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Entomophagy as an alternative source of protein and a new food strategy

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Abstract

With the projected growth of the world population, an increase in food production on a sustainable commercial scale, the search for alternative sources of protein and a shift to new eating strategies are needed. The article provides an overview of the existing relevant scientific information based on the analysis of publications in international (PubMed, MedLine, Google Scholar) and domestic (RSCI) electronic databases. The review considers the phenomenon of entomophagy as a potential solution to the problem of food shortage in the world, its biomedical, ecological, sociocultural, evolutionary and economic features. The species of the most commonly used edible insects and the countries in which insect biomass products have become traditional in the diet of the population are described. The nutritional value and consumer attitude to such products are highlighted. Insect biomass products are characterized by a high content of proteins, fats, minerals, vitamins and are superior in calories to traditional sources of animal and vegetable protein. In this regard, entomophagy has a preventive potential in the preparation of a diet and treatment for metabolic disorders, osteoporosis and other nosologies. The article notes gender differences in relation to adherence to entomophagy in Russia. Despite the revealed values of entomophagy, the issue of food safety for humans remains unresolved. Among the main concerns are the development of possible allergic reactions, the content of pathogenic microorganisms and harmful substances in the composition of food from insect biomass. The review presents the prospects for increasing the share of consumption of insect products and the economic benefits that the globalization of entomophagy will entail.

Keywords: entomophagy, edible insects, nutritional value, consumer behavior, insect biomass.

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Introduction

Entomophagy, the practice of eating insects, is considered an alternative method of obtaining protein and is a new food strategy for Western European and Russian societies. In tropical climates, indigenous people have been eating edible insects for thousands of years, contributing to food security. Insects provide nutritional value and serve as a source of income when sold [1–3].

This approach is currently under investigation in Western European countries because of the necessity of discovering sustainable protein sources that can be produced commercially [4, 5]. The global population and demand for meat products are increasing, whereas the land available for livestock production is limited. This problem is exacerbated by global environmental problems, such as climate change caused by greenhouse gas emissions, soil acidification from ammonia leaching, deforestation, soil erosion, desertification, loss of plant biodiversity, and anthropogenic water pollution [5, 6].

However, whether large-scale industrial production of insects as an alternative protein source is more environmentally sustainable than livestock production must be further considered [1–6]. This review describes the factors that contribute to the globalization of entomophagy, nutritional value of edible insects, geography of their consumption, prospects for increasing the number of insect products, and economic benefits and environmental effects of further development of such a food strategy.

Thus, this study aimed to systematize key aspects and scientific data of current research in entomophagy as an alternative means of obtaining nutrients for humans.

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Nutrition as a global social construct

According to forecasts by the United Nations, specifically the Food and Agriculture Organization (FAO), the world population is projected to reach approximately 9.7 billion people by 2050, resulting in a 70% increase in food demand [7]. Therefore, the production of sustainable commercial-scale food is an urgent and significant issue.

Moreover, the demand for animal meat is projected to increase by 73% in 2050 because millions of people are overcoming poverty in developing countries. This will exacerbate the ethical and environmental challenges associated with traditional meat production as the main source of protein. It is not sustainable to continue livestock production indefinitely because 75% of the world's agricultural land is already used for this purpose. Approximately 70% of the world's freshwater reserves are used for agricultural and livestock production. This usage is believed to contribute to an increase in greenhouse gas emissions, a factor contributing to global warming [8–11].

Various types of meat substitutes and alternative protein sources can help solve these problems. Therefore, the FAO considers entomophagy a potential solution to global food shortages [7, 12, 13].

Although insects have been a food source for thousands of years, entomophagy is not a new phenomenon. However, only recently have insects been commercially reared as human food. Edible insects are mostly obtained from the wild, particularly in remote rural areas and tropical countries with high biodiversity [12, 14, 15]. Insects are assumed to be a part of the diet of approximately 2 billion people worldwide and have long been a staple in traditional cuisine in Asia, Latin America, and Africa [2, 14, 15].

Insect farming requires fewer land and water resources than traditional protein sources. Commercializing insect biomass as an alternative protein source will reduce the global burden on the livestock sector and environment. Neuromarketing studies are underway to increase the global market contribution of insect-derived products to 30% as a new food source. The development of new protein sources is relevant for several reasons. Humanistic factors and the trend toward reasonable food consumption by consumers are among the reasons [6, 13, 16, 17].

Nutritional value of edible insects

The nutrient composition of an insect is dependent on its species, diet, and developmental stage. Edible insects are generally considered highly nutritious and contain high levels of protein, fats, minerals, and vitamins. They are often more calorically dense than traditional animal and plant protein sources [1, 3].

Insect products are primarily valued for their protein content, ranging from 33.5% to 64.7% depending on the insect type. The raw protein content ranges from 27 g/100 g of mulberry silkworm to 54 g/100 g of house cricket. In comparison, beef has a protein content of 18.6 g/100 g, pork has 14.3 g/100 g, and chicken meat has 18.2 g/100 g [1, 2].

Insects can contain up to 80% protein by mass, which is comparable to that of animal proteins. For instance, the larvae of *A. Diaperinus* (mini-mealer), *T. molitor* (mealybug), and *Z. Morio* (zophobas) contain all essential amino acids in the amounts required for human consumption. Edible insects also have higher concentrations of polyunsaturated fatty acids. The fat content varies depending on the insect species. For example, black ants have a fat content of 49.8%, whereas winged termites have a fat content of 34.1%.

The energy value of insect meals ranges from 128 to 153 kcal per 100 g of product for mulberry silkworms and crickets to 409–499 kcal per 100 g of product for mopane caterpillars, palm weevils, and bees. These values are significantly higher than the caloric value of traditional meats, which ranges from 92 to 218 kcal per 100 g of product. Edible insects are a rich source of calcium (30–700 mg per 100 g of dry weight) and iron (1.8–18.5 mg per 100 g of dry weight). They also contain other essential minerals and vitamins, including thiamine, riboflavin, and vitamins A and C.

Because of the properties of insect foods, entomophagy has the potential to prevent and treat metabolic disorders, osteoporosis, and other conditions [18–22].

The nutritional composition of edible insects has been extensively examined. Several researchers have suggested that insects are a more nutritious source of protein than other sources of plant or animal origin [2, 18, 20, 22]. In a large-scale study, S. Payne [2] systematically collected information on the relative nutritional value of commercially available edible insect products, such as crickets, mulberry silkworms, mopane caterpillars, palm weevils, and mealworms, compared with traditionally consumed meats, such as chicken, beef, and pork, and their by-products.

The authors used specialized nutrient-profiling models for direct comparison and assessment of the effect on human health. Chicken by-products have the highest saturated fat content (12.1 g per 100 g), whereas insects exhibit a much wider range of median values (2.28–9.84 g of saturated fat per 100 g). The median values of sodium content in insects (0–152 mg per 100 g) also exhibit a greater range

than those in meat (60–132 mg per 100 g). The protein content of edible insects ranges from 9.96 to 35.2 g of protein per 100 g, whereas chicken and beef contain 16.8 and 20.6 g of protein per 100 g, respectively. A study found that crickets and bees have average iron contents, which are 180% and 850% higher, respectively, than that of beef, which have the highest iron content among the three types of meat [2]. In addition, all insects examined had higher calcium and riboflavin contents than any meat or meat by-products.

Key finding: The authors noted that different insect species have significantly varied nutrient and mineral contents, affecting their potential to combat public health problems. In addition, meat products may be more nutritious than insects in cases of excessive food intake, whereas some edible insects may be superior to meat protein sources in cases of malnutrition.

Major groups of edible insects and their geographic distribution

Approximately 2000 species of insects are considered edible, and this number is constantly growing. The main groups of edible insects currently include hardwings (beetles; families *Dytiscidae, Gyrinidae*, *Hydrophilidae,* and *Rynchophorus*) and lepidopterans (butterflies that usually eat caterpillars, e.g., *Imbrasia belina, Saturniidae, Omphisa fuscidentalis*, and *Endoxyla leucomochla*), hymenopterans (wasps, bees, ants, e.g., *Polymachis dives, Vespula* and *Dolichovespula spp., Atta mexicana, Atta cephalotus, Bombycidae, Meliponidae*, and *Apidae*), orthopterans (locusts, grasshoppers, and crickets, particularly R*uspolia differens, Oxya yezoensis, Patanga succincta, Sphenarium purpurascens, Acheta domesticus*, and *Gryllus bimaculatus*), termites (*Macrotermes* and *Syntermes*), and hemipterans (*Agonoscelis versicolor, Corixidae* and *Notonectidae, Pentatomid, Tessaratomae*, and *Encosternum delegorguei*) [4, 16, 23]. The most commonly consumed insects include beetles (31%); caterpillars (18%); bees, ants, and wasps (14%); grasshoppers, locusts, and crickets (13%); hemipterans (10%); dragonflies (3%); termites (3%); and flies (2%) [22, 23].

Entomophagy, or the practice of eating insects, has been widespread for thousands of years in Southeast Asia, Latin America, and Africa, where high biodiversity and numerous edible insect species are present. Insect consumption is practiced in over 110 countries worldwide; however, it remains limited among food cultures in Western Europe and Russia. Dietary rules and regulations may be influenced by various factors, such as psychological barriers, religious beliefs, human life cycle, and presence or absence of disease [13, 14, 23–25].

In the Asia-Pacific countries such as China, edible insects are cultivated for food, medicine, and animal feed [11, 26]. Some insects are also completely domesticated [26]. In Thailand, three official groups of people consume insects [27]:

– "Nostalgic consumers" are those born in a province where entomophagy was prevalent.

– "Urban consumers" are those who considered eating insects a new phenomenon, which subsequently became firmly embedded in their daily lifestyle.

– Foreign tourists attracted by the novelty of eating various insects prepared as delicacies.

In Latin America, specifically in Mexico, the consumption of edible insects is a traditional practice. This is evidenced by the sale of such products in open markets [28, 29]. Indigenous populations in many southern African countries also practice entomophagy [23, 30]. Edible insects are a valuable natural resource used for survival, particularly during events of food scarcity, such as droughts or other climatic disasters [30, 31].

Neuromarketing and economic potential in the entomophagy industry

The European population often distrusts entomophagy as a new means of nutrition because of the mistaken belief that insects and insect-based food are harmful to humans. In reality, only 0.2% of insects are harmful [8, 13]. In addition, the appearance and texture of insects discourage their consumption more strongly than their taste characteristics. However, neuromarketing studies have suggested that European respondents are willing to consume industrially produced insect biomass products because of their higher nutritional and energy values [1, 6, 16, 32–34].

Furthermore, insect consumption may appeal to individuals who seek alternative food options for ethical reasons and wish to reduce their animal meat intake. A study [35] examined how participants perceived individuals who had transitioned to consuming insect-based products. The findings indicated that these consumers were environmentally conscious, health conscious, and open to new ideas, solutions, and changes.

Polubesova et al. [36] investigated sex differences in attitudes toward commitment to entomophagy in Russia. The results showed that women were consistently 1.5–2 times more negative toward this issue than men. Of all respondents, 44% supported a ban on the production of edible insects in Russia, with men favoring the ban only half as often as women. Women are more concerned than men about allergic reactions to a new product. These results relate to respondents' concerns about the

safety of eating insects. Approximately 30% of male and female respondents noted the lack of sufficient scientific information about edible insects as a possible reason for not eating them.

Studies have shown [23, 30, 31] that among indigenous populations in African countries with traditional entomophagy practices, women have a greater level of expertise in collecting and preparing food from insect biomass and can distinguish better between species than men. In addition, men and women play different roles in the practice of collecting and breeding insects, which may be related to differences in biological needs and diet. Thus, conducting new scientific research in this area and using different marketing strategies and communications could help alter respondents' opinions and increase their confidence in insect-based foods [33, 35, 36].

Given the global population growth and anthropogenic climate change, sustainable sources of nutrients, particularly protein, are increasingly needed to achieve economic advantage and food security. Insects are a promising option because of their low economic and environmental costs for farming. Industrial insect production can use 50%–90% less land per 1 kg of protein, 40%–80% less feed per 1 kg of edible weight, and 1000–2700 g less greenhouse gas emissions per 1 kg of weight gain than livestock production [2, 4, 7, 33, 36]. However, insect-based foods are relatively new products in Western Europe and Russia, and information on the safety and nutritional value of edible insects is scarce, particularly because they represent such a diverse category [6, 16, 36].

In the past decade, the International Platform of Insects for Food and Feed, an international consortium, has been established in the European Union. It aims to change laws in favor of greater freedom in entomophagy marketing [7, 37, 38]. This not only encourages insect food products to enter European markets but also highlights the importance of systematic research into the nutritional value and safety of commercially available edible insects for human consumption.

Regular advertising campaigns aimed at improving the perception, taste, and appearance of edible insects have successfully reduced negative attitudes toward them in some Western European countries. For example, Belgian consumers increasingly view insects as a healthy and sensible food source. In the Netherlands, sales of insect biomass products are also increasing, particularly lyophilized insect powder, which has been suggested as a meat substitute [8, 10, 37, 38].

The global market for edible insects exceeded hundreds of millions of dollars at the turn of the last decade and is projected to exceed $1.5 billion by 2026 [39]. According to FAO, the current capacity of the edible insect market is already approximately $400 million. The industrial insect-breeding sector is expected to create more jobs and contribute to the economic development of the countries.

Based on recent statistics, the market volume of edible insects in the Asia-Pacific region is projected to reach USD 470 million in the coming years [26, 39]. The European and Latin American markets will experience almost a threefold growth (from 170 to 500 million USD) in the next 5 years, whereas the North American market is expected to grow more than threefold, reaching over $150 million. Currently, entomophagy is becoming an increasingly convincing food culture in the global market because edible insect breeding serves as one of the main sources of income for many countries [26, 27, 33, 39, 40].

Currently, sustainable manufacturers of insect biomass products include Entomotech (Spain), Meertens (Netherlands), Agriprotein (UK-South Africa), Ynsect (France), Proteinsect (Netherlands), Protix (Netherlands), Enterra (Canada), and Big Cricket Farms (USA).

FAO experts suggest that the black lion fly, house fly, migratory locust, desert locust, house cricket, two-spotted cricket, mealybug, zophobas, and marbled cockroach are the most promising edible insects for industrial breeding. In addition, flies of the family Calliphoridae are considered viable options.

Entomophagy can play an important role in overcoming the growing nutritional deficiency crisis globally by providing an alternative protein source. Insects contain sufficient macro- and micronutrients to ensure food security. Ongoing neuromarketing studies have indicated that modern society is ready to take the next step toward insect consumption [7, 13, 16, 41].

Conclusions

Based on available information, we propose conducting more investigations on the differences in consumption motivations, perceptions, and attitudes across socioeconomic and demographic profiles of consumers. Entomophagy currently appears as an alternative food consumption strategy to address food security. It offers a conceptual framework that identifies key factors related to social acceptance and the prospective growth of industrialized food production from insect biomass. Despite the identified values and potential benefits of entomophagy, the issue of food safety for humans remains unresolved. Therefore, consumers are mainly concerned about possible allergic reactions,

presence of pathogenic microorganisms, and harmful substances in insects. However, globalization of a food strategy can be achieved through industrial production that uses certified technologies for processing and preparing food from insect biomass. This approach is supported by existing and new scientific data [1, 3, 20, 36, 41]. The current growth rate of research on entomophagy as an alternative food source suggests the continuous development of their field.

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