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Review

Strategies to convince consumers to eat insects? A review

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A B S T R A C T

The idea of insects as human food in the Western world has only been around for a few decades. Insect products can be a substitute for conventional meat because: 1) their nutritional value is similar and there may be health benefits; 2) their environmental impact is lower; and 3) food safety is guaranteed. Nevertheless, it seems that Western consumers are reluctant to consume insects because of: 1) disgust – the product goes beyond the internalised norm of what food is; 2) neophobia – hesitance to consume unfamiliar food; 3) lack of product information; 4) lack of experience – never having consumed insects before; 5) disinterest and indifference. Differences in attitude towards insect consumption worldwide may be explained by cultural backgrounds and traditional eating patterns. It seems that about a quarter of the population in most countries are willing to try insect-based products. Strategies to convince consumers include: 1) emphasising that insects are nutritionally adequate; 2) incorporating them in unrecognisable form in familiar products; 3) making insect products delicious; 4) giving people a taste experience; 5) marketing insect-based products by taste; 6) providing detailed information about the insect product, taking into consideration that sustainability may not be the most convincing factor; 7) using celebrities to promote the product; 8) targeting specific groups such as sensation-seekers or children; 8) devising market strategies, such as using stylistic images and choosing supermarkets for retailing. The main objective is to find a combination of these strategies appropriate for a certain type of consumer depending on their socio-cultural background.

1. Introduction

In this article we start with reviewing the history of insect consumption, possible environmental benefits and which insect species can be consumed. Then we will analyse products' attributes such as nutritional value, possible health benefits and food safety. In the chapter product development, we discuss processing and the use of insect oils. After that we examine the factors that influence consumer behaviour when considering to consume insects. Then we review the strategies that can be used to convince consumers to accept insect-based products. We end with a concluding chapter.

1.1. History

Approximately several hundreds of million people consume insects as food (Van Huis et al., 2022), mainly in tropical zones (Bergier, 1941; Bodenheimer, 1951). This is probably because, compared to temperate zones, insects in the tropics are larger and often easily available throughout the year (Van Huis, 2018). It is assumed that for early humans, insects were an important dietary component. This has often been undervalued in comparison with vertebrates and plants (McGrew, 2014), probably because of the biased focus on male-oriented subsistence activities, i.e. hunting for big game (Sutton, 1995). From this perspective, insects have often been considered as a fall-back food resource (Lesnik, 2017), which is the reason that insect consumption has been erroneously considered backward and primitive (DeFoliart, 1999). The word 'entomophagy' is often used. However, this word is a Western invention to indicate that people in the tropics have a strange habit of eating insects, whereas we should consider it as normal food. After all, we do not call the eating of crustaceans 'crustaceáphagy' (Evans et al., 2015).

1.2. Environment

If insects would be more sustainable would that motivate consumers to eat insects? It is increasingly realized that our food pattern needs to

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change considering the environmental impact of animal products. What is the environmental impact of the production of common production animals compared to that of insects?

Of the production animals the greenhouse gas (GHG) emissions per kg are highest for beef (133 kg CO_2eq), followed by lamb and mutton (40), prawns (27), cheese (24), pork (12) and poultry meat (10); all other food items, like eggs, milk, cereals, vegetables and fruits all have CO_2eq below 5 kg (Poore & Nemecek, 2018). The same study indicated that animal products provide 37% of protein and 18% of calories but use 83% of farmland and contribute 56 to 58% of greenhouse gas emissions. Eliminating beef would reduce food GHG by 33%. According to Willett et al. (2019) substantial dietary shifts will be necessary, requiring by 2050 a greater than 50% reduction in global consumption of unhealthy foods, such as red meat and sugar, and a greater than 100% increase in consumption of healthy foods, such as nuts, fruits, vegetables, and legumes.

Insect products emit much fewer greenhouse gases and water (Kim et al., 2020), and require less land (Oonincx & de Boer, 2012) compared to all other meat products. Furthermore, certain insect species can be grown on organic side streams, e.g mealworms on carrot pomace (Rovai, Ortgies et al., 2021), thereby contributing to a circular economy.

1.3. Insect species being consumed

About 1600 species of insect are eaten (Van Itterbeeck & Pelozuelo, 2022), which is about 0.03% of their 5.5 million species on earth (Stork, 2018). Most insect species eaten are beetle larvae (Coleoptera), but also many caterpillar species (Lepidoptera), grasshoppers and crickets (Orthoptera), and ants, bees and wasps (Hymenoptera) as well as representatives of numerous other insect orders (Jongema, 2017). Most of these species are harvested from nature. The interest in the Western world started after the publication of the report *Edible insects: future prospects for food and feed security* by the Food and Agriculture Organization of the United Nations in 2013 (Van Huis et al., 2013). Several companies that were rearing insects for pet food started to shift their attention to producing insects for human food and animal feed. The species that are farmed as human food are: 1) various cricket species, but mainly the house cricket (*Acheta domestica*); 2) locust species, such as the migratory locusts (*Locusta migratoria*); 3) various mealworm species, in particular the yellow mealworm (*Tenebrio molitor*), and the lesser mealworm (*Alphitobius diaperinus*); 4) silkworm species, most commonly the pupae of the domesticated silkworm (*Bombyx mori*). The latter is a by-product of the silk industry, but also the production of honey has as its by-product the drones, which can also be used as food (Schiel et al., 2022). Tavares et al. (2022) reviewed more than 1100 documents and listed the main edible insect groups as silkworms, bees, beetles, mealworms, crickets, and cicadas. They found that the use of protein isolates as an ingredient/supplement in food products was the predominant technology, as they function as an ingredient in food products or supplements. Gere et al (2019) tried to establish which insect species should be proposed for consumption based on nutritional value. However, nutritional value of the same species depends on many factors (Finke and Oonincx, 2017).

It is likely that more edible insect species will enter the market. We will not discuss the use of insect as animal feed where flies are commonly used, in particular the black soldier fly (*Hermetia illucens*), although it has been suggested to use them as human food (Wang & Shelomi, 2017). Some species reared for other purposes, such as the sterile insect release technique to combat the Mediterranean fruit fly (*Ceratitis capitata*), have been proposed by an Israelian company to be used as food (Cordis, 2017).

We will review the nutritional value, food safety risks and environmental impact of reared edible insects. However, even if this turns out to be favourable, the main problem as regards the use of insect products by consumers in the Western market is lack of acceptance. In this review we will discuss the reasons for this reluctance and how to overcome it.

2. Product attributes

2.1. Nutrition composition

Edible insects contain proteins, lipids, polysaccharides such as chitin, and vitamins and minerals. In comparison to meat, insects are just as rich in nutrients and also provide essential amino acids and polyunsaturated fatty acids (Orkusz, 2021). Furthermore, edible insects might have health benefits due to their comparably high levels of vitamin B12, iron, zinc, fibre, essential amino acids, omega-3 and omega-6 fatty acids, and antioxidants (Nowakowski et al., 2022). However, their macro- and micronutrient contents are species-specific and even a variation among the same species has been observed (Orkusz, 2021; Payne et al., 2016a, 2016b). This variation is mainly due to differing feed compositions, but also dependent on life stage of the insect, rearing conditions such as light and temperature, processing conditions (Oonincx & Finke, 2021), and method of analysis (Janssen et al., 2017). Although a sufficient amount of data on the nutrient compositions of a number of edible insects exists in the scientific literature, its overall low quality has been criticised; but in any case, insects did not score less healthy than meat (Payne et al., 2016a, 2016b).

For example, the protein content is often determined by the Kjeldahl method, which measures the nitrogen content and estimates the protein content using the nitrogen-to-protein conversion factor 6.25. Since chitin also contains nitrogen, this leads to an overestimation (Jonas-Levi & Martinez, 2017) of approximately 17% (Boulos et al., 2020). A conversion factor of 5.6 was proposed for *T. molitor*, *A. diaperinus*, and *H. illucens* (Janssen et al., 2017). Boulos et al. (2020) determined even lower conversion factors of 5.41 for mealworm larvae (*T. molitor*), 5.25 for house crickets (*A. domestica*) and 5.33 for migratory locusts (*L. migratoria*) and proposed the use of an average conversion factor of 5.33 for insects and 5.60 for insect protein isolates. However, Ritvanen et al. (2020) obtained conversion factors as low as 5.0 for two different types of crickets and proposed 5.0 as a conversion factor for crickets. It appears more data as well as a species-specific approach are required to determine a reliable nitrogen-to-protein conversion factor. Additionally, it might be advisable to choose another protein analysis method.

Nevertheless, it can generally be stated that insects are high in proteins and lipids. Average protein contents ranging between 25 and 75% dry matter have been recorded (Oonincx & Finke, 2021). Crickets, locusts and grasshoppers have particularly high protein contents (Rumpold & Schlüter, 2013). Amino acid spectra varied greatly, but generally meet the WHO requirements for amino acids (Rumpold & Schlüter, 2013). The average lipid content of edible insects ranges from 10 to 70% dry matter (Oonincx & Finke, 2021). In general, the fatty acid spectra of insects are comparable to fish and chicken in terms of degree of unsaturation. However, insect lipids contain more polyunsaturated fatty acids (Rumpold & Schlüter, 2013). In addition, the lipid contents and the fatty acid spectra of insect lipids are highly dependent on the insect́s diet (Oonincx & Finke, 2021). For example, an enrichment in omega-3-fatty acids in the lipid profile of black soldier fly larvae by feed such as fish offal was feasible (St-Hilaire et al., 2007).

Insect chitin (N-acetyl-D-glucosamine) is located in their exoskeleton. Insects contain between 1.16 and 13.72 mg chitin/100 g dry matter (Finke, 2007) and its composition is comparable to shrimp chitin (Melgar-Lalanne et al., 2019).

Besides macronutrients, edible insects are also rich in micronutrients. It was determined that, on average, edible insects are rich in copper, iron, magnesium, manganese, phosphorous, selenium, and zinc and are suitable for a low-sodium diet (Rumpold & Schlüter, 2013) and are also a source of cobalamin (vitamin B12) (Schmidt et al., 2019). It can be concluded that insects are rich in macro- and micronutrients and represent a valuable alternative food source.

2.2. Health

In addition to their nutritional benefits, the health benefits of edible insects have been considered (Bawa et al., 2020, Nowakowski et al., 2022; Roos & Van Huis, 2017; Usman & Abdullahi, 2022; Van Huis, 2020). These include improved prevention of cardiovascular diseases, diabetes and cancer (Nowakowski et al., 2022). For example, angiotensin-converting enzyme (ACE) inhibitory activity levels comparable to other food sources have been observed in *Galleria mellonella*, *T. molitor* and *B. mori*. ACE inhibitory activity is beneficial against cardiovascular diseases and high blood pressure (Usman & Abdullahi, 2022). In addition, there were indications for anti-obesity effects of *T. molitor* larvae (Seo et al., 2017). Moreover, edible insects were also shown to have antioxidant and prebiotic properties (Van Huis, 2020). Stull et al. (2018) investigated the effects of a daily consumption of 25 g cricket powder on gut microbiota in human trials and observed increased growth of probiotic bacteria and indications for beneficial effects on gut health and reduced systemic inflammation. It was suggested that insect chitin may at least be partially responsible for beneficial changes in the gut microbiota diversity (Refael et al., 2022). It was further stated that chitin has anti-bacterial, anti-fungal and anti-tumour (Sharbidre et al., 2021) as well as prebiotic properties (Selenius et al., 2018; Sharbidre et al., 2021; Van Huis, 2020). More research is required on the functional and bioactive properties of edible insects and their impact on health.

2.3. Food safety

Aside from the nutritional and health benefits of edible insects, food safety issues need to be considered. This includes allergenic potential, anti-nutrient content, microbial safety as well as chemical contamination. In this respect, insects naturally containing or synthesising substances harmful to humans, such as cyanogen (Zagrobelny et al., 2009), thiaminase (Nishimune et al., 2000) or other toxins (Blum, 1994), are not considered edible or safe to eat and are not included in the following section.

Just like all protein-containing food, edible insects have an allergenic potential. A number of insect allergens have been identified, among them the pan-allergens tropomyosin and arginine kinase (Caparros Megido et al., 2016; De Gier & Verhoeckx, 2018; Ribeiro et al., 2021; Wu et al., 2021). Due to these pan-allergens, cross-reactivity and co-sensitisation between insects and crustaceans and insects and house dust mites occur (De Gier & Verhoeckx, 2018; Ribeiro et al., 2021). Consequently, consumers and insect-rearing workers allergic to crustaceans or house dust mites are a risk group (Ribeiro et al., 2021). Another insect component that is supposed to have allergenic potential is chitin (Jantzen da Silva Lucas et al., 2020). It was further observed that insect protein allergenicity was not removed by thermal treatments (De Gier & Verhoeckx, 2018). Allergic reactions triggered by insect consumption include gastrointestinal reactions like nausea, vomiting and diarrhoea, respiratory reactions like asthma, and skin reactions. In addition, allergic reactions due to inhalation have also been observed (De Gier & Verhoeckx, 2018). Thus, insect-rearing workers need to be protected. And clear labelling and communication of the allergenic potential of insects to the consumer is required.

Only trace amounts of anti-nutrients in acceptable quantities for food such as tannin, phytic acid and oxalate have been determined in edible insects (Ekop et al., 2010; Oibiokpa et al., 2017; Sailo et al., 2020). Moruzzo, Riccioli, et al. (2021) argues that – just like other fibres – chitin could also be considered an antinutritional factor since it could affect the bioavailability of minerals. More research on the antinutritional properties of chitin and other antinutrients is necessary.

A high number and diversity of microbiota have been found on raw edible insects that are both species-specific and due to rearing conditions. This includes *Enterobacteriaceae*, fungi, lactic acid bacteria, mesophilic aerobes, spore-forming bacteria as well as potentially harmful bacteria such as pathogens (Garofalo et al., 2019). And although there is currently no proof that insects contain pathogenic viruses or prions, they can act as vectors (Van der Fels-Klerx et al., 2018). This reinforces the need for effective decontamination, and the microbial hazards of insect-containing food products must be minimised by means of good hygiene practice during rearing, processing and storage (Garofalo et al., 2019).

A study of the chemical contamination in four edible insect species available as food in Belgium revealed low levels of organic contaminants such as dioxin compounds and pesticides and low levels of metals such as As, Cd, Co, Cr, Cu, Ni, Pb, Sn, Zn (Poma et al., 2017). This was in accordance with a study on the chemical contamination in 35 seasoned and unseasoned insect food products purchased in Europe and Asia that showed an overall low contamination level below the legal maximum amount. It was concluded that post-harvest processing was also factored into chemical contamination besides insect species and rearing conditions (Poma et al., 2019) and feed substrate (Van der Fels-Klerx et al., 2018). In a study on twelve insect species relevant for the European market, it was discovered that these species could accumulate a number of heavy metals such as lead, arsenic, mercury and cadmium. However, they did not appear to accumulate polycyclic aromatic hydrocarbons and mycotoxins. There was even evidence that they could degrade mycotoxins and veterinary drugs (Meyer et al., 2021). This emphasises that the chemical safety of the feed substrate of insect rearing warrants special attention to ensure food safety.

In conclusion, it is a prerequisite to rear and process insects in a controlled environment, using controlled feed substrates, effective decontamination processes, and good hygiene practice to ensure food safety.

3. Product development

Since consumer acceptance of edible insects is still low in many parts of the world (Hartmann & Siegrist, 2017a, 2017b), insect products need to be developed that appeal to the consumer. Martins et al. (2022) considered that potential consumers of edible insects would like to know the method of preparation, the ingredients, and the appearance. Insect processing has an impact on product quality, and taste. In the following sections, the influence of processing on product quality, and the beneficial properties of insect lipids as by-products of insect protein production are discussed.

3.1. Processing

Insect processing includes the production of, for example, whole dried insects, insect powder, defatted insect powder, and extraction of proteins, lipids and chitin. Current processing technologies applied are comparable to established processing technologies for conventional foods in the food industry (Parniakov et al., 2021; Rumpold et al., 2017). In addition, emerging technologies such as high hydrostatic pressure, ultrasound, pulsed electric field, ohmic heating (Queiroz et al., 2023) and cold plasma (Bußler et al., 2016) have been investigated.

For example, sun drying, smoke drying, roasting, freeze-drying and oven-drying of whole insects has been reported (Hernandez Alvarez et al., 2021). Innovative drying methods include microwave-drying (Lenaerts et al., 2018) and pulsed electric field assisted drying (Shorstkii et al., 2022). Analogous to conventional food, the drying process impacts the insect quality such as protein and lipid extraction efficiency, sensory characteristics of the insect and insect-based products, microbiological safety, shelf life and their impact on bioactive compounds (Hernandez Alvarez et al., 2021). A comparison of freeze-drying, oven-drying and microwave-drying of edible insects and their impact on cookies containing these dried insects resulted in differing odour and sensory properties of both insects and cookies (Mishyna et al., 2020). This is in accordance with Kröncke et al. (2019), who obtained different sensory and colour characteristics upon rack oven-drying, vacuum-drying or freeze-drying of *T. molitor*. Moreover, they also found reduced zinc bioaccessibility with all drying methods compared. In a study on the impact of drying on the nutrient content of *T. molitor*, microwave-drying was identified as a good alternative to freeze-drying. Both drying methods resulted in only small changes to the proximate composition. Microwave-drying led to a reduced vitamin B12 content but a better lipid quality than freeze-drying (Lenaerts et al., 2018). Huang et al. (2019) on the other hand observed a better digestibility of *H. illucens* larvae protein dried by oven-drying at 60 °C in comparison to microwave-drying. Similar results were obtained by Kim et al. (2021), who detected low protein digestibility of microwave-dried *H. illucens* protein but improved volatile fatty acid profiles and cholesterol levels of insect-fed broilers. And a cereal bar containing microwave-dried insect powder resulted in a higher liking and better sensory profile than an oven-dried insect-containing cereal bar (Ribeiro, Santos, et al., 2022).

A number of applications of insect powders and defatted insect powders in foods such as bread (Kowalski et al., 2022), burgers, meatballs (Borges et al., 2022), snacks and many other products have been investigated. In bakery products, it was aimed to increase the protein content with the inclusion of insects. It was shown that insect flour improved the nutritional value of bread, but also influenced texture, volume, colour and sensory properties of bread as well as dough and baking properties (Kowalski et al., 2022). An inclusion of up to 10% insect powder in bread was deemed acceptable (Kowalski et al., 2022; Osimani et al., 2018). For consumer acceptance there is a limit to how much cereals can be substituted by insects, see for example the use of cricket powder in crackers (Ardoin et al., 2021) or cookies (Castro Delgado et al, 2020). A safety issue is the detected presence of cricket-derived spore-forming bacteria in bread loaves enriched with cricket powder (Osimani et al., 2018). This is in accordance with Malaysia baked chips with 10% cricket powder, which had acceptable organoleptic properties (Cheng et al., 2022). Several steps can be applied to decrease microbial contamination when processing edible insects into powders. This includes boiling or blanching before drying, the use of food preservatives, fermentation, but also innovative technologies such as infrared heating, instant control pressure drop technology, high hydrostatic pressure, and cold plasma. The heat treatments in particular, while effectively reducing the microbial load, impact quality aspects such as nutritional and organoleptic properties (Yan et al., 2022).

The way of killing the insects may influence the sensory qualities and physiochemical properties of the product. Farina (2017) compared crickets frozen prior to cooking with those still alive prior to cooking, and found differences in the pH level, overall liking, and the perception of saltiness, and umami.

Edible insect proteins can be extracted based on their solvent solubility, via isoelectric precipitation, using a dry separation method such as air classification after milling, and other physical separation methods such as centrifugation or filtration (Rumpold et al., 2017). Enzyme-assisted extraction using proteases is also possible and was identified as a potentially effective and sustainable method to extract high-quality proteins from insects (Leni et al., 2020). Functional properties of insect proteins could be tailored by enzyme hydrolysis (Leni et al., 2020). Not only the addition of enzymes but also the addition of salts, temperature, concentration, incubation time and pH influenced the functional properties of insect proteins and could be used as levers to modify them for different food applications (Zhao et al., 2016). Emerging technologies such as high hydrostatic pressure, ultrasound, pulsed electric field, and ohmic heating also affect protein extraction and functionalisation (Queiroz et al., 2023). Further research is required to investigate the impact of processing on insect product quality and to identify sustainable and efficient methods that lead to safe products with improved nutritional and sensory properties and consumer acceptance.

3.2. Insect oils instead of plant oils

Lipids are the main components in insects after proteins (Aguilar, 2021; Rumpold & Schlüter, 2013). Lipid extraction from insects is comparable to other foods and can be done mechanically by pressing (Rumpold et al., 2017), using Soxhlet, aqueous, and Folch extraction methods (Tzompa-Sosa et al., 2019), using conventional solvents such as hexane, ethanol or methanol, by three-phase partitioning, and using supercritical CO_2 (Laroche et al., 2019), or ultrasound assisted or pressurised liquid extraction (Otero et al., 2020). Often, the lipids are removed to improve the nutritional composition of feed for a reduced lipid and increased protein content, to enable grinding into a powder or to enhance protein extraction. Lipid extraction greatly influenced the lipid quality and composition but also affected protein quality of subsequent protein extraction (Laroche et al., 2019).

Potential applications for insect oils and fats are the replacement of soy and fish oil in fish and poultry feed as well as applications in food (Lorrette & Sanchez, 2022). It was determined that *T. molitor* larvae oil is mainly composed of oleic acid (C18:1, 44%), linoleic acid (C18:2, 28%) and palmitic acid (C16:0, 18%), which is comparable to some vegetal oils such as rice bran and peanut oil (Lorrette & Sanchez, 2022). On the other hand, *H. illucens* prepupae fat has a comparable fatty acid spectrum and quality to coconut and palm kernel oil (Borrelli et al., 2021). What is also remarkable is the rather high content of lauric acid (C12:0, between 23 and 62% of total fatty acids) (Franco et al., 2021). Lauric acid has antibacterial properties (Borrelli et al., 2021).

Smetana et al. (2020) investigated the potential of insect-based margarine production in order to replace butter with its high environmental impact as well as *trans*-fat containing plant-based margarine which is associated with health risks. It was discovered that up to 75% of the plant lipids could be replaced with insect oils from *H. illucens* and *T. molitor* without negative effects on spreading abilities and with improved product colouring. This resulted in a product with a lower environmental impact than butter, but higher than conventional margarine. From an environmental point of view, a replacement of up to 50% would be beneficial (Smetana et al., 2020).

The colour, aroma, taste and overall acceptability of cookies prepared with either sesame oil, olive oil, or oils from two African Orthopterans were compared. The two insect oils both had higher levels of omega-3 fatty acids, flavonoids, and vitamin E than the plant oils. While the overall acceptability of cookies made with oils from *Ruspolia differens* (95%) and sesame (89%) were very high, both the aroma and taste of cookies made with the two insect oils were disliked by more than 50%, respectively (Cheseto et al., 2020).

It can be concluded that insect lipids are a potential alternative to conventional lipids in food. But environmental, economic, health as well as sensory aspects need to be considered.

4. Consumer psychology and behaviour

In this section we will discuss the factors that influence consumer behaviour when it comes to considering and consuming edible insects. The following factors have been identified to have a negative influence: disgust, food neophobia, lack of information, no prior experience, lack of interest and several others. They will be explained in detail below.

4.1. Disgust

For Westerners, disgust is the major predictor of not wanting to eat insects. (Kornher et al., 2019; La Barbera et al., 2017; Lammers et al., 2019; Ruby & Rozin, 2019; Russell & Knott, 2021). Disgust is considered a food-related emotion and defined as revulsion at the prospect of oral incorporation of offensive objects (Rozin & Fallon, 1987). The presumed origin of disgust is a rejection response that protects the body from 'bad' foods (Rozin et al., 2008) contaminated with pathogens (Rottman et al., 2019) and from the risk of disease (Val et al., 2004). It seems that contagion concerns and disgust are closely related and so when something is considered disgusting, it is a difficult emotion to undo (Russell & Knott, 2021). However, a study in Denmark found that the fear of contamination did not predict insect-eating disgust or willingness to eat insects (Jensen & Lieberoth, 2019).

A study in Japan found that insect disgust is reinforced by urbanisation (Fukano & Soga, 2021). How can we counteract disgust? Apparently social influence (providing information about someone else consuming insects) may lower the disgust factor (Russell & Knott, 2021; Sheppard & Frazer, 2015). Another study found that providing information about sustainability and nutritional value did not lower disgust but a description of how the product was made did (Gumussoy et al., 2021). However, disgust may not be the result of any of the foods' inherent qualities like taste or texture, but may simply result from the perception that such foods deviate from what consumers have internalised to be the norm, causing them to intuitively reject them (Koch et al., 2021). Due to negative emotions of Westerners towards invertebrates, eating insect maybe considered a threat to our psychological and cultural identity (Looy et al., 2014). This leads Kosonen (2023) to believe that cultural discourses and representations shape emotions, conceptions, and norms –including thoughts related to what is disgusting. Therefore, he concludes that 'disgusting foods' are a sociocultural construct. Strangely enough, among Danish children (not yet food-biased) disgust was not a predictor of willingness to consume insect products (Erhard et al., 2023). Disgust can also be used as an educational tool (Wade, 2021) as it may be a learned response that shifts alongside changes in our 'state of knowledge' about what is good to eat (Douglas, 1966). It is also interesting that there seems to be a negative correlation between disgust and sensation-seeking (Lammers et al., 2019; Rozin et al., 1993).

4.2. Food neophobia

Food neophobia can be defined as a reluctance to ingest unfamiliar or novel foods. A scale was developed to measure the trait of food neophobia in humans (Pliner & Hobden, 1992). The reason for food neophobia is probably that many food sources may be toxic and should be avoided as familiar foods are known to be harmless (Pliner & Salvy, 2006). According to Rozin and Fallon (1987) there are three reasons for rejecting food: 1) dislike because of sensory characteristics (novel foods are expected to be less palatable than familiar ones, and this predicts willingness to taste them); 2) danger, a fear of negative consequences of eating it (but a limited number of exposures to a novel food in the absence of negative consequences does teach us that the food is safe and can be ingested; 3) disgust about the idea of the origin of the food. Pliner and Salvy (2006) found a strong positive correlation between food neophobia and disgust. However, both have independent contributions to the intention to eat insects, although the explanatory power of disgust is considered higher than food neophobia (La Barbera et al., 2017).

In many studies neophobia has been reported to explain the consumer behaviour of not being willing to consume insects (Hartmann et al., 2015; Orsi et al., 2019; Sogari et al., 2023, 2018; Verbeke, 2015; Wassmann et al., 2021; White et al., 2023). Also in Turkey, food neophobia was negatively correlated with the intention to eat insects, and those who scored high on the food neophobia scale were nutritious-conscious consumers (Oğuz & Türkmen, 2020). However, there is no suggestion in the latter study that these consumers will not eat insects.

In Italy, food neophobia and willingness to eat insects were clearly correlated (Toti et al., 2020). The same effect was observed among children (average age 12) in Denmark (Chow et al., 2021). Children with high neophobia levels were less willing to taste and gave lower ratings to the insect oatmeal balls compared to those with medium or low neophobia levels. In Uganda, older consumers tended to be more neophobic about insect-eating than younger ones (Olum et al., 2020). In the same study, consumers with higher levels of education had lower levels of food neophobia than uneducated consumers.

In Finland, an experiment was conducted in which children (8–12 years old) were given a sensory education for one and half years (Mustonen & Tuorila, 2010). After the education, the treatment group had tried a larger proportion of unfamiliar foods than at the baseline with a decreased food neophobia score, while there was no change in the baseline group. The effects of education were stronger for younger children.

With increasing attention to insects as human food and more insect-based food products coming on the market, there is an assumption that food neophobia will decrease. However, according to La Barbera et al. (2017) this may take a generation. Also, we must consider that disgust is probably a more significant and substantial predictor than neophobia in causing people to refrain from eating insects (Ruby and Rozin, 2019).

4.3. Information

Considering unpleasant-tasting healthy foods, participants evaluated the product experience more positively when positive information about the food was given after tasting, than when the same information was given before tasting (Suzuki & Park, 2018), indicating that the emotional state of the consumers could be changed, and that the actual taste of food is not the only determining factor in the product experience. This was also shown by Barsics et al (2017) who asked participants to rate the organoleptic characteristics of two identical bread samples, but one was faux-labelled as containing an insect product. Participants, who received prior information on insects as food, rated appearance, flavour, and overall liking better for the bread sample labelled as insect-free. Tan et al. (2016) conducted a similar experiment in which she labelled similar burgers to contain beef or unusual novel ingredients (among which mealworms). Sensory liking of the mealworm containing labelled burger was lower than the beef burger but increased after tasting to a similar level, but not the food appropriateness. Willingness to eat again was predicted mainly by food appropriateness, and not so much by the experienced sensory-liking.

Providing information about edible insects was positively correlated with a willingness to consume edible insects among USA students, in particular among those consumers who believed that entomophagy is sustainable (Woolf et al., 2021). In Germany, 75% of interviewees who first declined tasting an insect were willing to try after having been given information about eating insects (Rumpold & Langen, 2019). In Thailand, providing product information increased the expected liking of fermented rice noodles containing crickets (Maw et al., 2022). Also in Kenya, consumers appreciated buns made with cricket-flour more after tasting and when information was provided (Pambo et al., 2018).

4.4. Prior experience

Prior consumption of insects did have an influence on willingness to consume insects in the future (Caparros Megido, Sablon, et al., 2014; Hartmann & Siegrist, 2016; Woolf et al., 2021), but particularly for those species of which the consumer is most familiar (Fischer & Steenbekkers, 2018). In Thailand, consumers evaluated fermented rice noodles containing crickets more positively when they had previously consumed crickets than consumers who did not have that experience (Maw et al., 2022). In the Democratic Republic of Congo, previous experience was also mentioned as a reason for consuming insects (Ombeni et al., 2022).

4.5. Curiosity

Curiosity or sensation-seeking may be a powerful motivator to try novel foods like insects, although it may be a balancing act between curiosity and fear, in particular for children (Nyberg et al., 2020). This also became apparent in a study among British citizens (Stone et al., 2022). Among Italian students of gastronomy and food science, curiosity was the most important reason for choosing to try cookies made with cricket flour (Sogari et al., 2017). Also in Italy, among professional athletes the main drivers to taste a cricket energy bar were protein content and curiosity (Placentino et al., 2021). In Brazil, among people interviewed, the second reason for insect consumption was curiosity; the first one was survival (Bisconsin-Júnior et al., 2022). In India, sensation-seeking was a consistent predictor of greater willingness to consume insects (Ruby et al., 2015). In Belgium, only about 10% of the participants in a survey mentioned curiosity as an argument for eating insects, after ecological and health reasons (each about 40%) (Boeckx & Van Der Borght, 2014). Wassmann et al. (2021) found that consumers who were 'food sensation and innovation seeking' were likely to have a higher willingness to try insects.

4.6. Sensory quality

In blind tests in California, cricket powder products (sausage, pasta, and brownies), appeared to be as acceptable as the control (Ho et al., 2022a, 2022b). However, in these studies the use of cricket powder may have affected the texture and flavour profile of the sausage and brownies. In the Republic of Korea, people with a high interest in insects as food, valued sensory properties (taste, colour, odour) more than those less interested (Lee and Bae, 2023). A study by Schouteten et al. (2016) revealed that the overall liking of a mealworm burger scored low in a blind test and for that reason, they recommend improving the sensory quality of the insect-based burger, because consumers who are willing to eat it will not do so again if they do not like the taste. Tan et al (2017) found that a better product can improve the sensory-liking and willingness to buy a mealworm containing meatballs, but only if consumers are motivated to eat it. After tasting, the quality of the sensory experience become more important in considering future willingness to buy. This indicates that improving the sensory quality of insect-based products contributes to the acceptance and lowers the product-related barriers to consumption, especially for adventurous consumers (Ardoin & Prinyawiwatkul, 2021).

4.7. Other factors

Would hunger be a motive to eat insects since they are often depicted as a survival strategy? White et al. (2023) did not find any relationship between hunger and willingness to eat insects. A possible explanation may be that severe hunger is not an issue for Westerners.

The effect of religion was mentioned in an article from Western Kenya (Ogal et al., 2022). The consumption of insects was lower in believers compared to the 100% consumption by non-believers. Christianity had no impact on the consumption of edible insects, whereas Islam had, which is to be expected as there are rules on consuming insects in the Bible and the Quran (Slater, 2021).

5. Geographical and cross-cultural differences

There are only a few studies that compared preferences across different cultures. This can be across continents or between countries on one continent.

Florença et al. (2022) reviewed 31 articles on willingness to consume edible insects. In Western countries, the focus was on nutritional value, sustainability, benefits, familiarity/experience, tradition/culture, food neophobia and disgust, while in countries with a tradition of eating insects the focus was more on factors related to sensory attributes, availability, affordability and preferences. In Western countries, the willingness increased when insects were incorporated in food products rather than presented as a whole insect. Ruby et al. (2015) found that when comparing Indian and American omnivores, Indians were more concerned about moral issues around eating insects, perhaps related to Hinduism and the related, much higher, incidence of vegetarianism in India. However, on other issues (willingness to try insects as food, preferred species, and sustainability) both groups were rather similar in their attitude towards eating insects. Tan et al. (2015) compared consumer attitudes between Thailand, where insects are part of the local food culture, and the Netherlands, where insects are generally not recognised as foods. For the Thai participants, the appearance of mealworms strongly resembled maggots that decompose carcasses, and they were therefore extremely unappealing as food, whereas this association was not present among the Dutch participants. Brunner and Nuttavuthisit (2020) also used Thailand (the Bangkok area) and compared consumers' attitudes towards edible insects with those of Switzerland. Not surprisingly, the segment of early adopters in Thailand (with a custom of eating insects) was much larger than in Switzerland. However, educated consumers in Bangkok consider the eating of insects, primitive (and regarded it as an old rural tradition they didn't want to be associated with), while in Switzerland, highly educated consumers consider the eating of insects progressive and innovative. Hartmann et al. (2015) compared consumer willingness to eat different (un)processed insect-based food among consumers in China and Germany. The Chinese indicated a greater willingness to eat the tested food products and rated all insect-based food more favourably on taste, nutritional value, familiarity and social acceptance compared with the Germans. Concerning the differences between ratings of processed and unprocessed food, Germans were more willing to eat processed insect-based foods compared to the unprocessed foods, while for the Chinese it made no difference. Sogari et al. (2023) had similar results comparing consumers from Belgium, Italy and the USA with those of China and Mexico. The willingness to try products with insect-based ingredients was higher in China and Mexico than in Western countries (Castro & Chambers, 2019). This willingness was similar among South African and Swedish consumers, but for the first group, neophobia was the most important factor, and for the Swedes disgust (Hallin, 2020). Tzompa-Sosa, Sogari et al. (2023) compared consumers' motivations to accept or reject whole and processed yellow mealworms in Belgium, China, Italy, Mexico, and the USA. Interestingly, they did not find much differences between traditional and non-traditional insect-eating countries. "Healthiness" was the most frequent driver to accept, except in Italy. Across all five countries "aversion" and "dislike" were the most important barriers that led to rejecting these products.

A comparison between countries (France, Germany and the Netherlands) within Europe has been made with meat alternatives (Weinrich, 2018). Meat substitutes seem to be more established in the Netherlands and Germany compared to France, while German consumers were more open-minded than French consumers about trying new meat substitutes. However, for consumers in all three countries the taste of meat was the reason for not substituting it, so realistically it may be better to aim for substitution once or twice a week. Piha et al. (2016) compared consumers' attitudes towards insect food in northern Europe and central Europe. Consumer willingness to buy insect food in Central Europe was more related to product-related experiences and to food neophobia than in Northern Europe, where consumers had a more positive attitude towards insect food. The same was reported by Ribeiro et al. (2022) who found that Norwegian consumers accepted insects as food more than Portuguese consumers. Dutch participants trusted consumer organisations more when promoting insects as food than Australian participants (Lensvelt & Steenbekkers, 2014).

However, it should be noted that in all the above-mentioned examples, sample sizes were rather low and probably did not represent the opinion of all inhabitants of a whole country. In addition, the developments of insects as food are fast-moving and surveys from several years in the past may no longer be valid.

6. Strategies to convince consumers

The number of people willing to try edible insects is rated in several surveys in Western countries at about 25% (Galány et al., 2021; Jarchlo & King, 2021; Niva & Vainio, 2021), depending also on the level of neophobia (Moruzzo, Mancini, et al., 2021). Often a large proportion of the people in surveys indicate that they cannot be persuaded to try insect-based food, e.g. 75% of the people in the UK (Jarchlo & King, 2021). In Japan, the positive acceptance of insects was 20%, while other meat alternatives scored much higher (plant-based meat 70%, microalgae 58%, milk alternative 51%, and cultured meat 41% (Takeda et al., 2023). In Italy, when comparing the willingness to eat and incorporate seaweed, jellyfish or insects in the diet, insects scored lowest (Palmieri et al., 2023). In a review of more than 90 articles, Onwezen et al. (2020) compared acceptance of alternative proteins (pulses, algae, insects, plant-based alternative proteins, and cultured meat) and found that insects scored lowest; lack of familiarity, digust and neophobia were the most important drivers. The attitude towards insects as food is much higher in tropical countries, e.g. in Nigeria more than 80% of the interviewees ate insects for their taste and nutritional value (Ancha et al., 2021). Also in Zimbabwe, insect consumption is high, mainly for nutritional or medicinal reasons: in rural areas 90% versus 80% in urban areas (Manditsera et al., 2018).

Often the arguments about adequate nutritional value and low environmental impact are used to promote insect consumption. This information is often not enough to make consumers less sceptical about consuming insects. The question would be which kind of information will persuade consumers at least to try insects or which organisation or persons should be used. Would presenting insects in a non-recognisable form make a difference and what about for example the taste, tasting experience, information provided, and packaging?

6.1. Nutrition and health

Health issues can be interpreted in two different ways: nutritionally adequate (Rumpold & Schlüter, 2013) or having supposed health-beneficial bioactivity (antioxidants, strengthening immune systems, combatting hypertension, fat reduction) (Van Huis et al., 2021). However, more research is needed on the bioactivity claims, and this is also not very well known among the public. The nutritional value is very much comparable to meat products and sometimes even better (Payne et al., 2016a, 2016b), but also sometimes overrated (Ventanas et al., 2022). However, it should be stressed to consumers that insect products are nutritionally adequate, and thus comparable to meat products.

6.2. Ground insects or protein meals versus whole insects

It has been suggested that the use of processed insects in food products is a more beneficial strategy for achieving consumer acceptance than the use of whole insects (Baiano, 2020; Caparros Megido et al., 2014, 2016; Gmuer et al., 2016; Hartmann et al., 2015; Lammers et al., 2019; Orsi et al., 2019; Wilkinson et al., 2018; Zielińska et al., 2020), since the visibility of insects in a food product was identified as a barrier (Cicatiello et al., 2020; Mandolesi et al., 2022) and invisibility was shown to increase willingness-to-taste (Lombardi et al., 2019; Mancini, Moruzzo, et al., 2019, Mancini, Sogari, et al., 2019). Van Huis (2013) stated that the incorporation of insect flour or insect proteins into conventional food has the potential to increase consumer acceptance. Consumers may be more likely to trust unusual foods if they are not visible and are prepared in familiar ways. For example, invisible, processed mealworms were more accepted when introduced in familiar products such as energy shakes, energy bars, burgers, soups, sandwiches and snacks (Van Thielen et al., 2019). Cookies with the 5% and 10% cricket flour showed the highest overall organoleptic acceptability (Tedjakusuma et al., 2022). Biró et al. (2019) observed that incorporation of silkworm powder into buckwheat pasta could improve the consumer acceptance of buckwheat pasta due to improved taste while increasing its nutritional value. Processed insects could be considered as a more indirect form of eating insects (La Barbera et al., 2021). However, the latter study argues that when the interest factor in insect food is pursued, focusing on products with whole insects may be more interesting, which was confirmed by the study of Riverso et al. (2023). Rovai et al., 2022 also found that adventurous people are motivated by the novel experience and are willing to consume whole insects.

What about consumer acceptability of insect oil as frying oil? Deodorised yellow mealworm oil improved sensorial experiences and increased consumer acceptance of dough and potato chips and scored similar to vegetable oil (Tzompa-Sosa et al., 2022; Tzompa-Sosa, Provijn, et al., 2023).

6.3. Deliciousness

Sensory characteristics of the insect product affects participants' experiences and evaluations, and should therefore be assessed when developing the most suitable products (Hellwig et al., 2021). Finnish respondents to a survey considered taste to be the most important factor in accepting insects as food (Halonen et al., 2022). In Zimbabwe the main motive for respondents to eat insects was taste: 89% in rural and 74% in urban areas (Manditsera et al., 2018). Moruzzo, Mancini, et al. (2021) recommend investing in advertising messages with gastronomic and sensory characteristics to overcome the disgust feeling. Making products more tasty may increase the overall liking, e.g. a chocolate bar with 5.5% cricket flour was very much appreciated by Italian consumers, scoring 7 on a 1–9 sensory scale (Cicatiello et al., 2020). Apart from the crickets, this bar contained, dates, almonds, figs, dark chocolate, bean and sunflower proteins, honey, fig juice, and natural flavours. Marketing insect-based products primarily by taste might be a promising strategy (DeRoy et al., 2015).

6.4. Tasting experience

Taste is a fundamental driver for food choices (Tan et al., 2015). However, the results of tasting experiments with new foods depend on many factors such as venue, country, culture, context, samples, panel, socio-demographic diversity, and others, and are therefore context specific (Hellwig et al., 2021). In a survey in Australia and the Netherlands it seems that people who have eaten insects before have a more positive attitude towards consuming insects than those who have not (Lensvelt & Steenbekkers, 2014). In Spain, after tasting pizzas with yellow mealworm the liking increased as compared to the initial expectation (Ventanas et al., 2022). In the USA, the overall liking of insect-based products showed only an 'interested' emotion before tasting, but after tasting (without providing further information) emotions such as 'good' and 'adventurous' were also significant drivers (Gurdian et al., 2022). This shows the importance of evoking sensation-seeking emotions. According to Sogari et al. (2023) disgust towards insects as a food source can be reduced by organising tasting sessions and by legitimising insects as a food source. Repeated exposure to insect-based products may be necessary for improving consumer acceptance of edible insects.

6.5. Sustainability argument

If European consumers have to replace meat with a more sustainable alternative, it is assumed that they are aware of the environmental impact of meat production, but in a review by (Hartmann & Siegrist, 2017a, 2017b) this knowledge proved to be very poor. This also means that their willingness to substitute meat for insects is also very low. Environmental impact information may increase the willingness of people in the USA to try insects as food (Bao & Song, 2022). Also, one of the most important factors for the willingness of Finnish consumers to eat insect-based food was the low environmental impact compared to conventional meat (Halonen et al., 2022). However, it should be realised that increased sympathy towards edible insects for sustainability reasons does not necessarily result in increased consumption. Also, Wendin and Nyberg (2021) argued that sustainability is seldom the main factor influencing acceptability of insect consumption. Italian people with a large sensitivity towards sustainable diets barely accept insects as food (Laureati et al., 2016; Simeone & Scarpato, 2022). Dagevos and Taufik (2023) also found that sustainability-conscious consumers in the Netherlands are not specifically keen to consume insects; although their readiness to eat insects increased modestly when information was provided about the environmental benefits. Also, in Australia (Sydney), even though edible insects were considered a sustainable option, the readiness to adopt them as an alternative to meat was very low (Sogari et al., 2019). Fischer (2021) argues that dietary change for sustainable products will not occur easily as they are generally more expensive than conventional ones. He proposes a consumer-centred insect market, creating products desirable for their properties and not their origin.

6.6. Information and information providers

Providing information to Danish and Italian consumers about the benefits of eating insects did raise the intention to eat insects (Verneau et al., 2016). It also increased the liking of an insect-based burger among Belgian consumers (Schouteten et al., 2016), but not among Italian consumers about edible cricket protein (Gurdian et al., 2022). White et al. (2023) reasoned that if food neophobia towards insects were to be reduced, Western consumers might be more inclined to eat insects. So, the strategy would be to familiarise Westerners with edible insects through exposure to insects as food. In general, providing information (educating consumers) is generally considered a strategy to increase the consumption of insects (Lensvelt & Steenbekkers, 2014). It will certainly reduce food neophobia.

Would the willingness to consume insects depend on the provider of information? According to Lensvelt and Steenbekkers (2014) it would if the information was provided by scientists, close relatives, the government, or persons using the product. However, it would not if the information were provided by food producers, or celebrities. Park et al. (2022) found that males in the USA could be influenced by using advertisements for insect-based food featuring actors/actresses and athletes, while for females it was only the first group. Musicians as celebrities do not seem to have an effect. The effect of endorsement of insect-based products by other types of celebrities (political or celebrity chefs) was not studied. For example, it would be interesting to know whether the interviews given in a cookbook (Van Huis et al., 2014) with celebrities like Kofi Annan (seventh Secretary-General of the United Nations; 1997–2006) and Rene Redzepi (Danish chef of the restaurant Noma, voted five times the best restaurant in the world) would have an effect on consumers.

6.7. Targeting specific groups

Gere et al. (2020) investigated how consumers responded to messages about meat alternatives like algae, insects, and cultured meat. Geography, gender, or age had no effect on how consumers responded to topics such as sensory characteristics, possible usage in products, health aspects, and environmental aspects. Finding ways to identify possible adopters of insect-based food products could help in targeting strategies, as these groups are more susceptible to acceptance (Rovai, Michniuk, et al., 2021). These authors distinguished four groups: adventurous eaters, those willing to consume insects in most forms, those only willing to consume if they are nonvisible and those unwilling to consume insects in any form. The first group was most willing to accept a meal with mealworms, followed by the second group, and therefore they suggest to target these groups first, as this will increase the acceptance by all groups (Rovai et al, 2022), provided that these insect products are tasty (Ardoin & Prinyawiwatkul, 2021).

With respect to children in Denmark, those with high neophobia levels were less willing to taste and gave a lower rating to insect products compared to those with a low neophobia level (Chow et al., 2021). In this study the first tasting of the insect product was rated higher than the second tasting. This was explained by the fact that the insect product in the first tasting was more palatable than expected, causing an upward adjustment of the expectations in the second tasting. Hémar-Nicolas et al. (2022) recommend promoting children's willingness to consume insects by means of sensory and participatory activities and targeting children's peer culture. Young children seem to be more susceptible than older children (Harper & Sanders, 1975). According to Nyberg et al. (2020) there was a mix of curiosity and fear about eating insects among Swedish children. Therefore, they recommend integrating insects in well-known dishes in a familiar context, and exploring the curiosity and imagination of young children in experimenting with new food.

In China, participants who had eaten insects were older, more educated, and likely to be male (Su et al., 2022). In the review of Florença et al. (2022) providing references from many parts of the world, the consumption of insects was related to the following characteristics of the target group: age, gender (males), level of education, level of income (high), level of knowledge, interest in entomophagy, and children. Also, in Switzerland the consumers of insect products were characterised as more health-conscious, environmentally friendly, imaginative, brave, interesting, and knowledgeable than meat consumers (Hartmann et al., 2018).

6.8. Marketing

According to Ventanas et al. (2022) marketing strategies should emphasise positive emotions (i.e. adventurous) to persuade potential consumers. Also, products should be developed that are similar to the normal diet, such as bakery products containing insect flour (Menozzi et al., 2017). Insects processed into flour or pastes have a greater chance of being accepted when insect images are not displayed on the packaging (Meyer-Rochow & Hakko, 2018). Abstract or stylistic representations of insects on the packaging generally cause less repulsion than realistic images (Kauppi, 2016; Pozharliev et al., 2023; Reverberi, 2021). According to Phonthanukitithaworn et al. (2021) in Thailand, marketing strategies are crucial and should include attractive advertising and promotion strategies as well as accessible distribution channels; promotional tools such as buy-one-get-one-free could stimulate insect consumption. Insect products probably sell better when made available in supermarkets rather than local markets (Alemu et al., 2017) or e-commerce (Reverberi, 2021).

7. Limitations and future research

The field of insects as food is very recent. Using the Web of Science and using the keywords "edible insects" and "consumer" there are 430 hits with more than 75% of all publications since 2019 (up to the 1st of May 2023). Therefore, with increasing attention the perception of insects as food may change rapidly. Neophobic reactions may diminish as insects as food is generally becoming more accepted. For example, the authorization by the European Union during the last three years of a number of insect products, provides a legal framework of food safety, and this may increase public acceptance. Considering that insects as food is a relatively new phenomenon it would be interesting to study how acceptance of insects as a culturally unusual food would develop over time. All consumer studies have the limitations of not being representative for a whole country or region, and the interviewees are often a particular group, such as university students. Another problem is that it is difficult to compare studies as methodologies differ. It may be questioned whether cultural backgrounds or contexts are really that important or that the focus should be more on individual expectations and preferences, related to sensory liking, and for that reason targeting consumers may need more focus. Also, it should be studied not only whether consumers are willing to consume insects as an occasional snack, but how to incorporate insects into a regular diet (long-term acceptance).

8. Conclusions

Although it was already well known in the tropical world that insects could be used as human food, it was only a few decades ago that it was realised that insects are also potential food for humans in the Western world. In the tropics, the insects are mainly harvested from nature, but in the West this is not really possible, due to the limited availability. This means that the insects must be farmed. The first concerns about insects for humans centred around nutritional value and food safety. We have shown that their nutritional value is very comparable to meat products and that there may even be health benefits. Concerning food safety, more and more insect products (crickets, mealworms and locusts) have been declared safe by the European Food Safety Authority and allowed on the European market (https://www.IPIFF.org). Also, processing steps can lower food safety risks. Processing is also important in obtaining dried insects, insect powder, defatted insect powder and extracting proteins, lipids and chitin. This increases the possibility of incorporating insect ingredients in common food products. Another important aim of processing is to improve the nutritional and sensory properties, which may influence consumer acceptance. Also, it is investigated whether insect oils can replace butter/margarine and some plant oils for cooking.

Sometimes the introduction of insects as human food has been compared with the introduction of sushi as a new food item in the West. Ruby and Rozin (2019) found that sushi consumption was a predictor of insect consumption. However, House (2019) argued that sushi's establishment in the USA, contrary to insects, was due to the existence of pre-existing practices, such as food suppliers and culinary experiences.

Although Western consumers are getting more and more used to the idea of insect-based foods, they continue to have many prejudices, which complicates the introduction of foods containing insects into a normal diet (Moruzzo, Mancini, et al., 2021). The main problems are emotional reactions such as disgust and food neophobia. It may be expected that with the increased attention to insect-based-food being officially legalised as safe food, food neophobia as an emotion will diminish. Disgust is closely related to food neophobia, but more related to an intuition and a cultural norm. Here again, disgust may be lowered when providing as much information as possible about the insect product. In general, providing information increased the willingness to eat insect-based food and it even positively influenced the taste experience. Furthermore, the use of celebrities to provide the information could be considered.

We showed that environmentally conscious consumers may not automatically shift to insect-based food because of its sustainability. So, the desirable properties of the insect product should perhaps be stressed more than its origin (Fischer, 2021). Most publications about consumer acceptance also indicated that consumer acceptance increases when the insects are presented in a non-visible form (ground insects or using the extracted components such as protein or fat). This may not be true for the very adventurous consumers, who are sensation- and innovation-seeking and want to see the whole insect. For consumers, the appreciation for an insect product may be increased by giving them a tasting experience, which is often experienced as unexpectedly good; this may be an incentive to try eating insects again. For that reason, the organisation of 'bug banquets' has been suggested (Looy & Wood, 2006). However, although positive sensory experiences play a role in the process of learning to accept a food, it could be inadequate when insect-containing products are involved, which are considered a culturally-inappropriate food (Tan et al, 2016). However, this perception could rapidly change as insects are increasingly being accepted as appropriate food.

Then the question about how to market the product and to whom. Marquis et al. (2020) proposes in marketing to stress, among other things, the food's attributes and to consider consumer characteristics, such as being adventurousness. It could be that, in terms of marketing, the push strategy has stressed too much to the detriment of the pull strategy, in other words, how to trigger the interest of the consumer. The consumers to target are the wealthy, knowledgeable, health and environment conscious, brave, imaginative, and children who are unbiased.

It is understood that bringing a new food item that was never considered as food before to Western markets is a serious challenge. It may not be sufficient to stress the nutritional value, or even health benefits and sustainability. It should also be noted that consumer attitudes towards insect-based products will not change overnight and may even take a generation. However, if we are at the beginning of an exponential curve of acceptance, we will not notice it now. The challenges are to find the triggers that will change consumer attitudes towards this new food item. Hopefully, we have provided a few entry points.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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