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Edible insects – a new trend in Functional Food Science

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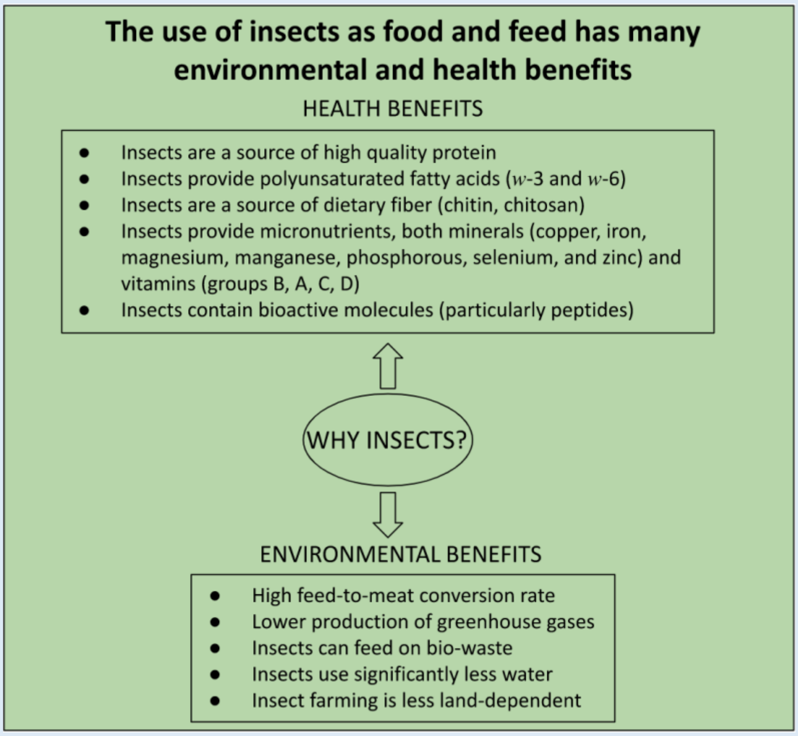
ABSTRACT

Population growth, rising global food demand, and environmental concerns related to (animal) food production have indicated the use of edible insects as a sustainable and healthy food source. However, despite edible insects being considered a novel food in Western countries, entomophagy is a traditional food habit in many human cultures and ethnic groups. Many preclinical studies have highlighted the health benefits of edible insects and their bioactive compounds, although evidence in humans is still limited. Therefore, further clinical studies are urgently needed for the exploitation of edible insects as functional foods.



Keywords: novel food; nutraceuticals; bioactive compounds; healthy diet; sustainability; traditional food; food security

INTRODUCTION

In the face of population growth, which is expected to reach nearly 10 billion by 2050, and the growing global demand for food (and meat), food insecurity is emerging as a global societal challenge [1]. In this scenario, human consumption of edible insects represents a viable solution to the global food shortage due to the exponential growth of the world population. However, the human consumption of insects is not a new habit, having been practiced since the beginning of human evolution, and is today part of the traditional diet in many cultures and ethnic groups around the world, particularly in tropical and subtropical countries [2]. Such a practice of consuming insects as food is known as entomophagy, which has been practiced since time immemorial by humans and their primate relatives. It is now widely practiced in countries covering almost every continent including Asia, Africa, Latin America, Australia, and Europe as traditional (and sustainable) food that provides nutritional, economic, and ecological benefits for rural communities, with Mexico, China, Thailand, and India being the top consuming countries [3-7]. In this brief review, insect products such as honey, royal jerry, and edible silk will not be covered.

Edible insects as a sustainable and healthy food: Insect consumption depends on many factors including availability, access, preference, nutritional value, religious beliefs, and social customs. Insects are consumed in different stages of metamorphosis depending on the species, and their eggs, larvae, pupae, and adult forms can be prepared in different ways such as fried, roasted, boiled, ground, and sometimes eaten raw. Furthermore, the medicinal use of insects, known as entomotherapy, has also been used throughout history in traditional medicine of many cultures. Edible insects have gained interest in recent years and entomophagy has become a new trend in food science and nutrition [3-6]. Globally, about two thousand species of insects are currently consumed, belonging to eight orders, namely Coleoptera (beetles), Lepidoptera (caterpillars, butterflies, and moths), Hymenoptera (wasps, bees, and ants), Orthoptera (crickets, grasshoppers, and locusts), Hemiptera (cicadas, honey ants, aphids, plant hoppers, leafhoppers, scale insects, and true bugs), Odonata (dragonflies and damselflies), Blattodea (cockroaches and termites), and Diptera (flies) (Figure 1) [7].

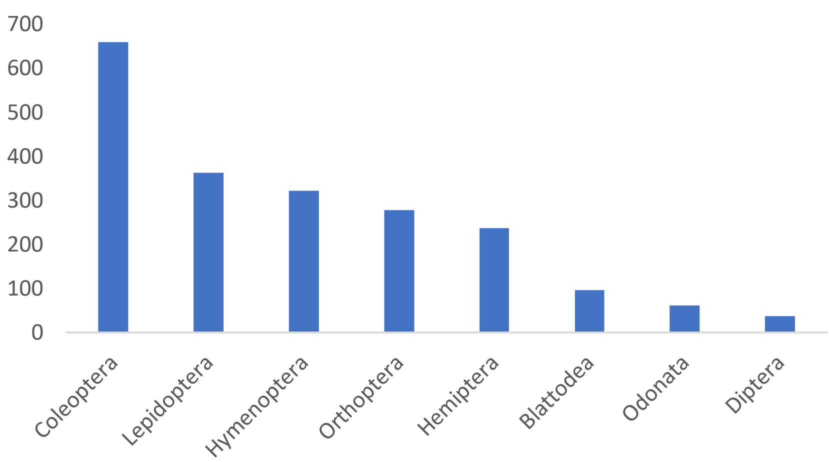


Figure 1. Number of edible insect species per Order (adapted from [7]).

In Europe, the European Food Safety Authority (EFSA) has approved three species as novel foods, being house crickets (*Acheta domesticus*), yellow mealworms (*Tenebrio molitor*), and migratory locusts (*Locusta migratoria*).

From a conservation perspective, the consumption of edible insects can be an environmentally sustainable and cheaper substitute for meat and animal products and could provide ecological and economic benefits by reducing greenhouse gas emissions and land use while strengthening the fragile food supply [8]. In fact, since meat production has been considered an unsustainable process, the farming of edible insects can contribute to reduce the environmental impact due to agriculture, animal husbandry, and aquaculture, since their production requires a reduced amount of water, feed, energy, and land [3-6].

From a nutritional point of view, edible insects represent a rich source of nutrients characterized by high levels of high-value and easily digestible protein, essential amino acids, polyunsaturated fatty acids ω-3 (α-linolenic acid) and ω-6 (linoleic acid), dietary fiber (the non-digestible constituents of exoskeleton chitin and chitosan), vitamins (group B, C, A, and D), minerals (iron, zinc, copper, calcium, magnesium, manganese, phosphorus, selenium), and polysaccharides [9,11]. The content of macro- and micronutrients can vary greatly due to the different insect species, metamorphosis and developmental stages (adults, larvae, pupae, and nymphs), sex, life cycle (sedentary nymphs or adult workers or queen), type of feeding (for example, pupae usually do not consume any food), origin (farming or collection site), and processing methods before consumption and cooking. In general, the fat and protein contents are higher in the less and more mature stages, respectively. In addition to being a nutritious food, edible insects can also be healthy ingredients of various dishes or can be used as a substitute for cereal flour for the enrichment of snacks to increase the nutritional value of different dishes. Many products containing insects or parts of them have been marketed worldwide, for example in cereal-based foods, protein foods of animal origin, and animal feed [3-6].

On the other hand, safety assessments are needed in terms of anti-nutrient content, chemical and microbial contamination, and adverse reactions [12-15]. Feeding on plants, herbivorous insects accumulate allelochemicals in their bodies and secondary metabolites produced by plants to defend themselves against pests. Allelochemicals include condensed tannins (or proanthocyanidins), phytates, oxalates, trypsin inhibitors, lectins, and hydrocyanides whose primary action is to inhibit digestive enzymes and absorption of nutrients (particularly minerals) and therefore termed anti-nutrients [16,17]. In addition, residues of chemical pesticides sprayed on host plants can accumulate in the insect's body, as well as heavy metals [18,19]. A wide range of pathogens and spoilage bacteria can be present in edible insects, making them carriers of human pathogens and vectors of foodborne diseases [20]. Bacterial contamination of edible insects is mainly due to *Bacillus cereus*, *Bacillus subtilis*, *Staphylococcus aureus*, *Escherichia coli*, *Rickettsiella* spp., *Pseudomonas aeruginosa*, *Proteus vulgaris*, *Salmonella* spp., *Campylobacter* spp. and *Shigella* spp. The most important fungal contaminations can derive from the genera *Cladosporium*, *Penicillium*, *Aspergillus,* and *Fusarium,* which are able of producing mycotoxins in particular conditions [17,18,21,22]. These risks can be mitigated by appropriate hygiene and production practices, such as a microbiocidal processing step to avoid or reduce the risks associated with intake of insects. Cases of allergic reactions or even anaphylaxis could occur after the intake of insects, most likely due to the presence of allergens identified as muscle proteins (myosin and sarcoplasmic Ca-binding proteins tropomyosin and arginine kinase), probably exacerbated by the relationship between insects and other phylogenetically related groups of arthropods, especially crustaceans [23,24]. Therefore, because of the consumption of insects, cross-reactivity with homologous proteins can occur due to allergens that bind to IgE and cross-react in subjects allergic to crustaceans [3-6, 25-27].

Despite the undoubted benefits for health and the environment deriving from the intake of insects, their non-acceptance in Western society represents the most critical factor hindering the exploitation of insects as a food source, probably because insects are not traditional food components in these countries [28,29]. Therefore, several factors influence the consumer's perception of entomophagy and cause rejection of insect consumption due to disgust, origin from dirty habitat, neophobia, taboo, and belief. However, the tendency of consumers to eat insect flour as an ingredient in Western food preparations (such as cereal snacks, breads, wheat pasta, and meat formulations) is greater than for whole insects [30].

CONCLUSION

An innovative aspect and a new field of research is related to the role of edible insects as food capable of inducing a functional effect in humans. In addition to the basic nutritional value, edible insects can be considered functional foods that provide bioactive compounds (e.g., peptides, phytosterols, policosanols) with a high nutraceutical potential. Functional foods are defined as 'natural or processed foods that contains biologically active compounds which, in defined, effective, and non-toxic amounts, provide clinically proven and documented health benefit utilizing specific biomarker for the prevention, management, or treatment of chronic disease or its symptoms' [31,32]. Bioactive peptides of edible insects include cecropin, attacin, mellitin, moricin, and diptericins, which are part of the insect immune system and defend against infectious agents [6].

Several preclinical *in vitro* and *in vivo* studies have elucidated the properties of edible insects in modulating oxidative stress, inflammation and cytokine production, platelet aggregation and the anti-coagulation process, lipid and glucose metabolism, and the control of weight. To the best of our knowledge, only two dietary intervention studies are available in humans [33]. In an acute intervention study, *Bombyx mori* powder-enriched wheat noodles administered to thirteen healthy male subjects following a cross-over design significantly lowered postprandial blood glucose concentration, area under the blood glucose curve, and glycemic index compared to control noodles [34]. Following a cross-over chronic intervention design, a muffin enriched with 25 g/d of dried roasted cricket was administered to twenty healthy volunteers for breakfast for 14 days. Treatment with cricket powder increased the growth of the probiotic bacterium *Bifidobacterium animalis* by 5.7-fold and decreased plasma levels of TNF-α [35]. In conclusion, further evidence from human dietary intervention studies is needed to support promising evidence from *in vitro* and animal models on the functional role of edible insect consumption, according to the classification and regulation of functional foods proposed by the Functional Food Center [36].

List of Abbreviations: EFSA: European Food Safety Authority, IgE: immunoglobulin E, TNF-α: tumor necrosis factor α.

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