Beyond the buzz: A review of the prospects of replacing meat consumption with insect-based foods

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Preface

The substantial environmental footprint of meat production means that dietary shifts are needed to reduce greenhouse gas emissions. Insects may offer one alternative. However, to deliver genuine benefits for sustainability of the food system, insects must first be widely accepted and consumed by the general public. In this review, we examine the necessary stages that need to be fulfilled before insects can compete with meat, and we assess the chances for insects to fulfil these requirements in reality.

Introduction

The global food system significantly contributes to environmental degradation. Livestock is the primary driver of deforestation – surpassing even palm oil –and is responsible for 57% of water pollution and 33% of freshwater withdrawals while providing only 18% of the world's calories [1–3]. Consequently, some studies regard meat consumption as one of the largest threats to fauna and flora globally [4]. If current trends continue, it is predicted that by 2030, meat consumption will be responsible for 37% and 49% of the greenhouse gas emissions (GHG) emissions permissible under the 2°C and 1.5°C targets, respectively [5]. On a personal level, the standard diet in Western, developed countries is high in meat and dairy and therefore accounts for large volumes of GHG emissions each day (e.g., 8.8 kg CO_2e in the UK) [6,7]. Animal agriculture also contributes to a range of other environmental and health issues, including antimicrobial resistance, pandemic risk, cancer and cardiovascular diseases, and water and air pollution [8–10]. For these reasons, scientific literature underscores the need for dietary changes to mitigate environmental impacts [11]. However, achieving long-term behavioural change in dietary habits is challenging [12], leading to a need for meat substitutes to facilitate this transition.

Industrialised insect farming is one emerging technology that could reduce environmental impacts. Insects are most promising regarding GHGs, land use and energy use, although they would likely lead to increased water consumption [13–15]. Human health risks would also be lower compared to traditional livestock.

While the opportunities outlined above look promising, it is important to keep in mind that the lower environmental impact of insects compared to meat is not extraordinary—most products, including protein-rich products, are less resource-intensive than meat. For instance, most plant-based options produce only a fraction of the GHG emissions than equivalent meat-based products [1,16,17]. Therefore, finding a product with a lower environmental impact than meat is not a difficult task since most foods already surpass this benchmark. The real challenge lies in creating alternatives that are compelling enough for consumers to prefer over meat.

Social and consumer preferences are of the utmost importance for the widespread market inclusion of these products [18]. Focusing solely on the environmental benefits of insects compared to meat, or their nutritional value, does not provide the entire picture. A sustainable food option cannot reduce the environmental impact of the global food system if no consumers choose to eat that option. The central question is: can insect-based foods become more appealing to consumers than traditional meat options?

Drivers of meat consumption

To assess the potential of insects as a meat alternative, it is crucial to understand why people consume meat in the first place. Price, taste, appearance, and social and cultural habits are key factors. Therefore, for insects to be a viable alternative, not only do they need to be environmentally more sustainable, but they also need to be competitive in these areas. Nutrition, while important, is not the main factor driving meat consumption in Western countries. The World Health Organization judges that appropriately planned plant-based or predominantly plant-based diets are healthier and more environmentally friendly than conventional diets [19]. However, despite recent progress, these diets have not gained widespread popularity. This observation implies that concerns about nutrition and environmental impact are insufficient to significantly reduce meat consumption on a broader scale.

What factors, then, contribute to the enduring appeal of meat? Key reasons for meat consumption include taste appeal and texture, as an inferior sensory quality can be a barrier to widespread adoption [20,21]; perception of meat as a necessary part of a healthy diet; social norms and tradition; price and affordability; and availability and convenience[22]. The cultural significance of meat, entwined with aspects like religion, gender, community, and social identity, makes this more than just a dietary choice. Meat consumption choices are deeply embedded in social and cultural values [23]. De Boer and Aiking [24] emphasise the cultural implications of reducing meat consumption, which can sometimes conflict with aspects of personal identity related to masculinity, social class, or political orientation. Consequently, individuals with a strong attachment to meat often resist changing their dietary habits.

Moreover, the meat industry's substantial economic presence and political influence can shape public perception and policies. According to Carrington [25], “the money spent on lobbying the US government by meat producers was 190 times more than for [plant-based meat or cultivated meat groups] and was three times higher in the EU. [...] Livestock farmers in the EU received 1,200 times more public funding.” During the formulation of the U.S. Dietary Guidelines, lobbying from the meat industry was intensive, with several organisations claiming that this influenced final recommendations [22]. Leaked documents, reported by the press, even reveal that the meat industry successfully lobbied the Intergovernmental Panel on Climate Change to remove mentions of meat's environmental impact from the Panel's most recent report [26]. If insect-based meat substitutes gain traction, they may encounter significant opposition from the meat industry [27]. This is evidenced by recent campaigns against plant-based foods, including both negative advertising and efforts to regulate the labelling of plant-based products such as “milk” or “cheese” [26,28].

Replacing meat with alternatives such as insect-based foods requires addressing deeply rooted social, cultural, and ideological beliefs about food and society. Societal norms can evolve with the support of civil society, health organisations, and governments, yet this is a lengthy and complex process [29].

Consumer acceptance of insects as food

The successful establishment of the insect industry in Western societies depends not only on environmental benefits and technical feasibility but also on the willingness of consumers to use these products [30,31].

A systematic review of 91 studies found that, among several meat substitutes, insects were the least accepted [32]. Many studies show a very low willingness among consumers to try insect-based products, generally below 30 percent, although higher percentages sometimes emerge in the literature [33]. In the UK, the inclination to consume insects is similarly low, with only about 24 percent of consumers showing a willingness to do so [34]. A survey by the UK Food Standards Agency [35] found that only 26 percent of participants were open to trying insect-based foods[35]. Notably, among those who did not want to try any suggested substitutes, the majority (67 percent) stated that nothing could persuade them to try edible insects. One of the few studies on UK consumer attitudes towards insect-based foods examined consumer willingness to pay for insect-based versus pork-based sausages [36]. The study concluded that the potential for insect-based foods to revolutionise modern diets is limited by the pervasive negative consumer perceptions of these products, evidenced by the significant price penalties consumers placed on insect sausages. While certain consumer groups, particularly eco-conscious consumers with low food neophobia, might be increasingly open to incorporating insect products into their diets, they still imposed significant price penalties on insect sausages, despite being informed about their health and environmental benefits.

The proportion of consumers willing to *try* a novel food product may be greater than the proportion willing to incorporate it as a substantial, regular part of their diet (especially at the expense of a highly-valued and culturally significant product such as meat). That the willingness to try edible insects is so low may bode ill for the prospects of the edible insect market.

Disgust

The main barrier to market development in Western countries is the “psychological rejection experienced by consumers”, predominantly due to feelings of disgust [33,34,36–40]. Disgust, a response of revulsion or strong disapproval to something perceived as unpleasant or offensive [41], serves as an emotional defence mechanism to avoid ingesting potentially harmful substances through the mouth [42].

While entomophagy (the practice of eating insects) is widespread in many non-Western countries, with an estimated two billion people globally practising it [43], perceptions in Europe and North America differ significantly. In these regions, insect consumption is often associated with poverty and a "primitive" lifestyle [44–46]. The common presence of many insect species in and around waste further reinforces insects' association with disease, dirt, and decay [47]. Overcoming this disgust reaction in Western societies presents a significant challenge, as the aversion to insects is a deeply embedded core emotion, shaped by culture, social norms, and past experiences [40,48].

Food neophobia and food safety

Another barrier is food neophobia, the avoidance of unfamiliar foods [49–51]. Individuals with high levels of food neophobia are less likely to even consider trying and purchasing insects for consumption, irrespective of their origin [36,52].

Perceived health risks also play a role [33,53,54]. These concerns encompass potential allergens and biological and chemical hazards [46]. Even with regulatory approvals, such as the European Union's authorisation to include insects in various food products, substantial efforts are required to assure consumers of their safety.

Furthermore, the prospect of feeding insects with food scraps may add to the difficulty, as it is unclear whether Western populations would be receptive to consuming waste-fed insects [55]. By comparison, the acceptability of food waste as feed for conventional livestock has already encountered significant resistance in China [56]. Ensuring the use of hazard-free insect feed (substrate) in insect agriculture is therefore crucial [46].

Social norms

Social norms, or the influence of other people's opinions, also contribute to consumers' negative perceptions of entomophagy [33,57–59]. One notable obstacle to insect consumption is its "incompatibility with local food culture" [60]. Generally, the stronger the gastronomic culture within the society, the greater the rejection, and vice versa [52,61]. Even in France, known for its acceptance of invertebrates like snails, a study found that people were slightly unwilling to consume insect-based foods [62]. When survey participants were asked to rate their willingness to regularly consume insect-based foods on a 5-point scale, the average score was only 2.8 out of 5.

These trends are deeply rooted in culturally determined food habits, making them challenging to change. In regions where entomophagy is commonplace, insects are considered valuable protein sources. In contrast, Western cultures often associate insects with negative connotations. This perception is reinforced by Western media, as seen in reality television shows— in *Fear Factor* and *I'm A Celebrity, Get Me Out Of Here!*, eating raw insects is portrayed as a test of bravery [63].

Moreover, even among those open to purchasing insects, there is a lack of knowledge regarding how to incorporate them into recipes. House [64] reports the experiences of individuals facing this challenge, including those open to entomophagy and eager to learn new recipes. For instance, one woman tried to prepare a mealworm curry based on an online recipe. However, her cooking attempt was unsuccessful due to the insects' small size, and she eventually resorted to consuming them as snacks while watching television.

Acceptance of different food types

To mitigate unfamiliarity and enhance acceptance, a common strategy involves processing insects into forms where they are less recognisable, such as grinding them into powder [21,65] or incorporating them into familiar products [38,66].

However, it is important to note that the aforementioned low willingness to consume insects pertains even to these more attractive, processed forms (such as chips or cookies). Acceptance remains low even in insect-based foods consumers were the most willing to try, such as snacks (37 percent), main dishes (26 percent), and desserts (23 percent) [67]. For instance, a study on the use of insect proteins in bread found that most participants were unwilling to try it [68]. Acceptance drops further for meals like insect-based salads (7 percent) or soups (6 percent). Unprocessed insect dishes scored lowest (1 percent), as certain physical attributes of insects are particularly off-putting, such as long, spiny legs or a slimy body texture [34]. Since meat-like insect products receive even less consumer acceptance than snacks, substituting traditional meat with insect-based alternatives appears even more challenging than anticipated.

Are there ways to make insect foods more acceptable?

The literature has explored various interventions to boost consumer acceptability of insect-based foods [69]. There are some notable limitations, such as a scarcity of studies examining consumers' actual willingness to pay for these products in real-world settings [52]. Additionally, attitudes towards entomophagy vary between societies, suggesting that findings from one country may not be universally applicable.

Research has identified characteristics associated with greater acceptance of insect products, though the results are sometimes conflicting. Men generally show more openness towards consuming insects [39,67], but findings regarding the influence of age and education are inconclusive, with income appearing to have little impact [34]. Factors with a positive influence include curiosity about new foods and frequent travel [33].

Consumer education

Prior experience with eating insects has been shown to increase future willingness to consume them [34,36,37,39], a finding corroborated by multiple studies [52]. A promising approach involves providing consumers with a positive initial experience with insect-based foods. Suggested strategies for generating a favourable first impression include educating consumers, such as through tastings in bars or museum exhibitions [46,70]. However, even these positive sensory experiences may prove insufficient to pass the significant hurdle of neophobia [71].

Consumer education may need to be very intensive to reach higher levels of consumer acceptance [72]. However, this approach demands a considerable amount of time and resources and must be executed carefully, as negative taste experiences can diminish acceptance of insect-based products [34]. The time and resources required may be prohibitive—former insect company co-founder Michael Badeski warns that “tastes change, but it can take a generation. Spending venture equity dollars on an uphill battle to educate customers is not a good use of capital” [73].

While increasing opportunities for consumers to try insect-based products could enhance familiarity and positively influence acceptance [33,74], doing so requires expanding the reach of the market. This is linked to another challenge: the limited availability of insect-based products.

Overcoming structural barriers and lack of availability

The limited size of the edible insect market is identified as a structural barrier [33]. The limited availability of insect-based products in restaurants and supermarkets and the scarcity of opportunities to try these foods are cited as a critical factor in not consuming insects [75–78]. Currently, the primary avenue for purchasing insects is through online shops, which attract only niche consumers, and product variety is limited by extended transportation times.

Furthermore, existing research largely focuses on consumers' willingness to try or buy insect-based products. However, there is a significant difference between trying a product once and incorporating it into the weekly shopping list, especially when it requires competing with well-established alternatives. For example, while someone might be willing to try insect-based tortilla chips, these chips are in direct competition with popular, well-marketed brands [79].

Competing with established companies relies significantly on taste and texture, yet research on that topic is limited, with inconsistent results. A study involving a consumer panel in Germany suggested that the insect-based burger was better rated than alternatives. However, this conclusion is based on a small sample size (70 participants, with nine refusing to taste the insect burger) [18]. On the other hand, another study indicated that, similarly to plant-based alternatives, successfully simulating a meat-like flavour, colour, and structure remains challenging for insect-based products [80]. Moreover, a study in the UK suggested that although crickets-based products did not taste bad, a pleasant taste and familiarity were not enough to overcome disgust [74].

Integrating new foods into society

The literature about insect-based foods often underestimates the complexity of introducing new food types into society. Abstract ideas such as the 'willingness to eat' tend to overlook the geographic and sociocultural contexts that influence the acceptance of new foods. House [64] challenges the assumption that widespread acceptance of insects, or other unconventional foods, is primarily a matter of convincing or educating consumers. Insects have been likened to "the new sushi" [81,82], suggesting a similar pathway to acceptance, as raw fish went from a scarcely accepted food in the 1950s to a widely accepted one in the US. Yet, the introduction of sushi in the West was not about selling a new food in a new location out of context. Initially offered in sushi bars by Japanese chefs, sushi was often experienced during business meetings, where skilled chefs showcased age-old practices and used well-known imported ingredients. Japanese immigrants represented a stable consumer base for sushi bars, and they introduced their Western counterparts to it. This approach allowed Western consumers to be gradually recruited to new food consumption practices, and involved more than just a new ingredient—it was a cultural experience [64].

In contrast, insects are often introduced in less contextualised settings, such as convenience stores or online platforms, without drawing on the practices of an established cuisine. The insect species produced by industrialised Western farms, such as mealworms, are rarely the same species consumed by

populations engaging in entomophagy. The approach of processing insects into familiar products in an "invisible" way strips away the uniqueness and distinctiveness of the ingredient. Positioned as just another option among many, insects face competition based on criteria such as price, taste, and availability, where they may not have distinct advantages for consumers [64].

The role of information about environmental and health benefits

While public authorities have often highlighted the environmental benefits of insect-based protein to promote consumption, the impact of this approach on consumer attitudes remains uncertain [33]. Some studies suggest that environmental concern can increase willingness to try insect-based products, yet others do not find it a significant factor in adopting entomophagy [36]. Even if environmental concerns enhance acceptability, their effect is relatively minor compared to factors like disgust and food neophobia. Moreover, meat substitutes are not always perceived as healthier or more environmentally friendly simply because they are meat-free, as observed in Switzerland [41,83]. If environmental education alone were sufficient to catalyse dietary change, diets with a larger share of plant-based foods (e.g., vegetarian and reducetarian diets) would likely be more prevalent than they currently are.

What emerges from the literature is that sustainability *per se* probably will not persuade consumers to incorporate insects into their diet [33]. In everyday consumer decisions, immediate personal benefits often outweigh long-term benefits for the community. Wassmann et al. [84] synthesised 37 studies and found that affect-based factors (like disgust, expected unpleasant taste, or neophobia) were strongly correlated with the willingness to consume insects as a meat alternative. Information-based factors (like 'the perceived sustainability of insects as food' and 'the perceived nutritiousness of insects as food') were less correlated. Weinrich [85] suggests that appearance and taste are the most important factors in eating meat substitutes regularly, while health or environmental factors only persuade consumers to try the product [84]. Environmental and health benefits are beneficial but distant, and Berger et al. argue that focusing on such benefits when marketing insects may even backfire [86].

Comparison with plant-based alternatives

In comparison, alternative proteins, such as plant-based meat substitutes, are gaining wider acceptance, as evidenced by their growing research focus and market share [87]. Plant proteins are projected to be the dominant alternative protein source in the next decade [88]. Economically, plant proteins are advantageous as they circumvent the feed-to-food conversion loss characteristic of animal protein sources.

A comprehensive review of 91 articles by Onwezen et al. [32] revealed that insect-based proteins ranked lowest in acceptance among various meat substitutes, falling behind cultured meat, with plant-based options receiving the highest acceptance. This finding aligns with Siddiqui et al. [89], who also reported greater acceptance for plant-based foods than insect-based options, a finding confirmed in several studies, even compared to cultured meat [90–92]. Notably, 91 percent of consumers in the UK are willing to try plant-based products, whereas "very few" are willing to consume insect food products.

Many plant-based products are already available in the market in various forms, such as whole, powdered, or processed. Meat substitutes like Impossible Nuggets or Beyond Burgers have penetrated the

mainstream. They feature in large food chains such as Burger King, a milestone not yet achieved by insect-based products. Their increasing presence in restaurants and supermarkets makes them more convenient to purchase. These products cater to environmentally conscious consumers interested in new protein sources [88]. Insect-based meat substitutes tend to target the same demographic and might compete with this market.

Conclusion

The strong psychological barriers leading to aversion in consumers may negatively affect the economic performance and growth of the insect feed and food sector [40,93,94]. In fact, the insect industry is aware of these issues—investments on insects as food products are surprisingly small. A Rabobank report notes that the current potential of insect-based foods for human consumption is “limited” and their market share “negligible” [95].

In contrast, the vast majority of Western industrial insect production aims to produce animal food, such as livestock feed and pet food [52,67]. In 2022, 95 percent of the industrial insect industry's funding, amounting to 1.2 billion USD, was directed to the feed market. This means that only 5 percent of funding is for insects as human food. Even within this 5 percent, only a minority is for meat substitutes specifically [96]. In contrast, the majority of insect-based foods designed for human consumption are snacks, which can be made from whole insect of insect powders, or foods in which insect powder is used as a substitute for plant-based flour, such as pasta or tortillas [96]. Therefore, it may be that insects used for human food are mostly replacing products that are made from plants and thus have a very low environmental impact, even compared to insects.

Insects are routinely labelled as "alternative proteins" and included in debates on the topic of meat replacements [27,32]. However, Western insect farms are predominantly providing an input (livestock feed) for conventional proteins. The challenges related to consumer acceptability are so significant that even insect industry investors are dedicating comparatively little resources to the market for human food. This suggests that insect-based foods are unlikely to significantly reduce the environmental impact of the global food system, especially when more accepted alternatives are available.

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This review article analyses different strategies to convince people to eat insects, which include addressing disgust factors, highlighting environmental benefits, and focusing on preparation methods.