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SHORT COMMUNICATION

Edible insects: A novel nutritious, functional, and safe food alternative

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Abstract

In a world where 1 billion people suffer from hunger, lands and seas are overexploited and production systems are unsustainable, and there is an urgent need to find alternative foods. In this context, insects represent a good source of macro- and micronutrients and even bioactive compounds that could contribute to reducing nutritional deficiency and preventing some human diseases. However, some aspects related to their consumption, including health risks, need to be clarified. This communication aims to summarize the nutritional/phytochemical profile of common edible insects and the main safety concerns, highlighting the possible strategies to promote entomophagy in a more conscious way.

KEYWORDS
allergens, biological and toxicological risks, entomophagy, fats, flavonoids, proteins

1 | INTRODUCTION

As stated by the Food and Agriculture Organization, trends toward 2050 predict a steady world population increase to 9 billion. To sustain this number, the current food production would need to be doubled. However, lands are scarce, and expanding the area devoted to farming is not a sustainable option; oceans are overfished, and climate change and related water shortages could have profound implications for food production in many regions. In addition, there are currently nearly 1 billion chronically hungry people worldwide. To meet the present and future dietary and nutritional challenges, food habits and production systems need to be reconsidered to rectify inefficiencies, reduce food waste, and find new ways of producing food (van Huis et al., 2013). It is therefore essential to promote the development of alternative food sources, which are more productive than traditional ones, even if, in some case, they could have a lower acceptance by consumers (Kröger et al., 2022). Entomophagy, the consumption of insects as a source of nutrition by humans has always been a worldwide practice that dates back to prehistory and could be one possible solution. Edible insects are an unusual food for westerners, so knowledge of consumer acceptance of insects as food is extremely important for understanding the adoption process. However, data on the needs, experiences, behaviors, and goals of consumers that stimulate their acceptance of insect-based products are scarce. In addition, the results of studies reported in the scientific literature on consumer acceptance of this type of food are quite fragmented and, in some cases, even present contradictory results (van Huis et al., 2013). However, the consumption of insects by humans is still traditional in many countries: over 2000 insect species form part of the usual diets of at least 2 billion people all over the word (Imathiu, 2020). Mexico is the country with the highest number of insect species used for human consumption, with more than 300 species (549 actually reported), followed by the countries of Southeast Asia (200–300 species), Australia, South America, and some African countries (50–200 species), and Middle Eastern and European countries (10–50 species) (van Huis et al., 2013). Within this wide variety, beetles (*Coleoptera*) stand out as the most consumed (31%), followed by caterpillars (*Lepidoptera*) (18%), bees, wasps, and ants (*Heminoptera*) (14%), grasshoppers, locusts, and crickets (*Orthoptera*) (13%), cicadas, fulgoromorphs, leafhoppers, mealybugs, and bugs (*Hemiptera*) (10%), termites (*Isoptera*), dragonflies (*Odonata*), flies (*Diptera*), and others that represent 3% (van Huis et al., 2013). There are multiple reasons for eating insects: (i) it is easy to find and collect them in water resources and forestland, (ii) they have a short life cycle, high growth rate, and fast reproduction that make their farming simpler, (iii) grains are not needed for their rearing and are thus more environmental friendly than traditional livestock, (iv) insect farming requires less water and space, (v) their conversion efficiency is higher than that of conventional meats, (vi) they produce less greenhouse gases than conventional livestock, and (vii) they provide satisfactory amounts of protein, amino acids, fats, and fatty acids and are rich in micronutrients, including minerals and vitamins. In some species, a good number of bioactive compounds, such as flavonoids, have also been detected (de Castro et al., 2018; Imathiu, 2020; Nino et al., 2021; van Huis et al., 2013).

TABLE 1 General composition of nutrients, vitamins, and minerals of edible insects (adapted from Jantzen da Silva Lucas et al., 2020)

Nutrients (%)	
Proteins	10.3%–70.7%
Essential amino acids	46.0%–96.0%
Fatty acids	10.5%–69.8%
Fibers	2.0%–25.1%
Ashes	2.5%–8.6%
Vitamins (mg/100 g)	
Folic acid	0.5–0.9
Niacin	0.9–12.6
Riboflavin	1.4–11.1
Thiamine	0.1–3.4
Vitamin C	0.1–36.1
Minerals (mg/100 g)	
Calcium	24.5–210.0
Iron	5.5–229.7
Magnesium	33.1–1094.4
Phosphor	352.0–957.8
Potassium	259.7–2206.0
Sodium	44.8–435.1

However, the consumption of edible insects has been associated with different risk factors, including biological, toxicological, and allergenic hazards, that may represent a major concern for human health (Schlüter et al., 2017). Indeed, the consumption of insects may lead to different health problems, such as microbial intoxications and infections, parasitic foodborne diseases, and ingestion of poisons, pesticides, heavy metals, and antinutrients. For these reasons, the factors associated with insect consumption safety must be deeply considered since several risk factors associated with insect consumption are not yet clearly defined.

The present short communication aims to summarize and update the nutritional and phytochemical composition of the main species of edible insects, as well as the main biological, toxicological, and allergenic hazards associated with their consumption, trying to highlight the main advantages and disadvantages of this controversial food source.

2 | NUTRITIONAL POTENTIAL OF EDIBLE INSECTS

The reasons for promoting and encouraging the future use of insects as sources of dietary nutrients are increasingly supported by their nutritional quality and chemical composition (Table 1).

From a nutritional point of view, insects stand out for their high protein content. Although this nutritional value can be influenced by diet, developmental stage, sex, species, growth condition, and analytical methods (de Castro et al., 2018), the data reported thus far agree with their high protein content. In fact, on average, the protein content of edible insects ranges between 10% and 70% of dry weight or between 10% and 25% of fresh weight, values higher than some plant products known for their high content of this macronutrient, such as cereals, soybeans, and lentils (Schlüter et al., 2017); edible insects also provide more proteins than chicken meat and eggs (Kim et al., 2019). However, one aspect to consider is the variability of the digestibility of insect proteins due to the presence of a hard exoskeleton. Exoskeletons with a high content of chitin, the most common form of fiber in the body of insects, are particularly difficult for humans to digest (Schlüter et al., 2017). The content of insoluble chitin in commercially cultivated insects ranged between 2.7 and 49.8 mg/kg of fresh weight (from 11.6 to 137.2 mg/kg of dry matter) (Finke, 2007); therefore, they could be considered an important source of fiber. A viable and effective solution to the effect of chitin on protein digestibility may be the removal of the exoskeleton during insect processing; indeed, it has been reported that the digestibility of the insect proteins is between 77% and 98% without the exoskeleton (Kouřimská & Adámková, 2016). On average, these values are slightly lower than values reported for egg (95%) or beef (98%) proteins and even higher than those reported for many plant proteins (Kouřimská & Adámková, 2016). Considering the amino acid content, edible insects also contain a nutritionally important group of amino acids, including high levels of phenylalanine and tyrosine. On average, the content of essential amino acids ranges between 46% and 96% of the total amount of amino acids (Xiaoming et al., 2010). Some species of insects contain significant amounts of lysine, tryptophan, and threonine, which are deficient in certain cereals and tubers. Thus, the resulting nutritional deficiency could be compensated by the consumption of insect species with high amounts of the amino acids that are lacking in these traditional foods. Taken together, these data demonstrate and support the potential use of edible insects in the food and nutritional industry in general for their use as sources of animal protein of high biological value.

The second most important component in the nutritional composition of insects is the fat content (de Castro et al., 2018). Edible insects contain an average of 10%–70% fat in dry matter, which is higher in the larval and pupal stages than in adults (Kouřimská & Adámková, 2016). The distribution of fats in edible insects varies. Triacylglycerols make up approximately 80% of the total fats, while phospholipids represent the second most important group, with a content generally less than 20%, depending on the life stage and the insect species. There is a relatively high content of C18 fatty acids, which includes oleic, linoleic, and linolenic acids. The palmitic acid content is also relatively high, while cholesterol is the most abundant sterol in insects, predominating over other sterols, such as campesterol, stigmasterol, β-sitosterol, and other minority sterols (Kouřimská & Adámková, 2016). Specifically, according to their fat content, edible insects of the order Coleoptera (beetles, larvae) show an average fat value of approximately 33.40%, followed by *Blattodea* (cockroaches) (32.74%), *Hemiptera* (30.26%), *Isoptera* (termites) (29.90%), *Lepidoptera* (caterpillars) (27.66%), and *Orthoptera* (crickets) (13.41%) (Rumpold & Schlüter, 2013a). Based on their fatty acid profile, they generally have more unsaturated fatty acids than saturated fatty acids (SFAs) (de Castro et al., 2018). On the other hand, it has been found that *Hymenoptera* (ants, bees, and wasps) and *Isoptera* (termites) stand out for their SFA content of approximately 30.83% and 41.97%, respectively (Rumpold & Schlüter, 2013b).

Edible insects can also represent an interesting source of minerals and water soluble or lipophilic vitamins (Kouřimská & Adámková, 2016). Their content in wild edible insects is seasonal dependent, while in the case of farm bred species, it can be controlled via feed. Among the main minerals, iron (Fe), zinc (Zn), potassium (K), sodium (Na), calcium (Ca), phosphorus (P), magnesium (Mg), manganese (Mn), and copper (Cu) have been described (van Huis et al., 2013). It is important to emphasize that, similar to the previous nutrients, the content and prevalence of some of these can be influenced by the species, stage of development and feeding. Thus, there are particular cases, such as the large caterpillar of the moth *Gonimbrasia belina* called "mopani" or "mopane," where the iron content ranged between 31 and 77 mg/100 g of dry matter, as well as the grasshopper *Locusta migratoria* with values between 8 and 20 mg/100 g of dry matter (Oonincx et al., 2010).

Although studies on vitamin content are not entirely sufficient, the available data suggest that edible insects could also be considered a dietary source of nutritionally important vitamins (B1, B2, B6, C, D, E, and K) and antioxidant provitamins with functional properties (i.e., carotenoids) (de Castro et al., 2018). For example, thiamine content in edible insects has been reported in a range between 0.1 and 4 mg/100 g of dry matter, while riboflavin has been reported between 0.11 and 8.9 mg to 100 g. Vitamin B12 has been found in abundance in larvae of the yellow meal worm beetle *Tenebrio molitor* (0.47 μg/100 g) and the domestic cricket *Acheta domesticus* (5.4 μg/100 g in adults and 8.7 μg/100 g in nymphs) (Kouřimská & Adámková, 2016). In addition, edible insects of the orders *Orthoptera* and *Coleoptera* have shown significant values of folic acid (Kouřimská & Adámková, 2016). Retinol was also detected in some butterfly caterpillar species, such as *Imbrasia oyemensis*, *Nudaurelia oyemensis*, *Ichthyodes truncata*, and *Imbrasia epimethea*, whose content ranges between 32-48 μg/100 g of dry matter. Several species of lepidopteran larvae and soldiers of the termite species *Nasutitermes corniger*, an arboreal termite that is endemic to the Neotropics, also contain significant amounts of preformed vitamin A, but reported data suggest that edible insects should not be considered a dietary source of this vitamin (Finke, 2002). Additionally, vitamin E and tocopherols have also been reported in some edible insects. The larvae of the red palm weevil *Rhynchophorus ferrugineu* showed mean values of 35 mg of α-tocopherol and 9 mg of $\beta + \gamma$ tocopherols per 100 g of dry matter (Bukkens, 2005), while in the silkworm *Bombyx mori*, 9.65 mg of tocopherols per 100 g of dry matter was reported (Tong et al., 2011).

Finally, escamoles and eggs of the Formicidae family could serve as a good source of vitamins A, D, and E, since values of 505 μg/100 g of retinol, 3.31 μg/100 g of cholecalciferol, and 2.22 mg/100 g of alpha-tocopherol have been reported (Kouřimská & Adámková, 2016).

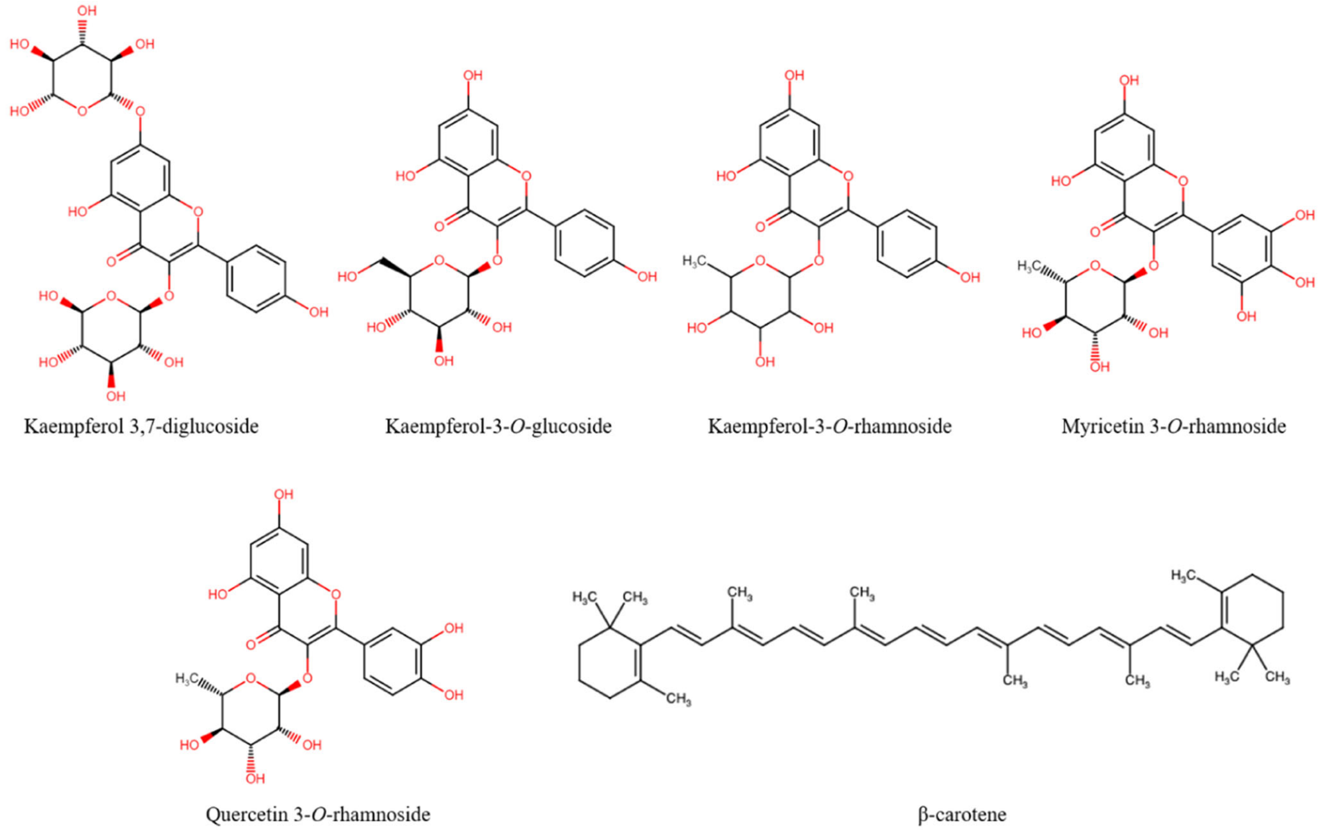

FIGURE 1 Chemical structures of the main bioactive compounds present in edible insects

3 | FUNCTIONAL BIOACTIVE COMPOUNDS FOUND IN EDIBLE INSECTS

Beyond their nutritional contribution, insects are attracting increasing attention as sources of bioactive compounds with potential health benefits and therefore as novel functional foods (Acosta-Estrada et al., 2021; Shah et al., 2022; van Huis et al., 2021). Their use in traditional medicine and the discovery of the chemical structure of the bright pigments in butterfly wings led to the detection of a diverse group of bioactive compounds in their bodies (cuticle, wings, and intestinal tract) (Figure 1).

The presence of these metabolites has been associated with (i) the absorption and metabolization by the insects of phenolic compounds of plant origin present in their diet (leaves, trunks, fruits, etc.) and with (ii) the ability of insects to synthesize de novo phenolic compounds through the sclerotization process (Nino et al., 2021). An example of the bioactive compound reported in edible insects is β-carotene, which has been detected in some butterfly caterpillars of the species *I. oyemensis*, *N. oyemensis*, *I. truncata*, and *I. epimethea* in values between 6.8 and 8.2 μg of β-carotene per 100 g of dry matter (Kouřimská & Adámková, 2016).

In addition, from the diversity of plants that insects encounter, flavonoids appear to be the most commonly absorbed, fundamentally attributed to herbivorous feeding behavior (Simmonds, 2003). Although the initial investigations did not focus on these compounds, recent studies demonstrated a close relationship between diet and the content of various types of phenolic compounds in the insects studied. Indeed, interesting contents of various groups of polyphenols and their metabolites, such as kaempferol-3-*O*-glucoside as the primary compound and kaempferol-3,7-di-*O*-glucoside, which are believed to be a biotransformation product of plant kaempferol, have been found. Other flavonoids reported are myricetin-3-*O*-rhamnoside, quercetin-3-*O*-rhamnoside, and kaempferol-3-*O*-rhamnoside (Nino et al., 2021). Thus, the presence of these compounds in edible insects constitutes an indicator of their functional potential and therefore of the nutritional benefits that can be attributed to them. Moreover, studies on raw and traditionally processed edible bed bugs (*Encosternum delegorguei*) (cooked in warm water followed by drying with heat) showed a total phenolic content (3.6 g gallic acid equivalents (GAE/100 g), tannins (0.31 g of catechin equivalents (EC/100 g) and flavonoids (5.20 g EC/100 g) higher than those found in processed insects (total phenols 2.8 g GAE/100 g, tannins 0.10 g EC/100 g, and flavonoids 4.80 g EC/100 g). These studies not only show the potential of these insects as sources of bioactive compounds but also the effect of processing on their availability (Musundire et al., 2014). Studies in the edible beetle *Eulepida mashona* reported a total phenolic content of 0.81 mg GAE/1 g of dry weight, while the presence of phenolic compounds in edible ground cricket (*Henicus whellani*) was quantified at 7.7 mg GAE/g, total flavonoid content at 15.5 mg CE/g, and tannins at 0.17 mg CE/g, suggesting that *H. whellani* is able to absorb these compounds from plant sources and sequester or metabolize them (Nino et al., 2021). Recently, investigations on the content of phenolic compounds in *A. domesticus* identified 4-hydroxybenzoic acid, p-coumaric acid, ferulic acid, and syringic acid as the major phenolic compounds present in this insect (Nino et al., 2021). On the other hand, a recent report using water and liposoluble extracts obtained from 12 commercially available edible insects (*T. molitor*, *Alphitobius diaperinus*, *R. ferrugineus*, *Tanna japonensis*, *Lasius niger*, *I. oyemensis*, *B. mori*, *Calliptamus italicus*, *A. domesticus* (Crickets and Mini Crickets), *Lethocerus indicus*, and *Scolopendra*) and two invertebrates (*Haplopelma albostriatum* and *Pandinus imperator*) concluded that edible insects and invertebrates represent a potential source of antioxidant ingredients with an efficiency related to their taxonomy and eating habits (Di Mattia et al., 2019).

In general, the data obtained thus far allow us to hypothesize that the phenolic compounds present in insects, mainly *Lepidoptera*, are the result of the absorption of dietary phenols from the plants, as well as their ability to metabolize these compounds and incorporate them into their body structures. From these results, it can also be derived that insects appear to have a selective uptake of flavonoids, mainly kaempferol and quercetin, as well as flavones such as tricine and isovitexin. Most of these compounds have been identified in their glycosylated form with a single sugar (glucose, rhamnose, or galactose). Both flavonols and flavones are synthesized by the host plant and are then metabolized or absorbed by the insect (Nino et al., 2021). Although current data are still insufficient, there is no doubt about the content and potential contribution of bioactive compounds by edible insects. These findings further support the hypothesis of the potential functional effects of edible insects and their promising future as functional foods.

4 | POTENTIAL RISKS ASSOCIATED WITH THE CONSUMPTION OF EDIBLE INSECTS

Edible insects that can be used for animal feed or for human nutrition must be nonpathogenic and nontoxigenic. While in Latin America, Asia, and Africa they are directly collected in the wild, in the other parts of the world, where the insects are to be reared, the factors associated with their safety should be carefully considered. In addition to their nutritional benefits, the consumption of edible insects may carry different risk factors, such as biological, toxicological, and allergenic hazards that are not yet clearly defined (Figure 2) (AECOSAN, 2018; Schlüter et al., 2017).

At the moment, there are no defined microbiological criteria for insects intended for human consumption, but it seems appropriate to develop specific criteria applicable to this kind of food, considering the type of products, the preparation, and other factors that may affect their quality and microbiological safety (AECOSAN, 2018). Indeed, different types of microorganisms, from bacteria (i.e., *Bacillus*, *Streptococcus*, *Staphylococcus*, and *Escherichia*) and viruses (i.e., *Baculoviridae*, *Parvoviridae*, *Picornaviridae*, *Reoviridae*) to protozoa (i.e., *Giardia lamblia*, *Toxoplasma spp*., *Entamoeba histolytica)* and fungi (i.e., *Aspergillus*, *Cladosporium Fusarium*, *Penicillium* and *Phycomycetescan*) can be found in several edible insects (AECOSAN, 2018; Imathiu, 2020; Raheem et al., 2019). Microbial intoxications and infections correlated with the consumption of insects have indeed been reported in scientific literature, thus highlighting the necessity to promote adequate hygiene practices in the whole food value chain, from the farm to the table, to safeguard consumer health (Imathiu, 2020). The amount and type of these microbes may depend on many aspects, including the insect species, the place where they are collected (wild vs. wild or reared), the way they are consumed (raw *vs* transformed), the processing and handling procedures used in their preparation, and the hygiene practices, among others.

Edible insects, especially those collected from the wild, can also transmit parasitic foodborne diseases to humans. For example, the consumption of wild antes has been associated with *Dicrocoelium dendriticum* infection, while the intake of wild cockroaches has been associated with *G. lamblia*, *Toxoplasma spp*., and *E. histolytica* zoonosis (Imathiu, 2020). To the best of our knowledge, the role of farmed insects in transmitting parasitic foodborne diseases has not yet been investigated.

Another important biological risk associated with insect consumption is represented by mycotoxins, which are secondary metabolites produced by several food spoilage and phytopathogenic molds belonging to the *Aspergillus*, *Penicillium*, and *Fusarium* genera. These toxins can be present in the feed substrate or in the insect gut of moths or termites, among others (Imathiu, 2020; van Huis et al., 2013). The most known and dangerous mycotoxins are aflatoxins, proven carcinogens isolated both in fresh and dried insects as a result of unhygienic processing conditions, including exposure to an open environment (e.g., during sun drying or during selling in the market street) (Imathiu, 2020).

Curiously, in addition to microbiological risks, some edible insects, such as *Musca domestica*, present an antibacterial peptide named Hf-1 that is effective against food bacterial pathogens, including *Bacillus subtilis*, *Pseudomonas aeruginosa*, *Escherichia coli*, *Shigella dysenteriae*, *Salmonella typhimurium*, and *Staphylococcus aureus*, highlighting the potential use of insects as food preservatives (Hou et al., 2007).

Concerning toxicological contaminations, the main risks comprise poisons, pesticides, heavy metals, and antinutrients (Imathiu, 2020; Raheem et al., 2019). Poisonous insects can be divided into two categories: phanerotoxics and cryptotoxics. The former comprises insects, such as bees and ants, that have specific organs to synthetize poison, usually inactivated in the digestive tract but that can be transmitted to humans through the insect bites. The latter includes insects that can synthetize and/or absorb harmful substances from the environment and accumulate them into specific structures or in diffused body areas, such as *Zonocerus variegatus* or *E. delegorguei*, which need to be prepared and cooked in a specific manner before consumption (Raheem et al., 2019; van Huis et al., 2013). Pesticide residues can be found in wild harvested edible insects, since they can feed on crops or vegetation treated with pesticides that can accumulate in insect bodies, as occurred, for example, in Kuwait with locust contaminated with organophosphorus and chlorinated pesticides (Raheem et al., 2019).

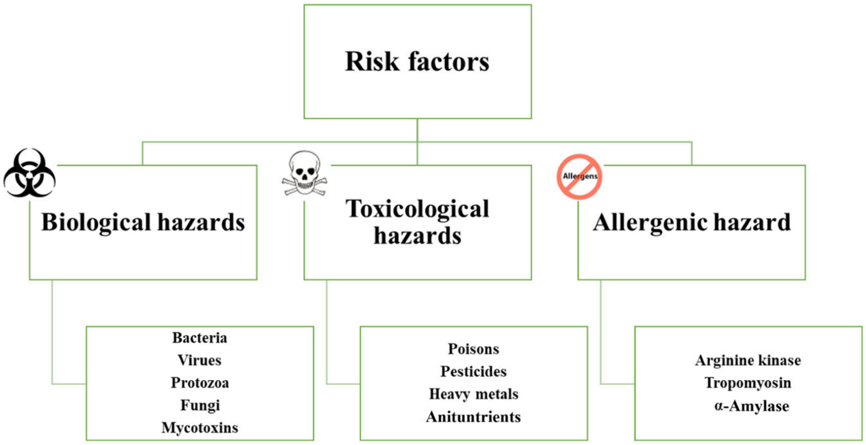

FIGURE 2 Schematic representation of risk factors associated with the consumption of edible insects

For these reasons, it is strongly necessary to promote insect farming where the feeding is strictly controlled and where it is conceivable to produce edible insects free of pesticide residue. At the same time, heavy metals, such as arsenic, lead, cadmium, and mercury, may accumulate in the insect body according to the insect species, growth stages, feed substrates, and to the metal element (Imathiu, 2020; van der Fels-Klerx et al., 2018). These metals represent a great health concern since they can induce toxicity even at low exposure levels (Imathiu, 2020). For example, arsenic and cadmium usually accumulate in yellow mealworm larvae and in black soldier flies, the two main insects used as feed and food in western countries (van der Fels-Klerx et al., 2018), as well as in Bombay locust, scarab beetle, mulberry silkworm, and house cricket, which are commonly consumed in Thailand (Imathiu, 2020). Finally, antinutrients are substances able to inhibit the intake, digestion, and absorption of macro- and micronutrients. For example, the consumption of *Anaphe venata* caterpillar has been correlated with the deficiency of thiamine and the consequent ataxic syndrome in Africa, easily surmountable with an adequate cooking process or even eating selected parts of insects, as occurred in Italy with the consumption of *Lepidoptera* of the genus *Zygaena* (Hou et al., 2007). The most common antinutrients found in edible insects include phytate, hydrocyanide, oxalate, alkaloids, saponins, and tannins and may involve termites, grasshoppers, long-horned beetles, palm weevil crickets, yam beetles, and meal bugs (Imathiu, 2020; Raheem et al., 2019).

Food allergies can be defined as an excessive and adverse response of the immune system to food that can lead to serious illness and even death (Johansson et al., 2004). Theoretically, any dietary protein can induce an allergic reaction in responsive subjects; therefore, some edible insects are potential allergen sources. A recent study carried out in Belgium showed that 19% of tested subjects were positive on skin prick tests based on grilled mealworm (*T. molitor*) and cricket (*A. domesticus*) samples, suggesting a high risk of allergic reactions correlated with the consumption of insects for a large part of the population (Francis et al., 2019). The most-known allergens present in edible insects include arginine kinase, tropomyosin, and α-amylase, and the most commonly involved insects comprise caterpillars, mealworms, sago worms, silkworms, locusts, grasshoppers, and cicadas (de Gier & Verhoeckx, 2018; Murefu et al., 2019). Allergic reactions have been frequently reported in China, Laos, Africa, and India both in consumers and in people in constant contact with insects, including entomologists and agricultural, laboratory, and industrial workers (Imathiu, 2020; van Huis et al., 2013). A separate discussion deserves chitin and its derivative chitosan, which, even if the past have been considered allergens, have recently been found to exert interesting biological properties, including antitumor, antiviral, and immunostimulatory effects, acting both on adaptive and innate immune responses (Lee et al., 2008).

5 | CONCLUDING REMARKS AND PERSPECTIVES

Entomophagy has been practiced for years in many areas of the world, especially in developing countries, including Asia, Africa, and Latin America, where edible insects are considered a nutritious and delicious dietary source. However, in the rest of the world, even if interest in edible insects and insect-derived products has increased in recent times, the wide promotion of insect consumption is still difficult due to several cultural aspects and safety concerns. For example, in Western countries, acceptance by consumers is the main barrier to their inclusion in the diet because insects are not part of the dietary culture, and most people consider insects to be disgusting and associate them with poor countries and with primitive practices. Another obstacle to the promotion of entomophagy is food safety issues, mostly because of the limited knowledge about the health risk associated with their consumption. However, it should be taken in mind that the majority of the infections or intoxications or illnesses reported derive from the consumption of insects collected in the wild, where it is not possible to control, for example, their feeding habits, as in the case of farmed insects. For these reasons, it is of vital importance to explore the potential of reared insects to develop human foodborne diseases, not only to promote the farming and controlled procedures of processing and storage both in developed and developing countries but also to reassure the consumer about their safety.

Generally, edible insects are important sources of energy, macronutrients, especially proteins, amino acids (especially essential ones), fats (i.e., unsaturated fatty acids, sterols, and phospholipids), and micronutrients, including minerals (Fe, Zn, K, Na, Ca, P, Mg, Mn, and Cu, among others) and vitamins (B1, B2, B6, B12, C, D, K, and E). Some insects are also an interesting source of bioactive compounds, such as polyphenols (mainly carotenoids and flavonoids). In addition to contributing to reducing nutrient deficiency in developing countries, recent studies have also highlighted that the protein hydrolysates of some edible insects may exert biological activities, such as antioxidant, antimicrobial and antihypertensive activities, helping to prevent many common human diseases, including hypertension and diabetes (Jantzen da Silva Lucas et al., 2020). Therefore, in order to encourage the consumption of insects worldwide, new studies and new strategy should be adopted in order to (i) promote insect rearing that produces safer and environmentally friendly products compared to grain-livestock systems, (ii) standardize the methods and protocols for the processing and the storage of both insects and insects-derived ingredients, such as proteins, to be used, for example, as food additive, (iii) develop insect-based products that could be more acceptable, appealing, and attractive for consumers, such as energy bars and cookies, among others, (iv) determine the nutritional profiles of edible insects, (v) deepen the biological, toxicological, and allergenic risks associated with entomophagy in order to understand the way of removing them before consumption and reassure the consumers, (vi) assess the health benefits associated with the consumption of insects, (vii) elaborate educational campaign about the nutritional composition of insect in order to change consumers perception and increase their willingness, and (vii) simplify, extend, and unify the legislative requirements and policies on rearing, production, and marketing worldwide.

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CONFLICT OF INTEREST

The authors confirm that they have no conflict of interest to declare for this publication.

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