Food Science and Processing
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Review

Nutritional Quality of Edible Insects Protein

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How To Cite: Jiménez-Pichardo, R.; Santos, E.M.; Lorenzo, J.M.; et al. Nutritional Quality of Edible Insects Protein. *Food Science and Processing* **2025**, *1*(1), 5. https://doi.org/10.53941/fsp.2025.100005.

Received: 11 July 2025
Revised: 25 September 2025
Accepted: 30 September 2025
Published: 15 October 2025

Abstract: World human population growth has increased the demand for sustainable protein sources, motivating interest in edible insects as a viable alternative to conventional protein from livestock. Insects offer significant environmental and nutritional advantages, requiring less land, water, and feed while emitting fewer greenhouse gases. Over 2000 species are consumed worldwide, with prominent examples including crickets, beetles, caterpillars, and ants. Their protein content is highly variable—ranging from approximately 3.9% to over 80% on a dry-weight basis—depending on species, developmental stage, and analytical methods. Notably, many insects surpass the protein levels of beef and chicken. However, traditional nitrogen-to-protein conversion factors may overestimate the protein content due to chitin, underscoring the need for tailored methodologies. The amino acid profile of insects' protein is rich in essential nutrients, with lysine, methionine, and tryptophan often exceeding the levels found in meat, supporting diverse physiological functions. Digestibility studies indicate that processed insect proteins approach 85–95% digestibility, comparable to casein and beef protein, though chitin can limit bioavailability if it is unprocessed. While cultural barriers and regulatory challenges persist, education, product innovation, and processing improvements can enhance their acceptance. Edible insects also present opportunities for bioactive peptides and functional food ingredients. Considering their nutritional value, low ecological footprint, and potential to strengthen food security, edible insects are positioned as a promising component of sustainable diets. Advancing research on processing methods, safety standards, and consumer engagement is essential to fully realize their role in addressing global nutritional and environmental challenges.

Keywords: edible insects; protein source; amino acids

1. Introduction: Edible Insects

The population growth has led to a significant increase in food demand, emerging as a critical issue worldwide in recent years. Elevated production costs, environmental concerns, limited space, and considerations related to animal welfare have promoted the interest of food producers and consumers in alternative sources of protein to meet their dietary needs. Among the most promising alternatives are plants, fungi, algae, and insects [1–3]. From these alternatives, edible insects have emerged as a sustainable food source that could contribute to global food security and help to mitigate the protein deficiency. Compared to traditional animal protein sources, insects require less land, water, and feed. In fact, they generate a lower carbon footprint and offer considerable nutritional value while being more environmentally friendly [3]. Consumption of insects dates back to ancient times and remains a traditional dietary practice in various regions of Asia, Africa, and Latin America, where they still play an integral role in local gastronomy [1].

Edible insect species can be found in aquatic (12%), terrestrial (88%), and, to a lesser extent, arboreal environments, since they typically feed from host plants [4]. The most frequently consumed insects fall within the Coleoptera (32%), Hymenoptera (15.5%), Lepidoptera (15.2%), Orthoptera (14.1%), and Hemiptera (11.4%) orders [2,5,6]. To date, over 2000 species of edible insects have been identified, including beetles, stink bugs, ants, moths, crickets, grasshoppers, worms, and caterpillars [6–13]. The prevalence of each insect order in human diets varies by region, influenced by factors such as cultural norms, regional availability, and consumer preferences [2,6]. Current estimates indicate that more than two billion people around the world regularly include insects in their diets [5,6,9]. Their nutritional value lies in their high content of proteins, essential amino acids, fats, fiber, vitamins, and minerals [4,10].

Insects also have a longstanding history not only as food but also in folk medicine in various cultures [2]. They may be consumed whole—with wings and legs removed—or processed into powders, pastes and sauces [14]. Nevertheless, in certain countries, insect consumption remains taboo or is regarded as unpalatable, presenting ongoing cultural and social challenges to their broader adoption [6,15]. Research suggests that public acceptance can be enhanced through education and exposure, particularly when edible insects are introduced into familiar meal preparations or incorporated into processed food products [6].

1.1. Insects as a Good Protein Source

The interest in entomophagy development as a sustainable protein source has led to extensive studies analyzing their nutritional composition. The protein content of edible insects is the main argument for their inclusion in human diets and animal feed, given the environmental footprint of conventional livestock. Insects from various orders are consumed worldwide, including beetle larvae (Coleoptera), caterpillars (Lepidoptera), ants, bees and wasps (Hymenoptera), crickets, grasshoppers, and locusts (Orthoptera). Traditionally, most are collected from the wild environment [16].

Table 1 shows a high variability in the protein content of edible insects, ranging from as low as ~3.9% (some termites) [11,13,17–20], to >80% (crickets and moths) [11–13,17–24]. These differences depend on the species, developmental stage, diet, and rearing substrate, moisture content, analytical methods applied (including nitrogen-to-protein conversion factor used), among others. Orthoptera order ranks among the highest-protein insects, reaching in crickets and grasshoppers with around 80% [11,13,19,20,24,25]. Coleoptera, Diptera, Hymenoptera and Lepidoptera orders range their protein content from 65 to 70 %. On the other side, the lower protein content (less than 40 % on average) is usually related to the Isoptera order (termites) [11,13,17–20]. This data indicates that insects are not a uniform nutritional category but a highly heterogeneous group.

In general, when compared with conventional protein sources, mainly chicken, pork and beef meat, many insects usually equal or exceed the protein content of fresh meats even on a fresh-weight basis. On a dry-weight basis, top insect species (e.g., *Acheta domesticus*, *Gryllus bimaculatus*, *Ruspolia differens*) frequently outperform beef and pork [13,20,25]. For example, *Acheta domesticus* (house cricket) reports up to 80.3% protein (dry matter), which substantially exceeds chicken (54.7%) and beef (40.5%) [6,23]. For reference, the protein content of conventional meats (pork, chicken, salmon and beef) reported in Table 1, is among 21–22% to 27–55% referred to a fresh and dry basis, respectively [6,23].

Table 1. Protein content reported in some species of various edible insects consumed around the World.

Order/Insect Type	Studied Species	Protein Range Content (%) *	References
	Blattodea		
Cockroaches	*Blaberus sp.*, *Blaptica dubia*, *Blatta lateralis*, *Periplaneta americana*, *Periplaneta australasiae*	57.30–76.00	[8,11,12]
	Isoptera		
Termites	*Macrotermes bellicosus*, *Macrotermes falciger*, *Macrotermes notalensis*, *Macrotermes* spp., *Microtermes bellicosus*, *Microtermes nigerensis*, *Odontotermes* sp.	3.90–43.26	[11,13,17–20]

Table 1. *Cont.*

Order/Insect Type	Studied Species	Protein Range Content (%) *	References
	Coleoptera		
Beetles	*Analeptes trifasciata*, *Aplagiognathus spinosus*, *Arophalus rusticus*, *Callipogon barbatus*, *Copris nevinsoni*, *Cybister flavocicinctus*, *Heteroligus meles*, *Holotrichia sp.*, *Homolepta sp.*, *Oileus rimator*, *Oryctes boas*, *Oryctes rhinoceros*, *Protaetia bravitarsis*, *Rhynchophorus palmarum*, *Rhynchophorus phoenicis*, *Tenebrio molitor*, *Zophobas morio*	5.00–69.01	[8,11–13,17,19,24,26]
	Diptera		
Flies	*Caliphora vomitoria*, *Copestylum anna*, *Ephydra hians*, *Hermetia illucens*, *Musca domestica*	17.50–64.90	[11,13,17,18,25,27]
	Hemiptera		
Cicadas	*Hoplophorion monograma*, *Krizousacorixa azteca*	53.00–64.00	[11,21]
Stink bugs	*Ascra cordifera*, *Aspongopus nepalensis*, *Aspongupus viduatus*, *Euschistus egglestoni*, *Pachilis gigas*, *Umbonia reclinata*	10.60–65.00	[11,13,21,27]
	Hymenoptera		
Bees	*Apis mellifera*, Bee brood	7.01–51.00	[11,17,19]
Ants	*Atta cephalotes*, *Atta mexicana*, *Carebara vidua*, *Liometopum apiculatum*, *Oecophylla smaragdina*	40.83–66.00	[11,13,18,20,21,28]
Wasps	*Brachygastra mellifica*, *Brachygastra azteca*, *Parachartegus apicalis*	38.24–70.00	[11,27]
	Lepidoptera		
Moths	*Aegiale hesperiaris*, *Anaphe venata*, *Ascalapha odorata*, *Cirina forda*, *Imbrasia epimethea*, *Imbrasia truncata*, *Usta terpsichore*	30.88–76.00	[11,12,20,21]
	Odonata		
Dragonflies	*Aeschna multicolor*, *Anax parthenope*, *Anax sp.*, *Crocothemes servillia*, *Epophthalmia elegans*, *Gomphus cuneatus*, *Ictinogomphus rapax*, *Orthetrum pruinosum*, *Pantala sp.*, *Sinictinogomphus clavatus*, *Sympetrum sp.*	26.22–76.75	[3,19]
Damselflies	*Lestes praemorsus*	46.37	[3]
	Orthoptera		
Crickets	*Acheta domesticus*, *Brachytrypes spp.*, *Brachytrypes orientalis*, *Gryllodes silligatus*, *Gryllus assimilis*, *Gryllus bimaculatus*, *Schistocerca sp.*, *Schistocerca gregaria*, *Teleogryllus emma*	6.00–80.3	[11,13,17–20,22–24]
Grasshoppers	*Chondacris rosea*, *Melanoplus femurrubrum*, *Melanoplus mexicanus*, *Ruspolia differens*, *Ruspolia nitidula*, *Schistocerca spp.*, *Sphenarium histrio*, *Sphenarium purpurascens*, *Taeniopoda eques*, *Zonocerus variegatus*	26.80–77.95	[13,18,20,21,24–25,29–31]
Locusts	*Patanga succincta*	36.31	[24]
	Others		
Worms	*Galleria mellonella*, *Mealworms* fresh	10.20–57.80	[6,18,32]
Silkworms/ Caterpillars	*Anaphe pande*, *Bombyx mori*, *Cirina forda*, *Elaphrodes lacteal*, *Imbrasia belina*, *Imbrasia hecate*, *Imbrasia epimethea*, *Imbrasia oyemensis*, *Imbrasia petiveri*, *Imbrasia truncate*, *Samia Cynthia ricinii*	10.10–61.80	[17,18,20,24]
Weevils	*Scyphophorus acupunctatus*	36.80	[33]
	Mammals/Fish Meat		
Salmon		22.20 (fresh)	[6]
Chicken		22.2 (fresh), 54.70 (dry basis)	[6,23]
Beef		22.50 (fresh), 40.50 (dry basis)	[6,23]
Pork		21.00 (fresh), 27.70 (dry basis)	[6,23]

* Most of the reported protein percentages are on a dry basis. However, not all references consulted clarify this item.

Such as variability in protein contents could not be only related to species type but also to the performed protein analysis, since some authors have suggested that these comparisons should be made, by considering edible fraction (some insects are consumed whole, including chitin). Although protein content is usually estimated by Kjeldahl method, the traditional nitrogen-to-protein conversion factor could be overestimating the protein content [34,35]. According to them, while 6.25 factor has been traditionally used in the conversion, insect proteins often require a correction because 6.25 may overestimate real protein content due to non-protein nitrogen included in chitin and nucleic acids. The exoskeleton is constructed primarily of chitin, polysaccharides composed of glucosamine and N-acetylglucosamine, which themselves contribute nitrogen atoms. Consequently, not all the nitrogen detected by total nitrogen methods originates from proteins.

This methodological limitation suggests that using methods which estimated only nitrogen (such as Kjeldahl method) with a conversion factor established for muscle meat, can not reliably estimate edible insects' protein. Instead, the logical conclusion is that a specific N-conversion factor tailored to insects is required for accurate measurement. However, insect cuticles present an additional problem: their composition varies not only across species but also across developmental stages. Hard cuticles typically have 70–85% protein and 15–30% chitin, whereas soft cuticles can contain about 50% chitin and 50% protein [36]. This structural variability means that protein quantification may be significantly different not only among species, but across life stages [35]. Janssen et al. [34] proposed more specific conversion factors for larvae of selected insects (*Tenebrio molitor*, *Alphitobius diaperinus*, and *Hermetia illucens*) to improve this issue, recommending a factor of ~5.33–5.60 for more accurate results. Nevertheless, there is a big challenge due to there are at least 1900 edible insect species documented [9], each with multiple developmental stages and variable exoskeletal composition, establishing universal conversion factors sounds almost impossible.

1.2. Amino Acid Profile

The amino acid profile is a critical determinant and one of the most relevant aspects for assessing their nutritional viability of their value as a food and feed protein source [37–39]. Amino acids are essential for multiple physiological functions, including protein synthesis, tissue repair, and metabolic regulation. Table 2 provides detailed ranges of amino acid concentrations across diverse insect species, including both essential and non-essential amino acids, which can be compared to the composition of conventional meats. These ranges reveal that many insect species reach or exceed the amino acid levels found in beef, pork, and chicken. The amino acid content in edible insects shows notable variability across species, reflecting their diversity and differing biochemistry.

Table 2. Amino acid composition and content found in some edible insects′ species compared with the main consumed meat types.

Insects' Species Tested	Amino Acid	Concentration (g/100 g)	Concentration in Beef/Pork/Chicken Meat (g/100 g)	References
Acheta domesticus, *Aeschna multicolor*, *American cockroach*, *Anaphe venata*, *Anax parthenope* , *Anax sp.*, *Apis ceranu*, *Apis dorsata*, *Apis floren*, *Apis mellifera*, *Ascra cordifera*, *Aspongubus viduatus*, *Atta Mexicana*, Bee brood, *Blatta lateralis*, *Bombay locust*, *Bombus ignites*, *Bombus terrestris*, *Bombyx mori*, *Boopedon flaviventris*, *Brachygastra azteca*, *Brachygastra mellifica*, *Callipogon barbatus*, *Copestylum anna*, Cricket flour, *Crocothemes servillia*, *Ephydra hians*, *Epophthalmia elegans*, *Euschistus egglestoni* , *Glyptotendipes testaceus*, *Gomphus cuneatus*, *Gonimbrasia belina*, *Gryllodes sigillatus*, *Hermetia illucens*, *Holotrichia sp.*, *Hoplophorion monogramma*, *Ictinogomphus rapax*, *Imbrasia epimethea*, *Imbrasia truncata*, *Krizousacorixa azteca*, *Lestes praemorsus*, *Liometopum apiculatum*, *Macrotermes bellicosus*, *Melanoplus ferrumbum*, *Musca domestica*, *Orthetrum pruinosum*, *Pachilis gigas*, *Pantala sp.*, *Parachartegus apicalis*, *Patanga succincta*, *Periplaneta americana*, *Periplaneta australasiae*, *Pogonomyrmex occidentalis*, *Polistes sagittarius*, *Polistes sulcatus*, *Polybia nigratella*, *Polybia occidentalis*, *Polybia parvulina*, *Rhynchophorus phoenicis*, *Samia ricinii*, *Sarcophaga bullata*, *Schistocerca spp.*, *Schistocerca gregaria*, *Sinictinogomphus clavatus*, *Sphenarium histrio*, *Sphenarium purpurascens*, *Sympetrum sp.*, *Taeniopoda eques*, *Tenebrio molitor*, *Umbonia reclinata*, *Usta terpsichore*,, *Vespa auraria*, *Vespa basalis*, *Vespa mandarinia*, *Vespa tropica duenlis*, *Vespa velutina*, *Zophobas morio*	Alanine **	0.97–10.95	1.32/1.25/1.15	[3,11,13,15,21,22,24,25,27–30,32,40–46]
	Arginine **	0.69–7.88	1.30/1.33/1.34	
	Aspartic acid **	1.54–13.97	2.07/1.13/1.91	
	Valine *	0.84–9.79	1.02/1.21/1.04	
	Glutamic acid **	2.03–16.75	3.61/3.26/2.85	
	Glycine **	0.78–7.82	1.08/1.02/0.90	
	Threonine *	0.75–4.42	0.87/0.94/0.95	
	Isoleucine *	0.69–6.91	0.92/1.14/0.98	
	Leucine *	1.04–10.00	1.82/1.74/1.64	
	Histidine *	0.42–5.09	0.82/0.82/0.69	
	Cysteine/Cystine **	0.08–3.60	0.23/0.29/0.25	
	Lysine *	1.03–8.64	1.94/1.80/1.79	
	Methionine *	0.36–4.50	0.61/0.59/0.62	
	Proline **	1.02–9.15	0.89/0.85/0.73	
	Serine **	0.82–5.94	0.86/0.90/0.88	
	Tryptophan *	0.41–1.63	0.24/0.22/0.28	
	Tyrosine **	1.88–9.57	2.24/0.90/2.10	
	Phenylalanine *	0.50–14.40	0.86/0.83/0.82	

*Essential; **Non essential.

Regarding essential amino acids, which are indispensable for the human diet because they cannot be synthesized endogenously and are particularly important indicators of protein quality, insects exhibit a competitive profile [11,13,27,29,43–46]. For instance, it can be observed that some insect species (e.g. *Acheta domesticus*, *Tenebrio molitor*) contain lysine (known for its role in collagen synthesis and the immune system) levels equal to or higher than chicken, pork, and beef (1.03–8.64 g/100 g in insects, against 1.79–1.94 g/100 g in meats). Comparable results were reported by Rumpold and Schlüter [8], showing lysine contents in cricket meal exceeding 6 g/100 g dry matter. For leucine and isoleucine, two important branched-chain essential amino acids for muscle protein synthesis, muscle repair and enzymatic functions, insects content ranging up to 10 g/100 g (1.7 g/100 g in meats). Respecting methionine, generally considered the most limiting essential amino acid in many plant proteins, insects show a relatively high range (up to 4.5 g/100 g), surpassing meats in some cases. For instance, *Bombyx mori* pupae are known to have methionine levels exceeding soy and approaching egg protein [47]. For tryptophan, which is essential for serotonin synthesis and often limited in cereals, insect levels (up to 1.63 g/100 g) are significantly higher than in meats (0.22–0.28 g/100 g). The presence of essential amino acids such as arginine, proline, and glycine is also notable. These compounds, although not always required in the diet of healthy adults, are essential in special situations such as growth, stress, or recovery from illness [48]. In insects, arginine reaches up to 7.88 g/100 g, while in meat, its presence is more stable, around 1.3 g/100 g.

In the same way, non-essential amino acids in insects are also found at high levels. Glutamic acid, 2.03–16.75 g/100 g in insects (beef ~3.6 g/100 g); proline, up to 9.15 g/100 g, exceeding levels in conventional meats. Tyrosine and glycine, are found in substantially higher concentrations in some insects. These amino acids contribute to flavor, digestibility, and potential bioactive functions (e.g., antioxidative peptides from insect protein hydrolysates) [49]. Taken together, these data demonstrate that insects not only match, but in many cases surpass traditional meats in terms of amino acid content. Their high variability also allows for the selection of specific species with personalized profiles to different nutritional needs.

2. Digestibility and Bioavailability

While insects´ amino acid composition demonstrates favorable nutritional equivalency or superiority, digestibility also matters. Studies have shown that de-chitinized insect proteins achieve digestibility up to 85–95%, similar to casein and beef [34,50]. However, chitin and sclerotized proteins can reduce bioavailability if insects are consumed whole [37,39,44]. Several processing methods, such as defatting, enzymatic hydrolysis or fermentation, could improve digestibility and amino acid release [42].

Bioavailability refers to the proportion of nutrients of a food that is actually available to the body after food digestion and intestinal absorption [44]. The biological value of edible insects is often determined on the basis of their dry matter mass and often favours edible insects in comparison to other foods. Evaluating the protein bioavailability in humans, could be hard and expensive. Therefore, *in vitro* and animal studies must be performed [34,35]. One of the available scores to measure the dietary protein quality for human nutrition is the protein digestibility-corrected amino acid score (PDCAAS), which is based on the true faecal digestibility of indispensable amino acids of the whole test protein in relation to the reference amino acid pattern. The true faecal digestibility is determined by relating the nitrogen content in the faeces after consumption of the test protein to the original nitrogen content in the test protein [16]. Studies conducted in rats and pigs have shown that PDCAAS from some insect species (e.g., *Tenebrio molitor*, *Alphitobius diaperinus* larvae, *Acheta domesticus* and *Locusta migratoria*) are lower (0.84–0.86) than those for chicken breast, pork, beef, and even soy or whey protein isolates (ranging from 0.92 to 1.34), however, higher than that of tofu or wheat (0.51–0.56). These findings suggest that the protein bioavailability of the insects is satisfactory to including them in food formulations. However, more studies in humans should be realized to assess the benefits of their consumption [51–53].

3. Conclusions

Due to their high protein content (up to 80% of dry weight) edible insects are a high-quality protein source comparable to or higher than that of meats and plants. Furthermore, almost all insects contain all essential amino acids in adequate proportions and they have a high digestibility as that of traditional animal proteins. Those characteristics lead to good functional properties that allow for use in processed foods, bioactive peptides, and pharmaceutical potential. Their health benefits include providing protein needs, minerals, and promoting bone growth. Even when there are some challenges, such as cross-allergies, consumer acceptance, regulations, and technological costs, considering their environmental advantages, such as reduced ecological footprint, waste recycling, and production efficiency, edible insects, the integration into sustainable food systems can significantly contribute to nutritional and environmental security. The research on edible insect´s properties, behavior in human nutrition as well as the development of innovative products and clear regulations will facilitate their large-scale adoption, and be a suitable alternative to face the food and nutritional security challenges.

Author Contributions

R.J.-P., R.A. and J.F.-L. contribute in search and collection of information and writing. E.M.S., J.M.L. and I.S.-O. writing, reviewing and editing. All authors have read and agreed to the published version of the manuscript.

Funding

This research received no external funding.

Data Availability Statement

Not applicable.

Acknowledgments

Authors (E.M.S., J.M.L., R.A., J.F.-L. and I.S.-O.) are members of the AlProSos network (sustainable regional protein-rich foods), funded by CYTED (ref. 125RT0165).

Conflicts of Interest

The authors declare no conflict of interest.

Use of AI and AI-Assisted Technologies

No AI tools were utilized for this paper.

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