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# INSECT-BASED PROTEINS: NUTRITIONAL BENEFITS, HEALTH EFFECTS, AND CONSUMER ACCEPTANCE

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**Abstract:** The excessive consumption of red meat in economically developed countries has been linked to obesity and the onset of inflammatory metabolic disorders responsible for chronic conditions including diabetes, different types of cancer, chronic pulmonary disease, cardiac and vascular diseases. As an alternative, insects, approved for consumption, are recognized as a sustainable, nutritional, rich source of protein due to their high protein concentration, amino acids profile and significant levels of vitamins and minerals. Despite these benefits, their acceptance as food remains low, influenced by cultural, psychological, and sensory factors. This review explores the quality of proteins that can be found in insects compared to plant-based alternatives, emphasizing their digestibility, amino acid profile, and sustainability. Furthermore, the bioactive properties of insect proteins, including their anti-inflammatory and immunomodulatory effects, are examined, highlighting their potential role in metabolic regulation and disease prevention. Additionally, the impact of chitin and other derivatives on the function of gut microbiota is discussed, along with their prebiotic potential. Finally, the legal frameworks governing the acceptances of insects that cand be used in human nutrition are reviewed, showcasing regional differences in their acceptance and regulation. Given the growing need for alternative protein sources, edible insects present a promising yet underutilized solution, requiring further research and public awareness to enhance their integration into global diets.

**Keywords:** edible insects, insect protein, anti-inflammatory effect, consumer acceptance, sustainability

## 1. Introduction

In economically developed countries, excessive consumption of products like meat, mainly red meat and meat products is directly related in the increase incidence of obesity but also to the emergence of an inflammatory metabolic state responsible for the onset and progression of long-term illnesses including type-2 diabetes, cancer, chronic pulmonary disease and cardiovascular diseases (Chavda et al., 2024) (Wang et al., 2022). In this context, the incorporation in the diet of new approved protein sources, such as plant-based meat (PBM) analogues or insect protein powder could bring real health benefits due to the content of proteins, vitamins or minerals (Jankowski et al., 2025). As well, the incorporation of alternative protein sources in human diet may be considered a sustainable option due to the reduction of ecological footprint, water consumption, pollution and

waste (Lange and Nakamura, 2023). The main advantages of using edible insects in human nutrition are shown in **Figure 1.**

There are extensive studies in the literature that aim to identify the reasons why different individuals adopt alternative diets that do not use animal products. Among these are: animal welfare, health, environment/sustainability, religious or economic reasons (Rosenfeld and Burrow, 2017). A 2022 report by a non-profit organization based in the United States that promotes vegetarian and vegan lifestyles through research shows that in the US 63% of adults always/sometimes eat vegetarian food, 29% vegan, and only 37% claim to never eat vegan/vegetarian food. Among them, most are women aged 18-34, motivated primarily by health concerns, followed by considerations for animal welfare and taste. Other influencing factors include cost, ethical beliefs, and environmental impact. (Stahler, 2020). In the UK, the Vegetarian Society reports that 4.5% of the population is vegetarian/vegan and meat consumption has decreased by 17% in 2019 compared to 2008 (Stewart et al., 2021). In 2024, the World Population Review analyzed dietary behavior in 45 countries on 6 continents and showed that worldwide the largest number of vegetarians is found in India (approx. 24%), mainly based on cultural reasons, the number of vegetarians is increasing in countries such as Germany (10%) or Sweden (12%), while in Latin American countries, Argentina (12%) and Brazil (14%) a real shift in dietary preferences has taken place (World Population Review, 2024).

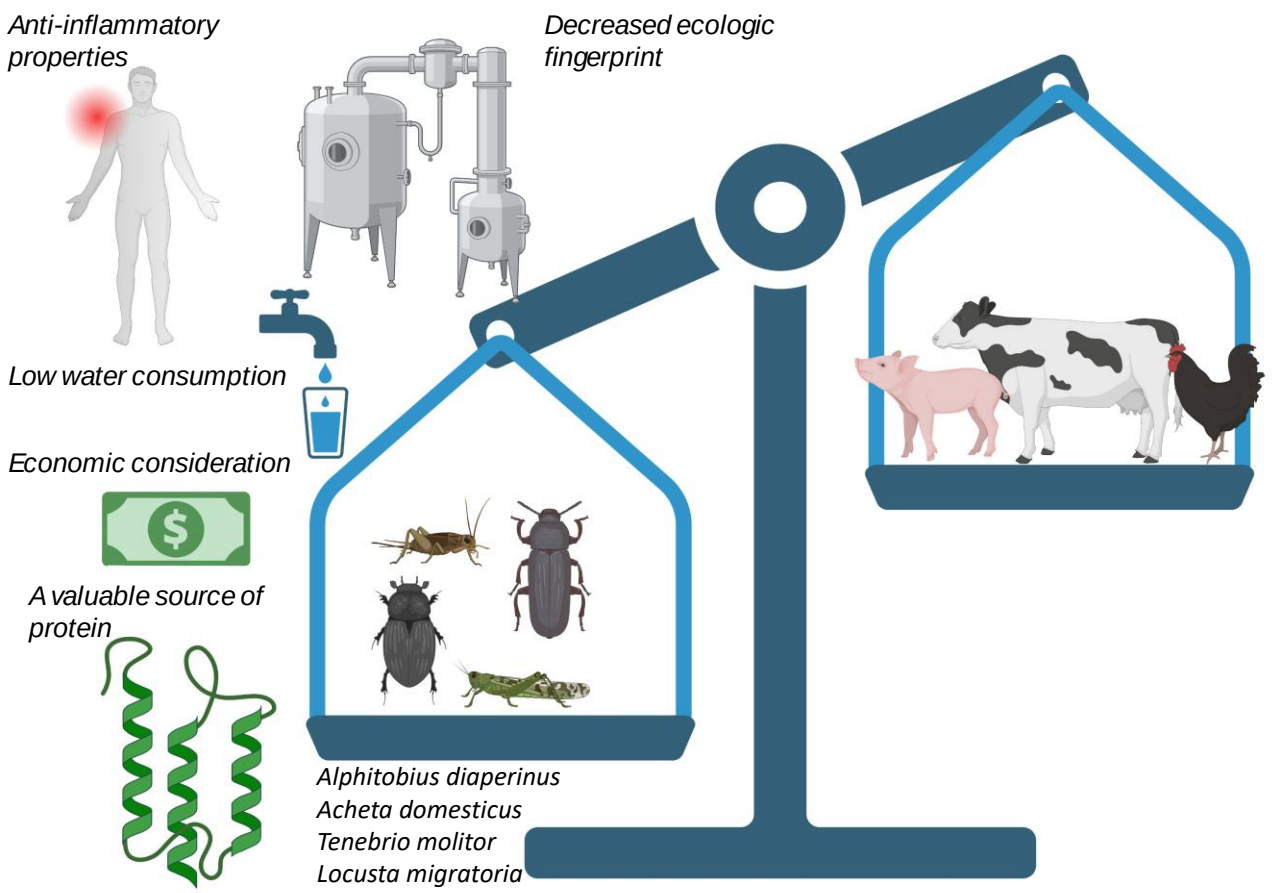


**Fig. 1.** The most important advantages of using edible insects (Created in https://BioRender.com)

The use of insect powder in food is currently legal in 120 countries, but despite the nutritional benefits (high content of proteins, unsaturated fats, minerals and vitamins) the degree of acceptance is low (Gedrovica, 2019, Bengtsson and Wendin K, 2023) the reasons being social, cultural, disgust and neophobia (Wendin and Nyberg, 2021). The regulations governing the use of edible insects vary across different regions. In EU member states, Regulation (EU) 2015/2283 classifies edible insects as farm animals, with approved species including house cricket (*Acheta domesticus*), the lesser mealworm (*Alphitobius diaperinus*), yellow mealworm (*Tenebrio molitor*), and migratory locust (*Locusta migratoria*) In the USA and Canada, the Food and Drug Administration (FDA) does not explicitly authorize insects for human consumption; nevertheless, the FDA allows insects for human consumption under certain conditions, mainly through regulations related to food safety and the correct labeling of products containing them. In African countries, the consumption of insects is practiced but legislation is scarce. In Asia, China, Japan, and Thailand, the consumption of insects is practiced but they are not included in the Catalogue of Edible Insect Resources (Li et al., 2023).

## 2. Consumer Acceptance of Insect-Based Foods: Gender Differences, Cultural Barriers, and Sensory Perceptions

A meta-analysis of 119 studies on gender differences in insect acceptance shows that, in most cases (71.2%), males accept insects as food. In contrast, 34.6% of studies indicate that gender has little influence on this acceptance (Kröger T et al., 2022).

An article published in 2024 shows that in Slavic countries, compared to countries where insects are considered a traditional food source, traditions, symbolism and religious beliefs promote aversion to entomophagy, and understanding these cultural barriers can contribute to developing strategies for the recognition of insects as a viable alternative protein source. (Orkusz and Orkusz, 2024).

A questionnaire-based study conducted in Sweden on 123 physically active healthy individuals showed that the extent to which insects are accepted as an alternative protein source is 35–40%. A different study examining perceptions of entomophagy in Western countries also attributes the low acceptance of food derived from insects to sensory properties associating the taste with that of spoiled food, mainly due to the fat content. (Ribeiro et al., 2024).

A study on the acceptance of insect consumption in Italy found that only 38% of respondents believe that insect-based foods could be part of the Italian diet, while 32% completely reject this idea. A study investigating the acceptance of insect consumption in Italy revealed that only 38% of respondents consider insect-based foods a possible part of their diet, whereas almost an equal number of respondents firmly oppose the idea of consumption. However, acceptance of insects as a food ingredient is higher when they are included in processed products, such as salty snacks, where they are not easily visible (Toti E et al., 2020).

## 3. Edible Insects as a Sustainable Protein Alternative: Nutritional Benefits, Health Impacts, and Microbiome Influence

### *3.1. Protein Quality and Sustainability: Edible Insects vs. Plant-Based Alternatives*

Plant-based proteins have a low nutritional value due to their deficient content in certain essential amino acids and the presence of antinutritional factors like inhibitors specific to proteases, phytates, polysaccharides different from starch, and phenolic compounds, which limit nutrients absorption. Paradoxically, the

removal of these components involves industrial processing that limits their sustainability (Duque-Estrada and Petersen, 2023). Insects approved for consumption are regarded as a significantly more resource-efficient source of protein than both animal and plant-based alternatives. (Aguilar-Toalá et al., 2025). The amount of protein present in the species approved in the EU is: *Tenebrio molitor* 50.32 ± 0.21% of dry mass (rich in essential amino acids including methionine), *Locusta migratoria* 69.80 ± 0.30% of dry mass (Oh and Kim, 2025), *Alphitobius diaperinus* 57.67 % of dry mass (Rumbos et al. 2019) and *Acheta domesticus* 64.3% of dry mass (Quinteros et al., 2022).

A 2024 study shows that the protein percentage in edible insects is between 67.49 - 72.36% of dry mass, with a high content in leucine (Lampová et al., 2024). In this study a specific scientific metric score was used to evaluate protein quality which offers insight into protein quality, specifically the adequacy of essential amino acid content The DIAAS, the digestible indispensable amino acid score, values determined were the highest in yellow mealworms, with values up to 103.32 ± 10.11% followed by house crickets with an average of 96.61 ± 8.86% and 89.71 ± 9.22% for migratory locusts highlighting a high to superior protein quality and quantity for the insect used in the study (Pan et al., 2022).

### *3.2. Anti-Inflammatory and Immunomodulatory Potential of Insect-Derived Bioactive Compounds*

Even though numerous studies show that insects are a potential source of compounds with antioxidants, insulin regulator effects on glucose and lipid metabolism, anti-inflammatory, immunomodulatory, hypotensive, antibacterial, and cardiovascular risk reduction (Acosta-Estrada et al., 2021, Cunha et al., 2023), these effects are still controversial. Even though the anti-inflammatory and immunomodulatory effects of insects are not fully demonstrated by in *vivo* studies, it is unanimously accepted that the prevention of inflammatory diseases is a socio-economic goal in developed countries. A 2024 review article introduces the term immunonutrition associated with biopeptides isolated from edible insects with the role of preventing macrophage stimulation resulting in the production of pro-inflammatory mediators (Rivero-Pino et al., 2024).

A 2018 study showed a decrease after 14 days period in plasma levels of cytokine inflammatory mediator TNF-α of cricket powder-based meals compared to isocaloric placebo meals (Stull et al., 2018). Chitin and chitosan exhibit anti-inflammatory properties by suppressing the NF-kB signaling pathway, which regulates the activation of B-cells, and by influencing the secretion of interleukin (IL)-10 (Acosta-Estrada et al., 2021). In a study from 2017 examining the impact of thermal processing (grilling, boiling) of protein hydrolysate isolated from insects (*Tenebrio molitor* and *Gryllodes sigillatus*) on the antioxidant and anti-inflammatory properties of them shows that the thermal processing has a beneficial effect by increasing the cyclooxygenase-2 (COX-2), the antioxidant effect and the inhibitory effect of lipoxygenase. (Zielińska et al., 2017).

Several peptides obtained by hydrolysis of insect proteins have been described as playing a role in modulating inflammatory processes. Thus, a study conducted in 2021 shows that the peptide Ala-Gly-Leu-Gln-Phe-Pro-Val-Gly-Arg (AGL9), isolated from the protein hydrolysate of *Allomyrina dichotoma larvae* administrated for five weeks to mice with hepatic steatosis unrelated to alcohol consumption resulted in the stabilization of serum levels of adiponectin, hepatic transaminases, lipoprotein profile levels such as triglycerides (TG), total cholesterol (CHOL),

high-density lipoprotein (HDL), very low-density lipoprotein (VLDL) and leptin by suppressing the AMPK/Nrf2 signaling pathway (Fan M et al., 2021). Peptides BPP-21 and BPP-22, isolated from honeybee pupae, significantly increased body weight gain and macrophage phagocytosis, while simultaneously reducing serum levels of the cytokines IL-2 and interferon (IFN)-γ, as well as immunoglobulins (IgA, IgG, and IgM). These effects were observed *in vitro* studies on RAW 264.7 cells and were associated with the stimulation of extracellular signal-regulated kinase (ERK) and p38 phosphorylation, which are involved in the modulation of the MAPK signaling pathway (Chen et al., 2022).

Regarding studies on the anti-inflammatory role carried out *in vivo*, in humans, there are no studies in the literature that explain the fate of chitin and biopeptides obtained by protein hydrolysis in the human body (Rivero-Pino et al., 2024).

### *3.3. Modulation of the gut microbiota*

Studies in the literature show that chitin, chitosans and low molecular weight chitooligosaccharides from insects and crustaceans have a prebiotic effect. Fungal chitins favor the growth of *Bifidobacterium species*, but the effect of insect chitin on the gut microbiota remains mainly unclear and is limited by the availability of sufficient quantities to be used in preclinical and clinical studies (Stull and Weir, 2023).

To date, only a few studies in humans, animals and *in vitro* models have investigated the prebiotic effect of whole insects (25 g/day cricket providing an equivalent of 2 g chitin/day), demonstrating that they can promote the proliferation of beneficial bacteria such as *Faecalibacterium*, *Lactobacillus* and *Bifidobacterium*, but it could not be clearly established whether these effects are exclusively attributed to chitin or its derivatives (Stull et al., 2018).

Insect chitin can influence the intestinal microbiota by inhibiting the growth of some bacteria, both pathogenic and probiotic, such as *Lactobacillus spp.*, *Clostridium perfringens*, *Escherichia coli*, *Vibrio cholerae* and *Salmonella typhimurium*, effects observed both in human studies and *in vitro* experiments (Lopez-Santamarina et al., 2020; Gil et al., 2004).

On the other hand, insects can be infested with specific bacteria that populate the insect exoskeleton, mouthparts and intestine, with potential pathogenic effects in humans, such as: *Escherichia coli*, *Salmonella*, *Clostridium perfringens*, *Enterobacteriaceae*, etc. Therefore, legislation in the US and Europe prohibits the consumption and marketing of insects collected in the wild, only those originating from insect farms (Aguilar-Toalá et al., 2022).

## Conclusions

Edible insects represent a promising alternative protein source with significant nutritional, environmental, and health benefits. Their high protein quality, rich amino acid profile, and bioactive compounds suggest potential advantages over both traditional meat and plant-based proteins. Additionally, their low ecological footprint makes them a sustainable solution for addressing global food security challenges. However, their acceptance remains limited due to cultural barriers, sensory perceptions, and food neophobia. Further research is needed to optimize processing techniques, improve consumer perception, and assess the long-term health effects of insect-derived proteins. Public education and regulatory support will contribute significantly to promoting entomophagy as a viable and sustainable component of future diets.

## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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