

Edible insects in strategies to address micronutrient deficiencies: nutritional composition, bioavailability, safety, and the European regulatory context

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Abstract

Micronutrient deficiencies can coexist with adequate or excessive energy intake and remain a major public-health problem. Edible insects have therefore been proposed not only as alternative protein sources, but also as ingredients capable of increasing the density of iron, zinc, vitamin B12 and other nutrients in staple foods. This structured narrative review critically evaluates that suggestion. PubMed and Google Scholar were searched up to and including July 2026, supplemented by backward citation searching and current European Union (EU) legal and risk-assessment documents. Evidence was prioritized from human intervention and stable-isotope studies through systematic reviews, validated compositional analyses, food-formulation studies

and authoritative assessments. The literature confirms substantial nutrient density in many edible species, but direct comparisons are complicated by differences in species, developmental stage, feed, processing, analytical method and whether results are expressed on a fresh- or dry-matter basis. Total nutrient content also does not establish nutritional efficacy. Human evidence is nutrient-specific: iron absorption from the house cricket (*Acheta domesticus*) was low in a stable-isotope trial, whereas a 2025 trial in Kenyan preschool children showed that cricket-enriched maize meals delivered well-absorbed zinc. Vitamin B12 concentrations are highly variable, and some insect products contain inactive corrinoid analogues, creating a risk of overestimating physiologically active B12. Food enrichment with insect powders generally increases protein and selected mineral contents, but higher inclusion levels may impair texture, colour, flavour and acceptance. Safety depends on controlled rearing substrates, hygienic processing, heat treatment, management of spore-forming microorganisms and chemical contaminants, and allergen labelling, particularly for consumers allergic to crustaceans or house-dust mites. In the EU, authorized preparations derive from four insect species and are regulated as product-specific novel foods. Edible insects should therefore be regarded as a potentially useful component of diversified, culturally adapted micronutrient strategies, not as a universal remedy for hidden hunger. Future research should quantify active nutrient forms, absorption, long-term clinical outcomes, affordability and real-world acceptability in target populations.

Introduction

Micronutrient deficiency, often described as hidden hunger, refers to inadequate intake, absorption, or utilization of essential vitamins and minerals. It may occur in people whose energy intake is sufficient and therefore cannot be inferred from body mass or food quantity alone. Iron, zinc, vitamin A, folate, iodine and vitamin B12 deficiencies are among the most consequential because they affect haematopoiesis, immune competence, neurodevelopment, pregnancy outcomes and physical capacity. Global pooled estimates show that deficiencies remain widespread among preschool-aged children and women of reproductive age, although prevalence and the dominant deficient nutrients differ substantially between populations (Bailey et al. 2015; Stevens et al. 2022).

Food-based strategies include dietary diversification, biofortification, industrial fortification and the use of nutrient-dense animal-source foods. Edible insects have attracted attention within this framework because many species combine protein, lipids, minerals and B-group vitamins in a compact matrix. Their role is nevertheless frequently overstated. Compositional tables are often treated as evidence of health benefit, even though nutrient concentration, chemical form, digestibility, absorption and habitual intake are separate determinants of nutritional impact. Moreover, insects are not a homogeneous food category: more than one species, developmental stage, rearing substrate and processing route can produce markedly different nutritional and safety profiles (Rumpold, Schlüter 2013; Kouřimská, Adámková 2016; Bbosa et al. 2025).

The purpose of this review is to assess whether and under what conditions edible insects can contribute to strategies addressing micronutrient deficiencies. The analysis focuses on: (1) reliability and variability of nutrient-composition data, (2) evidence for iron, zinc, vitamin B12 and selected additional nutrients,

(3) bioavailability and human outcomes, (4) technological use in enriched foods and consumer acceptance, (5) biological, chemical, and allergenic hazards, and (6) the current EU regulatory context.

Review approach

A structured narrative search was conducted in PubMed and Google Scholar from database inception up to 14 July 2026, with emphasis on literature published since 2010. Search combinations included “edible insects” with “micronutrient”, “hidden hunger”, “iron”, “zinc”, “vitamin B12”, “bioavailability”, “absorption”, “fortification”, “food safety”, “allergy” and “novel food”. Reference lists of eligible reviews and key primary studies were searched manually to identify earlier foundational publications. Official European Commission, EUR-Lex, European Food Safety Authority (EFSA) and Food and Agriculture Organization of the United Nations (FAO) documents were used for regulatory and safety claims.

Titles and abstracts were screened for relevance and potentially eligible sources underwent full-text assessment. Peer-reviewed studies were included when they concerned insects intended for human consumption, addressed the review domains, and identified the species or product and methods. Duplicate reports, commercial materials, studies without an identifiable product or analytical basis and animal-feed studies were excluded, except when the latter provided directly relevant evidence on nutrient variability or biofortification unavailable from food studies. Because the objective was critical integration rather than pooled estimation, selection was purposive and no meta-analysis was performed. Human studies were weighted above in vitro evidence, while systematic reviews assessed consistency and compositional studies were used only when their analytical basis was clear.

Nutritional composition: high potential, high variability

Edible insects commonly contain substantial protein and fat on a dry-matter basis, together with varying amounts of fibre-like chitin, ash and micronutrients. Foundational reviews and multi-species analyses have already documented broad interspecific variation in proximate and micronutrient composition (Bukkens 1997; Ramos-Elorduy et al. 1997), a finding confirmed by later analytical work. However, reported protein values can be inflated when a conventional nitrogen-to-protein conversion factor of 6.25 is used, because non-protein nitrogen from chitin and other compounds is included. Species-specific conversion factors of around 4.5–5.0 have been proposed for several commonly farmed insects, illustrating that analytical conventions materially affect nutritional claims (Janssen et al. 2017).

Mineral composition varies with species, developmental stage, sex, feed substrate, environmental conditions, fasting before harvest and processing. Drying concentrates nutrients per unit mass but may also promote oxidation or alter heat-sensitive vitamins. Defatting increases the proportional protein and mineral content of the remaining powder, whereas washing, blanching and aqueous processing can cause losses of soluble nutrients. Comparisons are further distorted when fresh-matter and dry-matter results are placed in the same table without conversion. A recent systematic review of iron, zinc and vitamin B12 found wide ranges both within and between species and highlighted inconsistent analytical reporting as a major obstacle to dietary interpretation (Bbosa et al. 2025).

The practical implication is that “insect powder” cannot be assigned one universal nutrient profile. Nutritional evaluation should be product-specific and should include moisture, validated protein calculation, mineral and vitamin methods, the proportion of edible material, serving size and effects of processing.

Iron content does not guarantee absorption

Many edible insects contain analytically measurable iron, sometimes at concentrations comparable to or higher than conventional animal-source foods (Manditsera et al. 2019; Montowska et al. 2019). In vitro cell models have suggested that iron from certain insect species can be available for uptake (Latunde-Dada et al. 2016). These models are useful for screening, but they cannot reproduce the complete effects of digestion, iron status, inflammation, meal composition, and regulation of absorption in humans.

The strongest direct evidence is less favourable. In a randomized crossover stable-isotope study, fractional and absolute iron absorption from the house cricket (*Acheta domesticus*) was low, and adding cricket powder to refined maize porridge reduced iron absorption from the meal. Chitin and other components of the insect matrix were proposed as possible inhibitors, although the mechanism has not been fully resolved (Mwangi et al. 2022). The result does not mean that all insects are poor iron sources, but it shows that high total iron values cannot be translated directly into claims about preventing iron deficiency. Species, processing, de-chitinization, meal phytate content, iron chemical form and the baseline status of consumers require separate study.

Zinc: the most convincing human bioavailability evidence

Zinc is frequently present at nutritionally relevant concentrations in crickets and several other edible insects. In 2025, a randomized crossover stable-isotope study in Kenyan children aged 24–36 months compared maize meals enriched with intrinsically labelled house-cricket (*A. domesticus*) flour with low- and high-zinc maize meals. The amount of zinc absorbed from the whole-cricket meal was approximately 2.6 times that absorbed from the low-zinc meal and exceeded that

from the high-zinc fortified meal; reducing chitin did not materially improve absorption (Hilaj et al. 2025).

This trial provides rare direct evidence that a micronutrient from an insect ingredient can be well absorbed in a nutritionally vulnerable group. Generalization should nevertheless remain cautious. It assessed a defined cricket product, one meal matrix, and short-term absorption rather than correction of zinc deficiency or long-term growth. Replication in other populations and food matrices is required, but zinc currently has a stronger human evidence base than iron for the proposed micronutrient role of edible insects.

Vitamin B12 and other micronutrients

Vitamin B12 is of particular interest because naturally occurring dietary sources are predominantly animal-derived. Validated chromatographic analysis has detected B12 in yellow mealworm larvae (*T. molitor*), crickets (*Gryllus assimilis*), migratory locusts (*Locusta migratoria*) and Turkestan cockroaches (*Shelfordella lateralis*), but concentrations differ markedly among species (Schmidt et al. 2019). A critical complication is the presence of corrinoids that are structurally related to cobalamin but biologically inactive in humans. Commercial cricket products have been shown to contain pseudovitamin B12 and factor S as predominant corrinoids, meaning that microbiological or non-specific assays may overestimate nutritionally active B12 (Okamoto et al. 2021). Claims about B12 should therefore be based on methods that distinguish active cobalamin forms from analogues.

Beyond iron, zinc, and vitamin B12, edible insects may provide riboflavin, folate, vitamin E, magnesium, copper, manganese, calcium and selenium, but concentrations vary markedly among species and products (Bukkens 1997; Finke 2013; Lu et al. 2024). Calcium is often relatively low because most insect exoskeletons are not calcified; higher values in particular taxa may reflect species biology and diet, while processing further limits comparison (Finke 2013; Lu et al. 2024). Yellow mealworm (*T. molitor*) larvae accumulated selenium from supplemented feed, but 10–20 mg/kg reduced biomass, showing that enrichment must be balanced against biological tolerance (Yue et al. 2026). Vitamin D is generally low or variable without targeted treatment. UVB increased vitamin D3 in living insects and powdered *T. molitor*, but responses were species-dependent and treated cricket or locust powders did not consistently yield quantifiable vitamin D3 (Oonincx et al. 2018; Nölle et al. 2024). The 2025 EU authorization of UV-treated *T. molitor* powder therefore concerns a specific fortified product, not untreated mealworm generally (Commission... OJ L 2025/89).

Table 1 summarizes the distinction between compositional potential and evidence required for practical nutritional use.

Table 1. Critical interpretation of selected nutritional components of edible insects

Component	What composition studies suggest	Higher-level evidence and key limitation	Implication for use
Protein	Frequently high on a dry-matter basis; essential amino acids are generally present.	The factor 6.25 may overestimate true protein because chitin and other non-protein nitrogen contribute to total nitrogen.	Use validated, preferably species-specific conversion factors and report digestibility.
Iron	Some species and powders contain analytically high total iron.	Human stable-isotope evidence for house cricket showed low absorption; meal phytate and insect-matrix effects matter.	Do not claim prevention of iron deficiency from total content alone; test the final meal in humans.
Zinc	Crickets and several other insects can provide nutritionally relevant zinc.	A 2025 crossover trial in Kenyan children demonstrated greater absorbed zinc from cricket meals than from comparator maize meals.	Promising target nutrient, but replication and longer-term efficacy trials are needed.
Vitamin B12	B12 has been measured in several edible species.	Inactive corrinoid analogues may dominate some commercial products and inflate non-specific assay results.	Use analytical methods that separate active cobalamins from pseudovitamin B12 and related compounds.
Other vitamins and minerals	Riboflavin, folate, vitamin E, magnesium, copper, calcium, selenium and others may be present.	Concentrations are species-, feed-, and processing-dependent; fresh/dry basis and contamination can distort comparisons.	Evaluate the defined commercial ingredient and realistic serving size rather than a generic species average.

Source: own work based on Bukkens (1997), Finke (2013), Janssen et al. (2017), Oonincx et al. (2018), Schmidt et al. (2019), Okamoto et al. (2021), Mwangi et al. (2018, 2022), Nölle et al. (2024), Lu et al. (2024), Hilaj et al. (2025), Bbosa et al. (2025) and Yue et al. (2026).

Food enrichment, technological quality, and sensory acceptance

Grinding insects into powders or incorporating fractions into familiar foods reduces visual cues that often trigger disgust and makes controlled dosing possible. Studies on breads, extruded snacks, soups, pancakes and bars generally show an increase in protein and selected minerals after insect addition (Osimani et al. 2018; Roncolini et al. 2019; García-Segovia et al. 2020; Kowalski et al. 2022). This is a technologically feasible route to dietary diversification, but the nutritional gain must be calculated per realistic serving rather than per 100 g of dry ingredient.

Higher inclusion levels frequently darken products, intensify roasted or earthy aromas, reduce loaf volume, change dough rheology, and alter hardness

or crispness. Sensory acceptance often follows a non-linear pattern: low or moderate additions can be acceptable, whereas higher additions produce a larger nutrient increment but a lower probability of habitual consumption. Product familiarity, information about benefits, previous exposure, and whether the insect remains visible all influence willingness to eat a product (Hartmann et al. 2015; Orsi et al. 2019). Polish studies likewise show that acceptance differs by product type, species and age group and cannot be inferred from a general attitude towards entomophagy (Skotnicka et al. 2023).

Fortification should therefore be treated as food design rather than simple substitution. Appropriate flavour pairing, particle-size control, fat management, colour expectations and serving context may be as important as nutrient density. For vulnerable children, texture, choking risk, digestibility, microbial safety, allergenicity, and age-appropriate portion size require dedicated formulation and clinical evaluation.

Evidence for health and public-health outcomes

Human intervention evidence remains limited. A cluster-randomized trial in the Democratic Republic of the Congo tested a caterpillar-based complementary cereal from 6 to 18 months of age. The intervention did not reduce stunting, but haemoglobin concentration was higher and anaemia was less prevalent in the intervention group (Bauserman et al. 2015). The result is important because it illustrates both potential and limitation: a nutrient-dense insect food may improve a biochemical outcome without overcoming the multiple infectious, environmental and socioeconomic determinants of impaired growth.

A small double-blind crossover trial in healthy adults found that 25 g/day of cricket powder for 14 days was tolerated and was associated with exploratory changes in gut microbiota and inflammatory markers (Stull et al. 2018). The sample was too small and the duration too short to establish clinical benefit. Such studies support further investigation but should not be converted into broad probiotic or anti-inflammatory claims.

The current evidence hierarchy is therefore uneven. There is direct absorption evidence for zinc, contradictory evidence between total iron content and human iron absorption, limited intervention evidence for anaemia, and insufficient trials for correction of vitamin B12 or other deficiencies. Public-health implementation should be evaluated against established alternatives such as dietary diversification, conventional fortification, supplementation, infection control and poverty reduction. Insects may add value where they are locally available, culturally accepted, safe, and affordable, but the appropriate comparator is not “no food”; it is the best feasible nutrition strategy for the target population.

Safety: biological, chemical, and allergenic hazards

Edible insects are foods of animal origin and require hazard control across rearing, harvest, processing, storage and distribution. The microbial community of raw insects reflects the substrate and production environment. Blanching or boiling can substantially reduce vegetative bacteria, but bacterial spores may survive; drying alone does not reliably make a contaminated product safe (Klunder et al. 2012; Stoops et al. 2017). Validated time-temperature treatments, rapid moisture reduction, prevention of post-process contamination and appropriate shelf-life criteria are therefore essential.

Chemical hazards depend strongly on feed and environment. Potential concerns include cadmium, lead, arsenic, pesticide residues, mycotoxins, dioxins, veterinary or biocidal residues and natural toxins (Kurek et al. 2026). Some compounds are metabolized or excreted, while others may accumulate. The safety of an insect product cannot be separated from the legality and quality of its rearing substrate. Use of uncontrolled waste streams for human food production is not justified merely because insects can biologically convert them (EFSA Scientific Committee 2015; FAO 2021).

Allergenicity is a central clinical and labelling issue. Tropomyosin, arginine kinase, and other arthropod proteins can cross-react with allergens from crustaceans and house-dust mites. Primary sensitization is also possible, and allergens originating from feed may remain in the final product. Heat treatment may reduce some epitopes but does not guarantee elimination of allergenic potential. Proteomic studies have identified multiple candidate allergens across edible species (Barre et al. 2021). Consumers with relevant allergies require clear warnings, and population-specific prevalence data remain limited.

Other uncertainties include the physiological effects of high chitin intake, variability in digestibility, interactions with inflammatory bowel or allergic disease, and exposure in children, pregnant women and older adults. Safety conclusions are product- and use-specific; an EFSA opinion or EU authorization applies to the defined novel food, production process, specifications, intended uses and intake levels, not to every preparation of the same species.

European Union regulatory context

Under Regulation (EU) 2015/2283, whole insects and insect-derived ingredients without a significant history of consumption in the EU before 15 May 1997 are novel foods and require pre-market authorization (Regulation... OJ L 327). Authorized novel foods are entered in the Union list established by Commission Implementing Regulation (EU) 2017/2470. The legal entry specifies the species, developmental stage, processing form, compositional specifications,

permitted food categories, maximum use levels and labelling conditions (Commission... OJ L 351).

As of June 2026, authorized insect preparations in the Union list derive from four species: yellow mealworm (*T. molitor* larvae), migratory locust (*Locusta migratoria*), house cricket (*Acheta domesticus*), and lesser mealworm (*Alphitobius diaperinus* larvae). Authorizations cover selected frozen, paste, dried, powdered, or partially defatted forms, depending on the product. In 2025, the Commission additionally authorized UV-treated powder of whole *T. molitor* larvae under Commission Implementing Regulation (EU) 2025/89 (Commission... OJ L 2025/89).

The authorizations include species- and product-specific conditions and commonly require a statement that the ingredient may cause allergic reactions in consumers with known allergies to crustaceans and products thereof and to dust mites. Some entries are protected by proprietary-data provisions for a defined period, meaning that commercial access can depend on the legal basis of the specific entry. The existence of an authorization is therefore not blanket permission to market any insect powder. Table 2 provides a concise overview.

Table 2. Insect species represented in authorized novel-food entries in the European Union

Species/developmental stage	Examples of authorized forms	Principal regulatory interpretation
<i>Tenebrio molitor</i> larvae (yellow mealworm)	Dried; frozen, dried and powder; UV-treated whole-larva powder	Several separate entries and conditions apply. UV-treated powder was authorized under Implementing Regulation (EU) 2025/89 and has defined uses and vitamin D3 specifications.
<i>Locusta migratoria</i> (migratory locust)	Frozen, dried, and powder forms	Authorization applies to the specified whole-insect preparations, food categories, maximum levels, specifications and allergen labelling.
<i>Acheta domesticus</i> (house cricket)	Frozen, dried, and powder forms; partially defatted powder	Whole-insect and partially defatted products are distinct authorized novel foods with their own conditions and data-protection status where applicable.
<i>Alphitobius diaperinus</i> larvae (lesser mealworm)	Frozen, paste, dried, and powder forms	The entry includes defined consumer groups and labelling conditions; some food-supplement uses exclude persons under 18 years.

Source: European Commission, Commission Implementing Regulations (EU): Commission... OJ L 194 (*T. molitor* larvae); Commission... OJ L 28 (*T. molitor* larvae); Commission... OJ L 2025/89 (*T. molitor* larvae); Commission... OJ L 402 (*L. migratoria*); Commission... OJ L 30 (*A. domesticus*); Commission... OJ L 2 (*A. domesticus*); Commission... OJ L 5 (*A. diaperinus* larvae), authorising their specified forms as novel foods in the European Union.

Sustainability and implementation considerations

The environmental case for insects is plausible but conditional. Mealworm production has been associated with lower land use and greenhouse-gas emissions than some conventional livestock systems, yet climate control, drying, grinding and feed production can be energy-intensive (Oonincx, de Boer 2012). Comparisons depend on functional unit, allocation of co-products, feed conversion, energy source and whether insects replace meat, snacks, supplements or other protein ingredients. Sustainability should therefore be assessed for the actual supply chain rather than assumed from taxonomy.

For micronutrient programmes, affordability and access may be more decisive than environmental efficiency. Farmed insect powders sold as premium foods in Europe are unlikely to address socioeconomic causes of dietary inadequacy unless costs fall and products reach vulnerable groups. In regions with established entomophagy, local species and value chains may offer greater cultural fit, but wild harvesting can be seasonal and ecologically unsustainable. Production scale-up requires food-grade substrates, traceability, worker safety, animal-health and environmental controls, and reproducible nutrient specifications.

Communication also requires care. Presenting insects as a remedy for hunger can stigmatize communities or imply that nutritionally vulnerable populations should accept foods rejected elsewhere. Ethical implementation should be participatory, culturally respectful, nutritionally justified and compared with locally preferred alternatives.

Limitations of the review

This structured narrative review used PubMed, Google Scholar and purposive source selection; relevant studies indexed elsewhere or published in other languages may therefore have been missed. Heterogeneity in species, processing, analytical basis, meal matrix and outcomes prevented quantitative pooling. Regulatory information was verified up to July 2026 but may change. The conclusions are a critical synthesis rather than an exhaustive estimate of effects.

Research priorities

Immediate priorities are methodological standardization and product-specific validation. Studies should distinguish fresh and dry matter, use appropriate protein factors, quantify active vitamin forms, and report species, life stage, feed, processing, uncertainty and serving size. Stable-isotope studies should test minerals in final meal matrices, while product research should integrate

nutrient retention, sensory quality, allergenicity, microbial stability, contaminants and realistic intake.

Longer-term, adequately powered trials should determine whether sustained intake corrects deficiency and improves functional outcomes. Surveillance should characterize consumer and occupational allergy. Implementation studies should compare insect-based interventions with established fortification, supplementation, and diversification in terms of price, supply, cultural acceptance, equity and environmental performance. The decisive question is which product, dose, population, and meal produces benefit without disproportionate risk or cost.

Conclusions

Edible insects can provide concentrated protein and selected micronutrients, and they can increase the nutrient density of familiar foods. Their contribution to micronutrient strategies is nevertheless product-, nutrient-, and context-specific. The best current human evidence supports zinc absorption from house crickets in a maize-based meal, whereas iron data demonstrate that high total content may coexist with low absorption. Vitamin B12 claims require methods that separate active cobalamin from inactive analogues.

Safe use depends on controlled substrates, validated processing, contaminant monitoring, allergen management and compliance with product-specific novel-food authorizations. Sensory acceptance and affordability determine whether theoretical nutrient value becomes habitual intake. Consequently, edible insects should be positioned as one possible component of dietary diversification and food fortification, not as a universal solution to hidden hunger. Stronger clinical, technological, economic, and implementation evidence is required before population-level claims can be made.

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Declaration of Generative AI Use

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Conflict of Interest

Millena Ruszkowska (M.R.) is a member of the Editorial Board of “Państwo i Społeczeństwo / State and Society”. To manage this potential conflict of interest, she had no involvement in the selection of reviewers, the evaluation of the manuscript, or the editorial decision regarding this submission. The peer-review process and editorial decision were handled independently by another editor with no conflict of interest. The other authors declare no conflict of interest.