

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

Corentin Biteau<sup>a</sup>, Tom Bry-Chevalier<sup>b</sup>, Dustin Crummett<sup>a\*</sup>, Ren Ryba<sup>c</sup>, Michael St. Jules<sup>a</sup>

<sup>a</sup>The Insect Institute, 2424 E York St. Unit 204, Philadelphia, PA 19125, United States

<sup>b</sup>Bureau d'Economie Théorique et Appliquée, University of Lorraine, Maison de la Recherche, 23 rue Baron Louis, 54000 Nancy, France

<sup>c</sup>Animal Ask, Unit 10, The Linen House, 253 Kilburn Lane, London W10 4BQ, United Kingdom

\*Corresponding author: [dustin@insectinstitute.org](mailto:dustin@insectinstitute.org)

## **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<sup>1-3</sup>. Consequently, some studies regard meat consumption as one of the largest threats to fauna and flora globally<sup>4</sup>. 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<sup>5</sup>. 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<sub>2</sub>e in the UK)<sup>6,7</sup>. 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<sup>8-10</sup>. For these reasons, scientific literature underscores the need for dietary changes to mitigate environmental impacts<sup>11</sup>. However, achieving long-term behavioural change in dietary habits is challenging<sup>12</sup>, 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<sup>13–15</sup>. 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<sup>1,16,17</sup>. 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<sup>18</sup>. 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 <sup>19</sup>. 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 <sup>20,21</sup>; perception of meat as a necessary part of a healthy diet; social norms and tradition; price and affordability; and availability and convenience<sup>22</sup>. 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 <sup>23</sup>. De Boer and Aiking <sup>24</sup> 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 <sup>25</sup>, “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 <sup>22</sup>. 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 <sup>26</sup>. If insect-based meat substitutes gain traction, they may encounter significant opposition from the meat industry <sup>27</sup>. 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” <sup>26,28</sup>.

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 <sup>29</sup>.

## 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<sup>30,31</sup>.

A systematic review of 91 studies found that, among several meat substitutes, insects were the least accepted<sup>32</sup>. 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<sup>33</sup>. In the UK, the inclination to consume insects is similarly low, with only about 24 percent of consumers showing a willingness to do so<sup>34</sup>. A survey by the UK Food Standards Agency<sup>35</sup> found that only 26 percent of participants were open to trying insect-based foods<sup>35</sup>. 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<sup>36</sup>. 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<sup>33,34,36-40</sup>. Disgust, a response of revulsion or strong disapproval to something perceived as unpleasant or offensive<sup>41</sup>, serves as an emotional defence mechanism to avoid ingesting potentially harmful substances through the mouth<sup>42</sup>.

While entomophagy (the practice of eating insects) is widespread in many non-Western countries, with an estimated two billion people globally practising it<sup>43</sup>, perceptions in Europe and North America differ significantly. In these regions, insect consumption is often associated with poverty and a "primitive" lifestyle<sup>44-46</sup>. The common presence of many insect species in and around waste further reinforces insects' association with disease, dirt, and decay<sup>47</sup>. 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<sup>40,48</sup>.

## **Food neophobia and food safety**

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

Perceived health risks also play a role<sup>33,53,54</sup>. These concerns encompass potential allergens and biological and chemical hazards<sup>46</sup>. 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<sup>55</sup>. By comparison, the acceptability of food waste as feed for conventional livestock has already encountered significant resistance in China<sup>56</sup>. Ensuring the use of hazard-free insect feed (substrate) in insect agriculture is therefore crucial<sup>46</sup>.

### **Social norms**

Social norms, or the influence of other people's opinions, also contribute to consumers' negative perceptions of entomophagy<sup>33,57-59</sup>. One notable obstacle to insect consumption is its "incompatibility with local food culture"<sup>60</sup>. Generally, the stronger the gastronomic culture within the society, the greater the rejection, and vice versa<sup>52,61</sup>. Even in France, known for its acceptance of invertebrates like snails, a study found that people were slightly unwilling to consume insect-based foods<sup>62</sup>. 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<sup>63</sup>.

Moreover, even among those open to purchasing insects, there is a lack of knowledge regarding how to incorporate them into recipes. House<sup>64</sup> 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<sup>21,65</sup> or incorporating them into familiar products<sup>38,66</sup>.

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)<sup>67</sup>. For instance, a study on the use of insect proteins in bread found that most participants were unwilling to try it<sup>68</sup>. 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<sup>34</sup>. 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<sup>69</sup>. There are some notable limitations, such as a scarcity of studies examining consumers' actual willingness to pay for these products in real-world settings<sup>52</sup>. 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<sup>39,67</sup>, but findings regarding the influence of age and education are inconclusive, with income appearing to have little impact<sup>34</sup>. Factors with a positive influence include curiosity about new foods and frequent travel<sup>33</sup>.

### **Consumer education**

Prior experience with eating insects has been shown to increase future willingness to consume them<sup>34,36,37,39</sup>, a finding corroborated by multiple studies<sup>52</sup>. 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<sup>46,70</sup>. However, even these positive sensory experiences may prove insufficient to pass the significant hurdle of neophobia<sup>71</sup>.

Consumer education may need to be very intensive to reach higher levels of consumer acceptance<sup>72</sup>. 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<sup>34</sup>. 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”<sup>73</sup>.

While increasing opportunities for consumers to try insect-based products could enhance familiarity and positively influence acceptance<sup>33,74</sup>, 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<sup>33</sup>. 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<sup>75-78</sup>. 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<sup>79</sup>.

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)<sup>18</sup>. 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<sup>80</sup>. 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<sup>74</sup>.

### **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<sup>64</sup> 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" <sup>81,82</sup>, 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 <sup>64</sup>.

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 <sup>64</sup>.

### **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 <sup>33</sup>. 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 <sup>36</sup>. 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<sup>41,83</sup>. If environmental education alone were sufficient to catalyse dietary change, diets with a larger share of plant-based foods (e.g., vegetarian and redudctarian 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<sup>33</sup>. In everyday consumer decisions, immediate personal benefits often outweigh long-term benefits for the community. Wassmann et al.<sup>84</sup> 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<sup>85</sup> 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<sup>84</sup>. Environmental and health benefits are beneficial but distant, and Berger et al. argue that focusing on such benefits when marketing insects may even backfire<sup>86</sup>.

### **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<sup>87</sup>. Plant proteins are projected to be the dominant alternative protein source in the next decade<sup>88</sup>. 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.<sup>32</sup> 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.<sup>89</sup>, who also reported greater acceptance for plant-based foods than insect-based options, a finding confirmed in several studies,

even compared to cultured meat<sup>90-92</sup>. 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<sup>88</sup>. 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<sup>40,93,94</sup>. 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”<sup>95</sup>.

In contrast, the vast majority of Western industrial insect production aims to produce animal food, such as livestock feed and pet food<sup>52,67</sup>. 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<sup>96</sup>. In contrast, the majority of insect-based foods designed for human consumption are snacks, which can be made from whole insect or insect powders, or foods in which insect powder is used as a substitute for plant-based flour, such as pasta or tortillas<sup>96</sup>. 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<sup>27,32</sup>. 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.

### **Author contributions**

Conceptualization: CB, DC, MSJ; Investigation: CB; Writing - Original Draft: CB; Writing - Review & Editing: CB, TBC, DC, RR, MSJ; Supervision: DC, RR

### **Conflict of interests**

The authors have no conflicts of interest to declare.

### **Funding**

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

### **References**

1. Poore, J. & Nemecek, T. Reducing food's environmental impacts through producers and consumers. *Science* **360**, 987–992 (2018).
2. Ritchie, H. & Roser, M. Drivers of Deforestation. *Our World in Data* (2024).

3. Pendrill, F., Martin Persson, U., Godar, J. & Kastner, T. Deforestation displaced: trade in forest-risk commodities and the prospects for a global forest transition. *Environ. Res. Lett.* **14**, 055003 (2019).
4. Morell, V. Meat-eaters may speed worldwide species extinction, study warns. *Science* <http://news.sciencemag.org/environment/2015/08/meat-eaters-may-speed-worldwide-species-extinction-study-warns> (2015) doi:10.1126/science.aad1607.
5. Harwatt, H. Including animal to plant protein shifts in climate change mitigation policy: a proposed three-step strategy. *Clim. Policy* **19**, 1–9 (2018).
6. Hoolohan, C., Berners-Lee, M., McKinstry-West, J. & Hewitt, C. N. Mitigating the greenhouse gas emissions embodied in food through realistic consumer choices. *Energy Policy* **63**, 1065–1074 (2013).
7. Green, R. *et al.* The potential to reduce greenhouse gas emissions in the UK through healthy and realistic dietary change. *Clim. Change* **129**, 253–265 (2015).
8. Mottet, A. *et al.* Livestock: On our plates or eating at our table? A new analysis of the feed/food debate. *Global Food Security* **14**, 1–8 (2017).
9. Steinfeld, H. *et al.* *Livestock's Long Shadow: Environmental Issues and Options*. (Food & Agriculture Org., 2006).
10. Lavaine, E., Majerus, P. & Treich, N. Health, air pollution, and animal agriculture. *Review of Agricultural, Food and Environmental Studies* **101**, 517–528 (2020).
11. Hallström, E., Carlsson-Kanyama, A. & Börjesson, P. Environmental impact of dietary change: a systematic review. *J. Clean. Prod.* **91**, 1–11 (2015).
12. O’Riordan, T. & Stoll-Kleemann, S. The Challenges of Changing Dietary Behavior Toward More Sustainable Consumption. *Environment: Science and Policy for Sustainable Development* **57**, 4–13 (2015).
13. Smetana, S. Circularity and environmental impact of edible insects. *JOURNAL OF INSECTS AS FOOD AND FEED* **9**, 1111–1114 (2023).

14. Smetana, S., Palanisamy, M., Mathys, A. & Heinz, V. Sustainability of insect use for feed and food: Life Cycle Assessment perspective. *J. Clean. Prod.* **137**, 741–751 (2016).
15. Smetana, S., Spykman, R. & Heinz, V. Environmental aspects of insect mass production. *Journal of Insects as Food and Feed* **7**, 553–571 (2021).
16. Ritchie, H., Rosado, P. & Roser, M. Environmental impacts of food production. *Our World in Data* (2022).
17. Smetana, S. *et al.* Meat substitutes: Resource demands and environmental footprints. *Resour. Conserv. Recycl.* **190**, 106831 (2023).
18. Smetana, S., Profeta, A., Voigt, R., Kircher, C. & Heinz, V. Meat substitution in burgers: nutritional scoring, sensorial testing, and Life Cycle Assessment. *Future Foods* **4**, 100042 (2021).
19. WHO. *Plant-Based Diets and Their Impact on Health, Sustainability and the Environment: A Review of the Evidence.*  
<https://iris.who.int/bitstream/handle/10665/349086/WHO-EURO-2021-4007-43766-61591-eng.pdf?i=sAllowed=y&sequence=1> (2021).
20. Grandin, T. Welfare Problems in Cattle, Pigs, and Sheep that Persist Even Though Scientific Research Clearly Shows How to Prevent Them. *Animals (Basel)* **8**, (2018).
21. Schösler, H., de Boer, J. & Boersema, J. J. Can we cut out the meat of the dish? Constructing consumer-oriented pathways towards meat substitution. *Appetite* **58**, 39–47 (2012).
22. Godfray, H. C. J. *et al.* Meat consumption, health, and the environment. *Science* **361**, (2018).
23. Marteau, T. M. Towards environmentally sustainable human behaviour: targeting non-conscious and conscious processes for effective and acceptable policies. *Philos. Trans. A Math. Phys. Eng. Sci.* **375**, (2017).
24. de Boer, J. & Aiking, H. How meat reduction differs from other personal climate actions: Distinct concerns and cultural barriers among EU consumers. *Food Qual. Prefer.* **101**, 104646 (2022).
25. Carrington, D. ‘Gigantic’ power of meat industry blocking green alternatives, study finds. *The*

- Guardian* (2023).
26. Torrella, K. Why the media too often ignores the connection between climate change and meat. *Vox*  
<https://www.vox.com/future-perfect/23778399/media-ignores-climate-change-beef-meat-dairy>  
(2023).
  27. van der Weele, C., Feindt, P., Jan van der Goot, A., van Mierlo, B. & van Boekel, M. Meat alternatives: an integrative comparison. *Trends Food Sci. Technol.* **88**, 505–512 (2019).
  28. Karlson, K., Davidson, O. G., Polley, B. A. & Fox, M. Super bowl ad looks to score points against plant-based meat.  
<https://www.sierraclub.org/sierra/super-bowl-ad-looks-score-points-against-plant-based-meat> (2020).
  29. Espinosa, R. & Nassar, A. The Acceptability of Food Policies. *Nutrients* **13**, (2021).
  30. Sogari, G. *et al.* The future is crawling: Evaluating the potential of insects for food and feed security. *Curr Res Food Sci* **6**, 100504 (2023).
  31. Sogari, G. *et al.* Review: Recent advances in insect-based feeds: from animal farming to the acceptance of consumers and stakeholders. *Animal* **17 Suppl 2**, 100904 (2023).
  32. Onwezen, M. C., Bouwman, E. P., Reinders, M. J. & Dagevos, H. A systematic review on consumer acceptance of alternative proteins: Pulses, algae, insects, plant-based meat alternatives, and cultured meat. *Appetite* **159**, 105058 (2021).
  33. Mina, G., Peira, G. & Bonadonna, A. The Potential Future of Insects in the European Food System: A Systematic Review Based on the Consumer Point of View. *Foods* **12**, (2023).
  34. Kröger, T., Dupont, J., Büsing, L. & Fiebelkorn, F. Acceptance of Insect-Based Food Products in Western Societies: A Systematic Review. *Front Nutr* **8**, 759885 (2021).
  35. UK Food Standards Agency. *Survey of Consumer Perceptions of Alternative, or Novel, Sources of Protein*.  
<https://www.food.gov.uk/research/behaviour-and-perception/survey-of-consumer-perceptions-of-alternative-or-novel-sources-of-protein> (2021) doi:10.46756/sci.fsa.ncn554 .

36. Michel, P. & Begho, T. Paying for sustainable food choices: The role of environmental considerations in consumer valuation of insect-based foods. *Food Qual. Prefer.* **106**, 104816 (2023).
37. Hartmann, C. & Siegrist, M. Consumer perception and behaviour regarding sustainable protein consumption: A systematic review. *Trends Food Sci. Technol.* **61**, 11–25 (2017).
38. Hartmann, C., Shi, J., Giusto, A. & Siegrist, M. The psychology of eating insects: A cross-cultural comparison between Germany and China. *Food Qual. Prefer.* **44**, 148–156 (2015).
39. Verbeke, W. Profiling consumers who are ready to adopt insects as a meat substitute in a Western society. *Food Qual. Prefer.* **39**, 147–155 (2015).
40. La Barbera, F., Verneau, F., Amato, M. & Grunert, K. Understanding Westerners' disgust for the eating of insects: The role of food neophobia and implicit associations. *Food Qual. Prefer.* **64**, 120–125 (2018).
41. van Huis, A. Edible insects: Challenges and prospects. *Entomol. Res.* (2022) doi:10.1111/1748-5967.12582.
42. Oaten, M., Stevenson, R. J. & Case, T. I. Disgust as a disease-avoidance mechanism. *Psychol. Bull.* **135**, 303–321 (2009).
43. van Huis, A. & FAO. *Edible Insects: Future Prospects for Food and Feed Security*. (Food and Agriculture Organization of the United Nations, Rome, Italy, 2013).
44. Vane-Wright, R. I. Why Not Eat Insects? *Bull. Entomol. Res.* **81**, 1–4 (1991).
45. Rozin, P. & Fallon, A. E. A perspective on disgust. *Psychol. Rev.* **94**, 23–41 (1987).
46. Lange, K. W. & Nakamura, Y. Potential contribution of edible insects to sustainable consumption and production. *Frontiers in Sustainability* (2023).
47. Deroy, O., Reade, B. & Spence, C. The insectivore's dilemma, and how to take the West out of it. *Food Qual. Prefer.* **44**, 44–55 (2015).
48. Rozin, P. & Fallon, A. The psychological categorization of foods and non-foods: A preliminary taxonomy of food rejections. *Appetite* **1**, 193–201 (1980).

49. Pliner, P. & Hobden, K. Development of a scale to measure the trait of food neophobia in humans. *Appetite* **19**, 105–120 (1992).
50. Ritchey, P. N., Frank, R. A., Hursti, U.-K. & Tuorila, H. Validation and cross-national comparison of the food neophobia scale (FNS) using confirmatory factor analysis. *Appetite* **40**, 163–173 (2003).
51. Laureati, M., Proserpio, C., Jucker, C. & Savoldelli, S. New sustainable protein sources: consumers' willingness to adopt insects as feed and food. *Ital. J. Food Sci.* **28**, 652–668 (2016).
52. Mancini, S. *et al.* Exploring the Future of Edible Insects in Europe. *Foods* **11**, (2022).
53. Tuccillo, F., Marino, M. G. & Torri, L. Italian consumers' attitudes towards entomophagy: Influence of human factors and properties of insects and insect-based food. *Food Res. Int.* **137**, 109619 (2020).
54. La Barbera, F., Amato, M., Fasanelli, R. & Verneau, F. Perceived Risk of Insect-Based Foods: An Assessment of the Entomophagy Attitude Questionnaire Predictive Validity. *Insects* **12**, (2021).
55. Le Féon, S. *et al.* Life Cycle Assessment of fish fed with insect meal: Case study of mealworm inclusion in trout feed, in France. *Aquaculture* **500**, 82–91 (2019).
56. Chen, T., Jin, Y. & Shen, D. A safety analysis of food waste-derived animal feeds from three typical conversion techniques in China. *Waste Manag.* **45**, 42–50 (2015).
57. Balzan, S., Fasolato, L., Maniero, S. & Novelli, E. Edible insects and young adults in a north-east Italian city an exploratory study. *British Food Journal* **118**, 318–326 (2016).
58. Iannuzzi, E., Sisto, R. & Nigro, C. The willingness to consume insect-based food: an empirical research on Italian consumers. *Agric. Econ.* **65**, 454–462 (2019).
59. Fasanelli, R., Galli, I., Rivero, R. & Piscitelli, A. Social Representations of Insects as Food: An Explorative-Comparative Study among Millennials and X-Generation Consumers. *Insects* **11**, (2020).
60. Menozzi, D., Sogari, G., Veneziani, M., Simoni, E. & Mora, C. Eating novel foods: An application of the Theory of Planned Behaviour to predict the consumption of an insect-based product. *Food Qual. Prefer.* **59**, 27–34 (2017).
61. Menozzi, D., Sogari, G., Veneziani, M., Simoni, E. & Mora, C. Explaining the intention to consume

- an insect-based product: A cross-cultural comparison. in *Theory of Planned Behavior New Research* 201–216 (USA, 2017).
62. Ordoñez López, M. F., Ghnimi, S. & Liu, C. Willingness to consume insect-based food in France: Determinants and consumer perspectives. *LWT* **185**, 115179 (2023).
  63. Faes, N. *AgriTech: Insects as Feed*. <https://www.bryangarnier.com/agritech-insects-as-feed/> (2022).
  64. House, J. Insects are not ‘the new sushi’: theories of practice and the acceptance of novel foods. *Social & Cultural Geography* **20**, 1285–1306 (2019).
  65. Wendin, K. M. E. & Nyberg, M. E. Factors influencing consumer perception and acceptability of insect-based foods. *Current Opinion in Food Science* **40**, 67–71 (2021).
  66. Barton, A., Richardson, C. D. & McSweeney, M. B. Consumer attitudes toward entomophagy before and after evaluating cricket (*Acheta domesticus*)-based protein powders. *J. Food Sci.* **85**, 781–788 (2020).
  67. Żuk-Gołaszewska, K. *et al.* Edible Insect Farming in the Context of the EU Regulations and Marketing-An Overview. *Insects* **13**, (2022).
  68. Ribeiro, J. C., Soares, A., de Moura, A. P. & Cunha, L. M. Evaluation of Consumers’ Acceptance of Bread Supplemented with Insect Protein. in *Sustainable Innovation in Food Product Design* 153–170 (Springer International Publishing, 2021).
  69. van Huis, A. & Rumpold, B. Strategies to convince consumers to eat insects? A review. *Food Qual. Prefer.* **110**, 104927 (2023).
  70. van Huis, A. & Gasco, L. Insects as feed for livestock production. *Science* **379**, 138–139 (2023).
  71. Tan, H. S. G., Fischer, A. R. H., van Trijp, H. C. M. & Stieger, M. Tasty but nasty? Exploring the role of sensory-liking and food appropriateness in the willingness to eat unusual novel foods like insects. *Food Qual. Prefer.* **48**, 293–302 (2016).
  72. Naranjo-Guevara, N., Fanter, M., Conconi, A. M. & Floto-Stammen, S. Consumer acceptance among Dutch and German students of insects in feed and food. *Food Sci Nutr* **9**, 414–428 (2021).

73. Badeski, M. *Investment Insights for the Insect Industry: Perspectives from an Exited Founder*. <https://perma.cc/ML9R-QNDW> (2023).
74. Gumussoy, M. & Rogers, P. J. It tastes OK, but I don't want to eat it: New insights into food disgust. *Appetite* **188**, 106642 (2023).
75. House, J. Consumer acceptance of insect-based foods in the Netherlands: Academic and commercial implications. *Appetite* **107**, 47–58 (2016).
76. Collins, C. M., Vaskou, P. & Kountouris, Y. Insect Food Products in the Western World: Assessing the Potential of a New 'Green' Market. *Ann. Entomol. Soc. Am.* **112**, 518–528 (2019).
77. Lombardi, A., Vecchio, R., Borrello, M., Caracciolo, F. & Cembalo, L. Willingness to pay for insect-based food: The role of information and carrier. *Food Qual. Prefer.* **72**, 177–187 (2019).
78. Sidali, K. L., Pizzo, S., Garrido-Pérez, E. I. & Schamel, G. Between food delicacies and food taboos: A structural equation model to assess Western students' acceptance of Amazonian insect food. *Food Res. Int.* **115**, 83–89 (2019).
79. Godwin, R. If we want to save the planet, the future of food is insects. *The guardian* (2021).
80. Zhang, W. & Kang, D. Chapter 23 - Future meat market. in *Lawrie's Meat Science (Ninth Edition)* (ed. Toldrá, F.) 799–854 (Woodhead Publishing, 2023).
81. Ballingall, A. Toronto startup banks on bugs as 'the new sushi'. *The Toronto Star* (2014).
82. Watson, K. & Treanor, S. Grasshoppers - the new sushi? *BBC* (2016).
83. Siegrist, M. & Hartmann, C. Impact of sustainability perception on consumption of organic meat and meat substitutes. *Appetite* **132**, 196–202 (2019).
84. Wassmann, B., Siegrist, M. & Hartmann, C. Correlates of the willingness to consume insects: a meta-analysis. *Journal of Insects as Food and Feed* **7**, 909–922 (2021).
85. Weinrich, R. Opportunities for the Adoption of Health-Based Sustainable Dietary Patterns: A Review on Consumer Research of Meat Substitutes. *Sustain. Sci. Pract. Policy* **11**, 4028 (2019).
86. Berger, S., Bärtsch, C., Schmidt, C., Christandl, F. & Wyss, A. M. When Utilitarian Claims Backfire:

- Advertising Content and the Uptake of Insects as Food. *Front Nutr* **5**, 88 (2018).
87. Ford, H., Gould, J., Danner, L., Bastian, S. E. P. & Yang, Q. 'I guess it's quite trendy': A qualitative insight into young meat-eaters' sustainable food consumption habits and perceptions towards current and future protein alternatives. *Appetite* **190**, 107025 (2023).
88. Bashi, Z., McCullough, R., Ong, L. & Ramirez, M. Alternative proteins: The race for market share is on.  
<https://www.mckinsey.com/industries/agriculture/our-insights/alternative-proteins-the-race-for-market-share-is-on> (2019).
89. Anusha Siddiqui, S. *et al.* Consumer acceptability of plant-, seaweed-, and insect-based foods as alternatives to meat: a critical compilation of a decade of research. *Crit. Rev. Food Sci. Nutr.* **63**, 6630–6651 (2023).
90. Dupont, J. & Fiebelkorn, F. Attitudes and acceptance of young people toward the consumption of insects and cultured meat in Germany. *Food Qual. Prefer.* **85**, 103983 (2020).
91. Emma, C. V. & Robison, R. Exploring perceptions of sustainable proteins and meat attachment. *British Food Journal* **121**, 533–545 (2018).
92. Gómez-Luciano, C. A., de Aguiar, L. K., Vriesekoop, F. & Urbano, B. Consumers' willingness to purchase three alternatives to meat proteins in the United Kingdom, Spain, Brazil and the Dominican Republic. *Food Qual. Prefer.* **78**, 103732 (2019).
93. Madau, F. A., Arru, B., Furesi, R. & Pulina, P. Insect Farming for Feed and Food Production from a Circular Business Model Perspective. *Sustain. Sci. Pract. Policy* **12**, 5418 (2020).
94. Niyonsaba, H. H. *et al.* Barriers, risks and risk management strategies in European insect supply chains. *Journal of Insects as Food and Feed* **9**, 691–705 (2023).
95. de Jong, B. & Nikolik, G. *No Longer Crawling: Insect Protein to Come of Age in the 2020s*.  
<https://research.rabobank.com/far/en/sectors/animal-protein/insect-protein-to-come-of-age-in-the-2020s.html> (2021).

96. IPIFF. *Edible Insects on the European Market*.

<https://ipiff.org/wp-content/uploads/2020/06/10-06-2020-IPIFF-edible-insects-market-factsheet.pdf>

(2020).

### **Highlighted references**

O’Riordan, T. & Stoll-Kleemann, S. The Challenges of Changing Dietary Behavior Toward More Sustainable Consumption. *Environment: Science and Policy for Sustainable Development* 57, 4–13 (2015).

This publication demonstrates that shifting to more sustainable diets requires overcoming social and personal barriers, alongside stronger policies to encourage change.

Smetana, S., Spykman, R. & Heinz, V. Environmental aspects of insect mass production. *Journal of Insects as Food and Feed* 7, 553–571 (2021).

This study examines the sustainability of insect mass production from the perspective of life cycle assessment.

de Jong, B. & Nikolik, G. No Longer Crawling: Insect Protein to Come of Age in the 2020s.

<https://research.rabobank.com/far/en/sectors/animal-protein/insect-protein-to-come-of-age-in-the-2020s.html> (2021).

This industry analysis shows that the insect protein industry is poised for significant growth in the 2020s, but most of this will come from the agricultural feed and pet food sectors.

Niyonsaba, H. H. et al. Barriers, risks and risk management strategies in European insect supply chains. *Journal of Insects as Food and Feed* 9, 691–705 (2023).

This paper reviews the European insect supply chain, which faces challenges like regulations, consumer acceptance, and food safety.

Wassmann, B., Siegrist, M. & Hartmann, C. Correlates of the willingness to consume insects: a meta-analysis. *Journal of Insects as Food and Feed* 7, 909–922 (2021).

This meta-analysis provides a comprehensive overview of the drivers of willingness to consume insects.

Badeski, M. Investment Insights for the Insect Industry: Perspectives from an Exited Founder. <https://perma.cc/ML9R-QNDW> (2023).

This perspective article, from a former insect company founder, provides a sober view about the economic realities of insect farming.

van Huis, A. & Rumpold, B. Strategies to convince consumers to eat insects? A review. *Food Qual. Prefer.* 110, 104927 (2023).

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.