



Edible Insects for Future Food Security: Potential and Challenges

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Abstract:

Edible insects are emerging as a sustainable and nutrient-rich alternative protein source with considerable potential to improve food security and combat malnutrition. Approximately 262 edible insect species are reported in India, with protein contents generally ranging from 20–76% on a dry matter basis and lipid contents from 2–50%. Insects provide essential amino acids, vitamins, minerals and chitin contributing to dietary diversification and nutritional security. Their efficient feed conversion and lower environmental footprint make them attractive alternatives to conventional livestock; insect production generates approximately 1 kg of greenhouse gas emissions per kg of weight gain compared with 2.85 kg for cattle. In addition, insects require substantially less feed, land, and water and can utilize organic waste streams. However, ant nutritional factors, microbial contamination, chemical hazards, physical risks, and consumer acceptance remain important challenges. Improved processing, controlled farming, regulatory frameworks, and consumer education are essential for safe and scalable adoption of insect-based foods.

Keywords: Edible insects, food security, alternative protein

Introduction:

Food security is a situation that exists when all people at all times have physical, social, and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life (FAO, 2001a). A prime impact of food insecurity is malnourishment (literally 'bad nourishment') leading to malnutrition which includes under nutrition (wasting, stunting, underweight), inadequate vitamins or minerals, overweight, obesity, and resulting diet-related noncommunicable diseases. Globally in 2024, 6.6% of children under 5 suffered from wasting and 1.9% from severe wasting, which amounts to 42.8 million and 12.2 million children, respectively (UNICEF and WHO, 2025). High levels of malnutrition hinder the 2030 Agenda for Sustainable Development Goal (SDG) 2 (end hunger, achieve food security and improved nutrition and promote sustainable agriculture (WHO, 2021). Strategies such as dietary diversification, nutrient supplementation, food fortification, and biofortification can help address malnutrition and advance the Sustainable Development Goals (SDGs) (Meghwar *et al.*, 2021; Praharaj *et al.*, 2021). Edible insects are increasingly recognized as promising food and feed sources, particularly in

developing countries affected by nutritional deficiencies (Homann, 2015; Nadeau *et al.*, 2015).

Alternative Proteins:

Alternative proteins are derived from sources with relatively low environmental impacts and are intended to substitute conventional protein sources. In some cases, they may also originate from animal production systems that prioritize high standards of animal welfare (Grossmann & Weiss, 2021). Alternative protein systems draw on a wide range of non-animal sources, including plants, insects, fungi, and cell-culturing technologies to replace conventional meat with sustainable, protein-rich ingredients. These sources are designed to provide nutritional and functional characteristics comparable to those of traditional animal proteins including complete amino acid profiles, desirable texture, and sensory attributes. In addition, they offer advantages such as lower cholesterol content and significantly reduced demands on natural resources making them a more efficient and environmentally responsible option for future food systems.

Edible Insects as a Protein Source:

Edible insects represent a highly diverse and nutrient-rich food resource, with approximately

262 species reported as edible in India. The practice of consuming insects by humans is known as entomophagy. The most commonly consumed insect orders include Coleoptera (beetles), Lepidoptera (caterpillars) and Hymenoptera (bees, wasps, and ants) (Kurek *et al.*, 2022). Edible insects can be consumed at different life stages, including eggs, larvae, pupae, nymphs, and adults either whole or as processed food ingredients. Larvae are particularly valued for their high lipid content, while insects also provide high-quality protein and chitin, a dietary fiber with functional health benefits. Due to their excellent nutritional profile, efficient feed conversion and low environmental impact, insects are considered a sustainable alternative protein source. Insect farming generates about 1 kg of greenhouse gas emissions per kilogram of weight gain, compared with 2.85 kg for cattle (Arca *et al.*, 2024). Moreover, insects convert feed nearly twice as efficiently as poultry, four times more efficiently than pigs, and twelve times more efficiently than cattle (Van Huis *et al.*, 2021).

Nutritional Benefits:

The nutritional profile of edible insects differs considerably among species and developmental stages, but they are generally rich in proteins, lipids, carbohydrates, vitamins, and minerals.

Table 1. Summary of the nutritional contents of various edible insect species.

Insect Species	Protein (% Dry Weight)	Fat (% Dry Weight)	Essential Fatty Acids	Vitamin B12 (mcg/100 g)	Iron (mg/100 g)	Zinc (mg/100 g)
Crickets (<i>Acheta domestica</i>)	65–70	10–20	High in omega-6	5–10	5–8	3–5
Mealworms (<i>Tenebrio molitor</i>)	50–60	20–30	Balanced omega-3 and-6	0.5–1	6–9	2–3
Grasshoppers (<i>Locusta migratoria</i>)	60–75	6–8	High in omega-3	8–15	8–20	5–7
Silkworm Larvae (<i>Bombyx mori</i>)	55–65	8–12	Moderate in omega-6	2–4	10–15	3–4

Protein:

The protein content typically ranges from 20% to 76% on a dry matter basis, making insects a promising and sustainable alternative to conventional animal protein sources. Further studies have shown that insects can contribute to human health by promoting growth, influencing iron status, modulating gut microbiota with prebiotic effects, and providing amino acids comparable to soy protein (Stull, 2021). Edible insects are rich in essential amino acids, including isoleucine, leucine, lysine, methionine, phenylalanine, tryptophan, and valine, which are vital for human nutrition. The amino acid profiles of insects such as *Tenebrio molitor*, *Zophobas morio*, and *Alphitobius diaperinus* are comparable to those of established protein sources, including soybean and bovine casein (Yi *et al.*, 2013). The nutritional contents of various insects are enlisted in Table 1.

Lipid:

The lipid content of edible insects shows considerable variation among species, generally ranging from 2% to 50% of dry matter. In some insect species, polyunsaturated fatty acids (PUFAs) constitute as much as 70% of the total fatty acid content, enhancing their nutritional quality and potential health benefits (dos Santos Aguilar, 2021). Mostly lipids are stored in the form of triacylglycerols and their fatty acid composition is predominantly made up of saturated fatty acids (SFAs) and monounsaturated fatty acids (MUFAs) which together account for over 80% of the total lipid fraction. Palmitic acid and stearic acid are the principal SFAs and are generally present in higher proportions than MUFAs particularly in adult insects. Among the MUFAs, oleic acid is one of the most abundant fatty acids and has been reported to exert several beneficial physiological effects, including reducing blood pressure and lowering the risk of inflammatory, immune-related, and cardiovascular diseases (Sales-Campos *et al.*, 2013).

Carbohydrates:

Carbohydrates in edible insects are primarily present in the form of chitin, a structural polysaccharide that also functions as a source of dietary fiber. Chitin is a major constituent of the insect exoskeleton and shares structural similarities with cellulose, differing by the presence of an acetylated amino group (Lima, 2018). The chitin content varies considerably among insect species and developmental stages. Studies have suggested that chitin may be partially digestible by humans and could

provide nutritional and health benefits beyond its prebiotic role in promoting gut health (Ojha *et al.*, 2021). Kipkoech *et al.* (2021) demonstrated that cricket chitosan promotes the growth of beneficial probiotic bacteria including *Lactobacillus* and *Bifidobacterium*, while suppressing pathogenic microorganisms such as *Escherichia coli* and *Salmonella*.

Vitamins & Minerals:

Insects are rich in a variety of micronutrients that are crucial for human health including potassium, sodium, calcium, copper, iron, zinc, etc and vitamins such as A, B1-12, C, D, E, and K. For example, caterpillars are notably rich in vitamins B1, B2, and B6, while bee brood (pupae) is a good source of vitamins A and D (Finke *et al.*, 2005). Crickets contain approximately 2.88 µg of vitamin B12 per 100 g and cockroaches have the highest level 13.2 µg per 100 g (Schmidt *et al.*, 2019). The magnesium content in adults of *Macrotermes nigeriensis* provide 6.1 mg per 100 g (Igwe *et al.*, 2011), whereas those of *Euschistus egglestoni* can offer up to 1910 mg per 100 g (Tang *et al.*, 2019).

Environmental and Sustainability Benefits:

Insects are remarkably efficient in converting feed into protein, while requiring significantly less land and water than conventional livestock. They can also be cultivated using organic waste streams, promoting waste reduction and nutrient recycling within circular economy systems (Pan *et al.*, 2022). The incorporation of insect-derived proteins into food systems has the potential to generate substantial benefits at both regional and global scales. Replacing a portion of conventional livestock protein with insect protein can reduce greenhouse gas emissions, lower the demand for land and water resources, and strengthen circular economy practices through the conversion of organic waste into valuable biomass. Furthermore, the expansion of insect farming can contribute to local economic development by creating employment opportunities in production, processing, and distribution while improving food security through the availability of sustainable, locally produced protein sources (Lisboa *et al.*, 2024).

Challenges:

Edible insects contain naturally occurring antinutritional compounds such as phytic acid, oxalates, cyanogenic glycosides, saponins, thiaminase, and tannins, which can reduce nutrient digestion, absorption, and bioavailability. Processing methods including boiling, roasting, frying, fermentation, and enzymatic treatments effectively decrease these

compounds, thereby improving nutritional quality (Das *et al.*, 2022). Edible insects may also contain toxic bioactive substances or become contaminated with pesticides, heavy metals, and pathogenic microorganisms, including bacteria, viruses, and parasites, posing potential food safety risks. These hazards can be minimized through controlled farming practices, which reduce environmental contamination and toxic residue accumulation, along with appropriate post-harvest processing such as washing, blanching, and cooking (Aguilar-Toalá *et al.*, 2022). Physical hazards, including hairs, spines, and the chitinous exoskeleton, may cause gastrointestinal irritation if inadequately processed. Grinding, milling, or removing hard body parts enhances consumer safety. Furthermore, robust regulatory frameworks are essential to ensure the safe production, processing, and commercialization of edible insects (Lange *et al.*, 2021).

Future Prospects:

The development of innovative technologies for the efficient conversion of farmed insects into palatable and versatile food products is essential. This requires advancements in large-scale harvesting, processing, and storage techniques that preserve the nutritional quality of insect-derived proteins while ensuring food safety (Lisboa *et al.*, 2024). The development of novel food products incorporating insect protein in consumer-acceptable formats could play a significant role in improving market acceptance.

In addition, enhancing consumer awareness and implementing effective marketing strategies are crucial for the growth of the insect-based food industry. Future research should focus on understanding consumer attitudes and developing approaches to emphasize the environmental and nutritional advantages of insect-based foods. Such efforts may include educational initiatives, innovative product branding, and sensory evaluation studies aimed at increasing consumer familiarity and acceptance. Moreover, improving both conventional and advanced insect-rearing practices is important for increasing production efficiency and scalability. This includes optimizing rearing conditions, automating production processes, and formulating improved feed systems to maximize insect growth and nutritional quality.

Conclusion:

Edible insects and their products are a potential intervention strategy against low unhealthy fat contents, combined with their sustainability make insects ideal components of a health conscious and environmentally friendly diet.

This multifaceted approach addresses the dual challenges of improving food security and promoting sustainable food practices positioning insect-based products as a vital element in the future of global nutrition and food security.

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