

Chemical composition and nitrogen-to-protein conversion factor for honey bee drone brood –pupae of *Apis mellifera L.*

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Honey bee drone brood is one of the novel complementary protein sources despite its long global history as a food source. We have studied its nutritional value thoroughly, paying special attention to protein. In addition to nitrogen and amino acids, moisture, chitin, dietary fibre, fat, fatty acid profile, glycogen, sugars, minerals, heavy metals, and ash were analysed. According to our results, the appropriate nitrogen-to-protein conversion factor for drone brood is 4.82 and the protein content hence 8.62 g 100g⁻¹ as fresh weight. When the protein content of drone brood is calculated by the traditional conversion factor 6.25, the protein content appears to be almost a third higher, 11.26 g 100g⁻¹. The digestible indispensable amino acid score (DIAAS analysis) revealed the good nutritional value of the drone brood protein as DIAAS values were in the range of 0.9 to 1.5. The mean chitin content was 0.72 g 100g⁻¹ as fresh weight.

Key words: amino acids, chitin, DIAAS, insect, protein quality

Introduction

The need to expand protein sources has led to a growing interest in insects as food and feed in the EU (Vale-Hagan et al. 2023). Novel foods require safety assurance, and these aspects of this topic have recently been reviewed by Meijer et al. (2025). Generally, insect farming is considered more sustainable than conventional meat production, because the conversion rate of feed to protein is high and the need for water is low (Mariutti et al. 2021). According to Ulmer et al. (2020), markers of environmental burden, especially land use, were higher for beef production than for honey bee drone brood as a protein source. If drone brood is allocated as a by-product of honey or pollination service, the land use is even more effective. Traditionally, honey bee drone brood is consumed in many countries, e.g. in Ecuador, Mexico, Thailand, and China (Finke 2005). It can be used as fresh, homogenized, boiled, fried, extruded, or as a food ingredient, e.g. as lyophilized items or powdered (Sawczuk et al. 2019, Guiné et al. 2022, Schiel et al. 2022b, Gonçalves et al. 2025). Drone brood has good nutritional value as a rich source of phosphorus, magnesium, potassium, and chloride. In addition, it includes considerable amounts of iron, zinc, copper, and selenium (Guiné et al. 2022). According to the developmental stage, the protein content varies, increasing as larvae develop into pupae (Ghosh et al. 2016, Haber et al. 2019). The protein content of *Apis mellifera* larvae and pupae varies in the range of 41.68% to 50.00% in dry matter (Rumbold and Schlüter 2013), which makes it an excellent protein source. The thing to consider is that insects are often used in dried form. In comparison, broiler breast fillet (typically eaten fresh, not dried) has 22% protein in fresh weight (72% in dry weight), beef has 17–23% protein (45–72% in dry weight) depending on fat content, and dried soy bean has 36% (16% in boiled soy bean; www.fineli.fi 6.6.2025). As an immensely comprehensive class, insects (*Insecta*) naturally have very variable protein contents, but in general they are similarly rich in protein (Rumbold and Schlüter 2013). Ghosh et al. (2021) reviewed the nutritional potential of drone brood and identified specific needs for further research.

In Western countries, drone brood and insects are generally not a conventional part of people's diet. Although attitudes toward eating insects have been sceptical, even disgusting to some (Schomaker and Fiebelkorn 2026), attitudes can change. In a thesis on entomophagy in Finland, 48% of the respondents of the on-line survey reported that they could eat insects at least randomly (Kaltiala 2019). In that survey, crickets were the most often tasted insect species, while 9% of the tastings were of honey bee drone brood. The flavour of honey bee drone brood has been evaluated to be milky, buttery, and nutty (Haber et al. 2019, Guiné et al. 2022). In Germany, beekeeping is a hobby for most beekeepers (Ulmer et al. 2020), and the situation in Finland is similar. Despite the small-scale production at present, researchers see the possibility of adding honey bee drone brood to people's diet for a more sustainable and secure food system (Ulmer et al. 2020, Schiel et al. 2022b).

Protein content is commonly determined as nitrogen content which is calculated to protein using a protein conversion factor, usually set at 6.25. This method is based on the assumption that the nitrogen content of the proteins

is 16% and all the nitrogen comes from proteins. Although this method has been used for decades, the defects of this very simplified method have become more evident (Mariotti et al. 2008, Mæhre et al. 2018). The general protein conversion factor (Kp) 6.25 is known to overestimate the protein content of insects (Nowak et al. 2016, Jonas-Levi and Martinez 2017). Though specific protein conversion factors have been determined for many food matrices, the original publication (Jones 1941) did not include specific values for insects. Accordingly, there have been a growing number of studies on amino acid contents and protein conversion factors for variable insects (e.g. Janssen et al. 2017, Boulos et al. 2020, Ritvanen et al. 2020). Nevertheless, studies on the honey bee, *Apis mellifera*, are still scarce.

Chitin is the main non-protein nitrogen-containing molecule in insects which contributes to nitrogen analysis. Though chitin can be considered indigestible, several parameters, e.g. processing, have an effect on this (Rodríguez-Rodríguez et al. 2022). As a larva develops into a pupa and further into an adult insect, the chitin content increases (Hahn et al. 2018). On the other hand, pupae are bigger than larvae and have a higher protein content, making it more beneficial to collect pupae despite the increased chitin content. Although honey bee larvae and pupae are also gastronomically different mainly because of their different texture, both are well exploitable (Guiné et al. 2022).

In the present study, we have calculated the protein conversion factor for honey bee drone brood (pupae stage) by analysing the nitrogen and the amino acid contents. In addition, the chitin content, minerals, heavy metals, and basic nutritional composition parameters (moisture, dietary fibre, fat, fatty acid profile, glycogen, sugars, ash) were determined to gain better knowledge of the nutritional value of the drone brood. Furthermore, to evaluate the nutritional value of the studied insect protein, we calculated the digestible indispensable amino acid score (DIAAS) for honey bee drone brood.

Materials and methods

Samples

In the present study, the samples were honey bee drone brood (*Apis mellifera* L., pupae) from Finland donated by the Finnish Beekeepers' Association. The pupae were manually collected from the frozen honeycombs. A wax cover was broken, and pupae were dug out of the cells with a spatula, with one sample consisting of hundreds of pupae. Thus, although the age varied by a few days, the pupae were at the stage of development at which they are usually collected (15–24 days, before hatching), which characterizes their average nutritional value. A total of five hives were sampled and these samples were kept frozen until analysis. To increase representativeness of the samples, they were collected from multiple geographic locations over two different years.

Chemical analyses

The amino acid content was analysed according to Commission Regulation (EC) No 152/2009, annex III. Cysteine and methionine were oxidized to cysteic acid and methionine sulfone. The sample was oxidized with performic acid at 0 °C for 16 hours. After oxidation, the sample was hydrolysed with hydrochloric acid (HCl, 6 M) at 110 °C for 24 hours. Tyrosine was analysed from an unoxidized sample. The hydrolysed sample was adjusted to pH 7 and derivatized according to Waters AccqTag (Milford, Massachusetts, USA) derivatization kit. Amino acids were analysed with Waters Acquity UHPLC (Milford, Massachusetts, USA) with a photodiode array detector using Waters AccqTag Ultra C18 column (1.7 µm, 2.1×100 mm) and detected at 260 nm.

The tryptophan content was analysed according to Commission Regulation (EC) No 152/2009 annex III with some modifications. The sample was hydrolysed with sodium hydroxide (NaOH, 5 M) at 110 °C for 16 hours. After hydrolysis, tryptophan was analysed with Waters Acquity UHPLC with a fluorescence detector using Waters AccqTag Ultra C18 column (1.7 µm, 2.1×100 mm) and detected with fluorescence (ex 285 nm, em 340 nm).

The amino acid content of the drone brood from five hives was analysed as 4 replicates (except 2 replicates for cysteine, methionine, tyrosine, and tryptophan).

The Kjeldahl principle was used to analyse nitrogen (crude protein) according to Commission Regulation (EC) No 152/2009, annex III. Digestion was done with a Gerhardt Digestion Unit and distillation with a Gerhardt Vapodest system (Gerhardt GmbH & Co KG, Königswinter, Germany). The nitrogen content of the drone brood from five hives was analysed as 2–3 replicates.

Moisture was determined by drying the samples in an oven at 102 °C for at least 3 h to a constant weight (ISO 1442 1997). Ash was analysed by heating the samples in a muffle furnace at 550 °C for 3 h and weighed. The fat content was analysed gravimetrically as well after acid digestion with 3 M hydrochloric acid and solvent extraction with light petroleum (boiling range 40–60 °C). Both ash and fat were analysed according to Commission Regulation No 152/2009, annex III (EC 2009). Fatty acids were analysed from extracted fat after esterification by BF₃ (AOCS Ce 2-66 1997) to fatty acid methyl esters by GC-MS (AOCS 1997), as described in Pastell et al. (2021).

Sugars were extracted using warm water, and after SPE purification, they were separated and quantified by HPLC-RI (Waters, Milford, MA, USA) with Luna Omega 3 µm SUGAR column (Phenomenex, Torrance, CA, USA). As the polymeric structure of glycogen and starch resemble each other, a starch analysis was conducted to obtain an estimate of the glycogen content. After the removal of free sugars, glycogen was hydrolysed to glucose units by alpha-amylase (EC 3.2.1.1) and amyloglucosidase (EC 3.2.1.3). The amount of glucose was analysed by HPLC-RI, from which the content of glycogen was calculated. Dietary fibre was analysed according to AOAC 2022.01 (McCleary and McLoughlin 2023). To analyse the chitin content, the sample was completely hydrolysed with acid and alkali in a microwave oven (Mars5; CEM, Bremen, Germany). The amount of acetyl groups released was used to determine the chitin content spectrophotometrically, as described by Hahn et al. (2018).

Heavy metals, except for mercury (Hg), and minerals were analysed after microwave assisted pressure digestion either by inductively coupled plasma mass spectrometry NexION 300X (PerkinElmer, Waltham, MA, USA; As, Cd, Cr, Cu, Mn, Ni, Pb, Se, Zn) or by inductively coupled plasma optical emission spectrometry iCAP 6500 DUO (Thermo Scientific, Waltham, MA, USA; Ca, Co, Fe, K, Mg, Mo, Na, P), as described in Pastell et al. (2021). Mercury was analysed by a direct Hg analyser DMA-80 (Milestone, Sorisole BG, Italy) based on atomic absorption spectrometry (U.S. EPA 7473 2007) without any sample digestion. To achieve a qualitative result for as many elements as possible, freeze-dried samples were utilised in the analysis to maximise the concentration in the measurement solution. Therefore, all results, including those that fell below the methods LOQ, have been recalculated to correspond to fresh weight using the moisture content presented in Table 4.

With the exception of chitin, chrome, nickel, and tryptophan analysis, all methods were accredited according to SFS-EN ISO/IEC 17025 by FINAS Finnish Accreditation Service. The analyses were conducted at the Finnish Food Authority Laboratory, which is the testing laboratory No. T014 accredited by FINAS. Since accredited methods and normal quality assurance procedures were used in the laboratory analyses, the number of replicates (n) was quite small.

Calculated parameters

The protein conversion factor (Kp) was calculated as follows: the sum of amino acid residues (g 100g⁻¹) was divided by the nitrogen content (g 100g⁻¹). The protein conversion factor was calculated separately for each of the five sampled hives. Mean values were used for this calculation.

In addition to the protein and amino acid content analysis, the nutritional quality of protein was evaluated, for which the amino acid score and the digestible indispensable amino acid score (DIAAS) were calculated according to FAO (2013) guidelines. DIAAS is the ratio of the digestible amino acid content in the food (mg g⁻¹ of protein) to the same amino acid in a reference protein. Limiting amino acids are those with DIAAS values below 1.0. As no specific standardized ileal digestibility (SID) values for drone brood were found from the literature, the SID values for lesser meal worms from the study by Malla et al. (2022) were used as a substitute. The requirements for the reference values in the amino acid scoring pattern (mg g⁻¹ protein) were taken from the FAO publication (2013). Since it is a recommended process for regulatory purposes, the scoring pattern for young children from 6 months to 3 years was chosen.

Results

Tables 1 and 2 present the results of the amino acid and nitrogen analysis, respectively. As honey bee drone brood is considered here as a food source and usually utilized as fresh matter (i.e. not dried), the results are presented on a fresh weight basis (g 100g⁻¹). However, by using the moisture content given in Table 4, the results can be converted to dry weight basis (if needed for comparing).

Table 1. Amino acid concentrations of the honey bee drone brood as g 100g⁻¹ fresh weight (mean ± SD) as well as proportions of individual amino acids as mg g⁻¹ protein. The average results (mean ± SD) are from five hives in Finland.

	g 100g ⁻¹ mean ± SD	mg g ⁻¹ protein
Alanine	0.56 ± 0.17	50
Arginine	0.49 ± 0.04	44
Asparagine + Aspartic acid	1.00 ± 0.03	90
Cysteine	0.10 ± 0.01	9.1
Glutamine + Glutamic acid	1.58 ± 0.07	140
Glycine	0.53 ± 0.10	47
Histidine	0.26 ± 0.02	24
Isoleucine	0.51 ± 0.03	46
Leucine	0.83 ± 0.06	74
Lysine	0.72 ± 0.05	64
Methionine	0.24 ± 0.01	21
Phenylalanine	0.41 ± 0.02	36
Proline	0.72 ± 0.05	64
Serine	0.46 ± 0.05	41
Threonine	0.41 ± 0.03	37
Tryptophan	0.13 ± 0.02	11
Tyrosine	0.52 ± 0.05	46
Valine	0.59 ± 0.04	52

Table 2. Nitrogen content, sum of amino acid residues, calculated protein conversion factor, and calculated protein content of honey bee drone brood by two different conversion factors. The average results (mean ± SD) are from five hives in Finland as fresh weight.

	mean ± SD
N content, g 100g ⁻¹	1.80 ± 0.12
Sum of amino acid residues, g 100g ⁻¹	8.61 ± 0.61
Calculated protein conversion factor, Kp	4.82 ± 0.12
Protein content (standard Kp 6.25), g 100g ⁻¹	11.26 ± 0.76
Protein content (specified Kp 4.82), g 100g ⁻¹	8.62 ± 0.60

According to DIAAS calculations (Table 3), which also exploits the digestibility of amino acids in the small intestine, methionine and cysteine (SAA) were found to be the first limiting amino acids with a value of 0.9.

The results of the main composition analyses of the Finnish drone brood are presented in Table 4 and the results of the chemical element analyses are shown in Table 5.

Table 3. The amino acid score and the digestible indispensable amino acid score (DIAAS) for honey bee drone brood.

Amino acids	His	Ile	Leu	Lys	SAA	AAA	Thr	Trp	Val
FAO requirement mg g ⁻¹ protein *	20	32	66	57	27	52	31	8.5	43
Amino acid score	1.2	1.4	1.1	1.1	1.1	1.6	1.2	1.3	1.2
DIAAS [‡]	1.0	1.2	1.0	1.0	0.9	1.5	1.0	1.2	1.0

*Child (6 months to 3 years); recommended reference for regulatory purposes; [‡]The standardized ileal digestibility (SID) values for lesser meal worm, tested in growing pigs (Malla et al. 2022); SAA = Sulphur-containing amino acids (methionine + cysteine); AAA = Aromatic amino acids (phenylalanine + tyrosine)

Table 4. Chemical composition of honey bee drone brood. The average results (mean \pm SD) are from 3–5 hives in Finland. The number of samples (n) varies depending on the number of nests analysed and the number of parallel samples used in the analysis. The results are given in g 100 g⁻¹ as fresh weight.

	mean \pm SD (g 100g ⁻¹)
Moisture	77.05 \pm 3.12 (n=6)
Nitrogen	1.80 \pm 0.12 (n=13)
Dietary fibre	1.68 \pm 0.51 (n=6)
Chitin	0.72 \pm 0.15 (n=15)
Total fat	4.82 \pm 0.99 (n=6)
Fatty acid profile*	
MUFA	2.1 \pm 0.3 (n=6)
PUFA	0.05 \pm 0.02 (n=6)
SFA	2.5 \pm 0.7 (n=6)
TFA	traces
Glycogen (as starch)	2.53 \pm 0.46 (n=4)
Sugars, total	1.72 \pm 0.18 (n=6)
Fructose	0.13 \pm 0.03 (n=6)
Glucose	1.11 \pm 0.35 (n=6)
Maltose	0.48 \pm 0.27 (n=6)
Ash	1.01 \pm 0.31 (n=6)

*MUFA=mono-unsaturated fatty acids; PUFA=poly-unsaturated fatty acids; SFA=saturated fatty acids; TFA=*trans* fatty acids; n=number of replicates

Table 5. Chemical elements of honey bee drone brood (as fresh weight; n=6). Results marked with < were below limit of quantification (LOQ).

Mineral	Result	Unit	Heavy metal	Result	Unit
Ca	0.011 \pm 0.001	g 100g ⁻¹	As	<0.23	μ g 100g ⁻¹
Co	<0.0023	mg 100g ⁻¹	Cd	<0.023	μ g 100g ⁻¹
Cr	0.003 \pm 0.001	mg 100g ⁻¹	Hg	<0.023	μ g 100g ⁻¹
Cu	0.407 \pm 0.054	mg 100g ⁻¹	Ni	<2.3	μ g 100g ⁻¹
Fe	1.243 \pm 0.179	mg 100g ⁻¹	Pb	<0.23	μ g 100g ⁻¹
K	0.302 \pm 0.011	g 100g ⁻¹			
Mg	0.021 \pm 0.001	g 100g ⁻¹			
Mn	0.058 \pm 0.004	mg 100g ⁻¹			
Mo	<0.011	mg 100g ⁻¹			
Na	0.011 \pm 0.001	g 100g ⁻¹			
P	0.193 \pm 0.014	g 100g ⁻¹			
Se	0.003 \pm 0.001	mg 100g ⁻¹			
Zn	1.540 \pm 0.168	mg 100g ⁻¹			

Discussion

Previously, the amino acid composition of the honey bee drone brood (pupae stage) had been studied by García-López et al. (2025) and Ghosh et al. (2021), whose results are in line with those obtained here, especially individual amino acid concentrations. However, our result on the total amino acid content was slightly higher than the value reported in Ghosh et al.'s study (43.8 vs. 40.9 g 100g⁻¹ as dry weights). Indeed, the results are even more in line if the amounts of sulphur-containing amino acids (SAA; methionine and cysteine) and tryptophan are excluded. This effect is well explained by the difference in methodology, i.e. those amino acids were not fully analysed by Ghosh et al. (2021).

In the present study, the protein content of *Apis mellifera* pupae determined by Kp 6.25 in dry weight basis is $49.06 \text{ g } 100\text{g}^{-1}$. This is slightly higher than the result found by Ghosh et al. (2016) for pupae ($45.9 \text{ g } 100\text{g}^{-1}$ in dry matter) and clearly higher than the results for pupae by Haber et al. (2019): $24.6\text{--}26.6 \text{ g } 100\text{g}^{-1}$ in dry matter (Kp 4.88). Although the Kp has an obvious effect on the result, the difference between the studies remains at the nitrogen level. Gonçalves et al. (2025), Pavlović et al. (2025), Schiel et al. (2022a), and Finke (2005) reported similar values for drone brood: $37.32 \text{ g } 100\text{g}^{-1}$ in dry matter, $35.5 \text{ g } 100\text{g}^{-1}$ in dried brood, $40.63 \text{ g } 100\text{g}^{-1}$ in dry matter, and $40.5 \text{ g } 100\text{g}^{-1}$ in dry matter, respectively. In their study, Gonçalves et al. (2025) collected the pupae at an early stage, while Schiel et al. (2022a) did not report whether the drone brood were larvae or pupae, and Finke (2005) reported that though the brood consisted mainly of pupae, some (less than 10%) were larvae, which might decrease the protein content. Pavlović et al. (2025) collected both larvae and pupae, and indeed they observed a lower protein content. In addition, in the review article by Payne et al. (2016), a high variation of protein content in honey bee brood ($15.2 \pm 8.19 \text{ g } 100\text{g}^{-1}$, as fresh weight) was reported. Moreover, Kouřimská and Adámková (2016) reported a similarly great range for protein content in *Hymenoptera* species (bees, wasps, ants in different stages; $13\text{--}77 \text{ g } 100\text{g}^{-1}$ in dry matter). Comparing protein concentrations is challenging due to varying protein factors and because neither the nitrogen concentrations nor the used protein factors are reported in every study. Still, it can be concluded that despite somewhat higher protein contents, our results are in line with previous studies.

Based on the nitrogen and amino acid analysis, we calculated a specified protein conversion factor of 4.82 (min–max 4.72–5.02) (Table 2). This is very close to 4.76 calculated by Janssen et al. (2017) for the larvae of three species (*H. illusens*, *T. molitor*, and *A. diaperinus*), and to 4.9 calculated by Mishyna et al. (2019) for pupae of *A. mellifera*. Boulos et al. (2020) studied three species (*T. molitor*, *A. domesticus*, and *L. migratoria*) and suggested a Kp of 5.33 for all insects. In their studies, Finke (2005) and Jensen et al. (2019) recommended the standard Kp 6.25 for *A. mellifera* pupae and larvae, respectively. However, the latter – Jensen et al. (2019) – provided a method to calculate protein without chitin, which reduces the protein result as well. In our calculations chitin alone does not explain the unsuitability of the standard Kp. It seems that also the difference in the amino acid profile and hence the lower protein nitrogen play a role. Thus, using the specific Kp for drone brood would probably give more precise protein results than the method including both nitrogen and chitin analyses, and, the work load is not increased too.

According to DIAAS, methionine and cysteine (SAA) were found to be the first limiting amino acids with the value of 0.9; the same conclusion was drawn by Finke (2005). Otherwise, the amino acid profile of honey bee drone brood is fully within the limits set by FAO (2013). García-López et al. (2025) reported tryptophan as the limiting amino acid for drone pupa. However, in their study protein digestibility corrected amino acid score (PDCAAS) was used instead of DIAAS. PDCAAS does not adequately take into account the bioavailability of amino acids (FAO 2013).

Insects contain chitin, a long-chain polymer (N-acetyl-glucosamine), which is classified as dietary fibre. Although the amount of chitin in insects' exoskeletons varies from species to species, generally the chitin amount increases as the insect ages. In those edible insects approved in the EU, the chitin content ranges from 1 to $15 \text{ g } 100\text{g}^{-1}$ in dry weight (Kipkoech 2023). According to Finke (2007), dietary fibre analyses of insects tend to overestimate the amount of chitin. This is because in dietary fibre analysis, moisture, fat, starch, protein, ash, and sugars are removed from the samples using various techniques, but the remaining portion may contain small amounts of other compounds besides chitin. In the present study, we obtained similar results, as our dietary fibre analysis also gave a result 2.3 times higher than the chitin assay (Table 4). The analysed content of chitin ($3.1 \text{ g } 100\text{g}^{-1}$ in dry weight) was in line with the previous findings.

In fresh weight, the analysed fat content of honey bee drone brood was $4.82 \text{ g } 100\text{g}^{-1}$ (corresponding to 21.0% on dry matter basis). The fat content was very similar to those values reported for pupae by Finke (2005) and Haber et al. (2019) ($4.7 \text{ g } 100\text{g}^{-1}$ in fresh weight and 19.1 to $21.1 \text{ g } 100\text{g}^{-1}$ in dry matter, respectively) and slightly higher than the value reported for pupae by Ghosh et al. (2016) ($16.0 \text{ g } 100\text{g}^{-1}$ in dry matter). On the other hand, Gonçalves et al. (2025) and Schiel et al. (2022a) reported slightly higher values, $25.24 \text{ g } 100\text{g}^{-1}$ (in dry matter) and $6.99 \text{ g } 100\text{g}^{-1}$ (in fresh weight), respectively, for drone brood. Pavlović et al. (2025) reported an even higher fat content, namely $40.6 \text{ g } 100\text{g}^{-1}$ in dried drone brood. It is not clear why their results are higher than others. In the present study, roughly half of the fat (54%) was saturated fat and only a small portion (1%) was poly-unsaturated fat, which is not ideal for human nutrition but can be considered acceptable as part of a diet. Compared to the study findings of Haber et al. (2019), our value for the proportion of saturated fat is slightly higher (54% vs. 48%). In their study, Ghosh et al. (2016) also reported similar results for pupae (51.1% saturated fat and 0% poly-unsaturated fat).

As there is limited research on the mineral and heavy metal content of honey bee drone brood, in the present study, we compared the mineral concentrations (Ca, Mg, K, Na, Fe, Zn, and Cu) to those reported by Ghosh et al. (2016),

Tongchai et al. (2024), and Pavlović et al. (2025). The results were generally within the same order of magnitude, with our findings primarily falling between those of the previous studies. Schiel et al. (2022a) reported a very similar value for sodium, 111 mg kg⁻¹, and a slightly lower value for ash, 0.92 g 100g⁻¹. Likewise, Gonçalves et al. (2025) reported a slightly lower ash content, 3.26 g 100g⁻¹ in dry matter, as our result in dry matter basis is 4.40 g 100g⁻¹.

In contrast, the concentrations of heavy metals in the present study were lower than those reported by Tongchai et al. (2024) and Pavlović et al. (2025), with all results falling below the respective limits of quantification (LOQ) in our samples. One possible explanation for this discrepancy is the difference in the geographical origin of the samples: the present study was conducted in Finland, whereas Tongchai et al. (2024) examined samples from Thailand and Pavlović et al. (2025) from Serbia. Given the potential influence of environmental factors such as industrial activity and soil composition on heavy metal accumulation, geographical origin may be a contributing factor to the observed differences.

The present study revealed a lot of useful information on the nutritional value of honey bee drone brood. The samples were limited in number (five hives), leaving some uncertainty. As bees live mostly on nectar and pollen collected from nature, there is more expected variability in their composition compared to livestock, especially regarding environmental contaminants.

Conclusions

Based on these results, we suggest a protein conversion factor of 4.82 for the *Apis mellifera* L. drone brood, as using the universal protein conversion factor of 6.25 is likely to overestimate the protein content of honey bee drone brood by 30%. The protein quality, evaluated by the digestible indispensable amino acid score analysis (DIAAS), showed only one amino acid score being slightly below the recommendation (methionine + cysteine; 0.9). In addition, the present study produced a great quantity of useful compositional information on honey bee drone brood.

From a nutritional perspective, honey bee drone brood is a good source of nutrients. It is rich in protein with excellent nutritional value, yet the fatty acid profile does not comply with recommendations. On average, the mineral content is at the same level of meat. However, its use as food is restricted mainly because of its production scale: as a side stream of honey production, it has limited growth potential. Nevertheless, the possibility of offering drone brood as a speciality is likely to add value to beekeeping from a farmer's perspective and to add experience, more sustainable protein, and food flexibility from a consumer's perspective.

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