hens', *Poultry Science*, 103(12), 104460. <https://doi.org/10.1016/j.psj.2024.104460>

- Kim, Y.B., Kim, D.H., Jeong, S.B., Lee, J.W., Kim, T.H., Lee, H.G. and Lee, K.W. (2020) 'Black soldier fly larvae oil as an alternative fat source in broiler nutrition', *Poultry Science*, 99(6), pp. 3133–3143. <https://doi.org/10.1016/j.psj.2020.01.018>
- Kostik, V., Memeti, S. and Bauer, B. (2013) 'Fatty acid composition of edible oils and fats', *Journal of Hygienic Engineering and Design*, 4, pp. 112–116.
- Lu, X., Yang, Q., Wang, H., Huang, Z., Chen, Y. and Li, Q. (2022) 'Nutritional composition of black soldier fly larvae (*Hermetia illucens* L.) and its potential uses as alternative protein sources in animal diets: a review', *Insects*, 13(9), 831. <https://doi.org/10.3390/insects13090831>
- Maheshwari, C., Prathap, V., Kumar, S., Meena, N.L., Dalal, M. and Tyagi, A. (2025) 'Comparative evaluation of phytochemical, nutritional, in vitro antioxidant and anti-inflammatory properties of cold-pressed oils in India', *Scientific Reports*, 15, 39200. <https://doi.org/10.1038/s41598-025-09096-7>
- Marikkar, N., Alinovi, M. and Chiavaro, E. (2021) 'Analytical approaches for discriminating native lard from other animal fats', *Italian Journal of Food Science*, 33(1), pp. 106–115. <https://doi.org/10.15586/ijfs.v33i1.1962>
- Nekrasov, R.V., Ivanov, G.A., Chabaev, M.G., Zelenchenkova, A.A., Bogolyubova, N.V., Nikanova, D.A., Sermyagin, A.A., Bibikov, S.O. and Shapovalov, S.O. (2022) 'Effect of black soldier fly (*Hermetia illucens* L.) fat on health and productivity performance of dairy cows', *Animals*, 12(16), 2118. <https://doi.org/10.3390/ani12162118>
- Özogul, Y., Özogul, F. and Alagöz, S. (2007) 'Fatty acid profiles and fat contents of commercially important seawater and freshwater fish species of Turkey: a comparative study', *Food Chemistry*, 103(1), pp. 217–223. <https://doi.org/10.1016/j.foodchem.2006.08.009>
- Quigley, J.D., French, P., McCarthy, C.S. and Moloney, A.P. (2025) 'Nutritional value of black soldier fly larvae oil in calf milk replacers', *Journal of Dairy Science*, 108(2), pp. 1567–1579. <https://doi.org/10.3168/jds.2024-25841>
- Sabahannur, S. and Alimuddin, S. (2022) 'Identification of fatty acids in virgin coconut oil (VCO), cocoa beans, crude palm oil (CPO), and palm kernel beans using gas chromatography', *IOP Conference Series: Earth and Environmental Science*, 1083, 012036. <https://doi.org/10.1088/1755-1315/1083/1/012036>
- Santos-Silva, J., Bessa, R.J.B. and Santos-Silva, F. (2002) 'Effect of genotype, feeding system and slaughter weight on the quality of light lambs: II. Fatty acid composition of meat', *Livestock Production Science*, 77(2–3), pp. 187–194. [https://doi.org/10.1016/S0301-6226\(02\)00059-3](https://doi.org/10.1016/S0301-6226(02)00059-3)
- Schiavone, A., Cullere, M., De Marco, M., Meneguz, M., Biasato, I., Bergagna, S., Dezzutto, D., Gai, F., Dabbou, S. et al. (2017) '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 Journal of Animal Science*, 16(1), pp. 93–100. <https://doi.org/10.1080/1828051X.2016.1249968>

- Somparn, P., Molee, W., Chankitisakul, V. and Molee, A. (2024) 'Effects of replacing rice bran oil with black soldier fly larvae oil on growth performance, carcass traits, meat quality and blood parameters in broilers', *Frontiers in Animal Science*, 5, 1496763. <https://doi.org/10.3389/fanim.2024.1496763>
- Srisuksai, K., Boonma, P., Charoenwongpaiboon, T. and Chaiyasong, T. (2024) 'Physicochemical properties and fatty acid profile of black soldier fly larvae oil', *Veterinary World*, 17(3), pp. 518–526. <https://doi.org/10.14202/vetworld.2024.518-526>
- STN ISO 5508 (1996) *Animal and vegetable fats and oils — Analysis by gas chromatography of methyl esters of fatty acids*. Bratislava: Slovak Technical Standards.
- STN ISO 5509 (2000) *Animal and vegetable fats and oils — Preparation of methyl esters of fatty acids*. Bratislava: Slovak Technical Standards.
- Suryati, T., Astuti, D.A., Wibawan, I.W.T. and Evvyernie, D. (2023) 'Lauric acid from the black soldier fly (*Hermetia illucens*) and its potential applications', *Sustainability*, 15(13), 10383. <https://doi.org/10.3390/su151310383>
- Toishimanov, M., Suleimenova, Z., Myrzabayeva, N., Dossimova, Z., Shokan, A., Kenenbayev, S., Yessenbayeva, G. and Serikbayeva, A. (2024) 'Effects of organic fertilizers on the quality, yield, and fatty acids of maize and soybean in Southeast Kazakhstan', *Sustainability*, 16(1), 162. <https://doi.org/10.3390/su16010162>
- Ulbricht, T.L.V. and Southgate, D.A.T. (1991) 'Coronary heart disease: seven dietary factors', *The Lancet*, 338(8773), pp. 985–992. [https://doi.org/10.1016/0140-6736\(91\)91846-M](https://doi.org/10.1016/0140-6736(91)91846-M)
- Zhang, L., Zhang, K., Yang, H., Yue, K., Liu, R., Bi, Y. and Ma, C. (2023) 'Characterization of lard from different adipose tissues: Physicochemical properties, thermodynamics characteristics and crystallization behaviors', *Journal of Food Composition and Analysis*, 115, 105021. <https://doi.org/10.1016/j.jfca.2022.105021>