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Factors affecting consumers' evaluation of food derived from animals fed insect meal: A systematic review

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ABSTRACT

Background: Research in recent years has shown there is high potential for various insect species to converting organic substrates into high-quality feedstuffs. Insect-derived meal is increasingly being used to replace conventional feedstuffs such as soybean and fishmeal in animal diets, due to its high protein and essential amino acid content. However, research on consumer acceptance of foods derived from animals produced using insect-based meal is fragmented.

Scope and approach: A systematic literature review was carried out in Scopus, Web of Science, AgEcon, and Google Scholar, with a total of 28 articles meeting the selection criteria. Papers were reviewed to identify factors affecting consumer acceptance of insect-based feed.

Key Findings and Conclusions: Overall, the review indicated that insects are more acceptable to consumers as an animal feedstuff than as human food. The most important factors influencing consumer evaluation of insect-based feed included risk perceptions, knowledge and heuristic cues. Ethical and environmental concerns also played a role in the decision-making process, but their effect on consumer acceptance of using insects in animal feed was less important. Food neophobia, disgust and uncertainties about safety and health, mainly deriving from lack of knowledge on the part of consumers, emerged as critical barriers to acceptance of insects in animal feed. Greater familiarity with the technology used for the production of insect meals could alleviate disgust and even lessen the impact of neophobia, although affective emotional reactions are unlikely to be changed by awareness and provision of information alone. Technological issues (including substrates and insect species) as well as price changes in the resulting animal-based foods are relevant factors that warrant further research in relation to consumer acceptance.

1. Introduction

1.1. Background

Research to reduce dependence on scarce natural resources in production of animal feed is emerging as a solution to food insecurity. The use of conventional resources (e.g. soymeal, fishmeal, grains) in animal feed is unsustainable because of land and water scarcity, food-feed-fuel competition and climate change (Godfray, Crute, Haddad, Lawrence, Muir, Nisbett, et al., 2010; Khaemba, Kidoido, Owuor, & Tanga, 2022; Van Huis, Dicke, & van Loon, 2015).

Use of processed proteins derived from insect in animal feed is a

subject of various national and international regulations. The only international legislation in place is currently in existence in European Union, where products derived from several insect species are currently permitted in fish, poultry and pig feeds (EU 2021/1372). In the United States, the black soldier fly is permitted in diets for fish only (Lähteenmäki-Uutela, Marimuthu, & Meijer, 2021) while Canada allows only Black soldier fly products in poultry and fish (Lähteenmäki-Uutela et al., 2018). Elsewhere, the use of insect-derived proteins in animal feed is either regulated by national laws or is currently unregulated. Insect meals (i.e., processed protein derived from black soldier fly larvae) have been identified and confirmed by nutritionists as a feasible animal feedstuff (Ocha, Ujah, Adeniyi, Ochuole, & Yahaya, 2022; Van Huis

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et al., 2013). Rearing insects for animal feed reduces dependence on conventional feed resources, while also contributing to a circular economy by returning valuable components from waste biomass to the food system (Smith & Barnes, 2015). Insects as feed can substantially lower environmental impacts associated with animal husbandry if large-scale production can supply insect meals in quantities comparable to those of conventional resources such as soybean and fish (Van Huis et al., 2015). Insect production systems have low land and water requirements and high conversion efficiency of substrates into protein biomass (Fellows, Halloran, Muenke, Vantomme, & van Huis, 2014). However, current manufacture readiness levels and global supply are still limited, partly due to restrictive legislation but also due to relatively high prices and consumer perceptions (Gasco, Józefiak, & Henry, 2021). It is estimated that the supply of insect-based feed will be improved when the industry achieves sufficient economies of scale and hence reduced production costs (Lamsal et al., 2019).

Benefits to food security from using insect proteins as a feedstuff for farmed animals are well-recognised, but there is less information regarding whether this is acceptable from a consumer perspective. Recent reviews have identified some factors motivating or challenging consumer acceptance of insects as human food (Dobermann, Swift, & Field, 2017; Imathiu, 2020; Kröger, Dupont, Büsing, & Fiebelkorn, 2022; Rumpold & Schlüter, 2013b; Sun-Waterhouse, Waterhouse, You, Zhang, Liu, Ma, et al., 2016). To our knowledge, the literature assessing consumer attitudes to foods derived from animals fed an insect-based diet has not been synthesised. Therefore, in this systematic review, we reviewed the literature on consumer attitudes to, and acceptance of, foods derived from animals fed insect meals as part of their diet. The aim was to identify gaps in existing knowledge, compile evidence regarding the societal acceptability of insect meals as animal feed, and provide decision support for policy and industrial development in this area. Following Kamrath, Wesana, Bröring, and De Steur (2019) and Hess, Lagerkvist, Redekop, and Pakseresht (2016), we considered “consumers’ evaluation” as a comprehensive concept for consumers’ views on insect-based feedstuff, which represents measures such as likelihood or

intention to perform a behaviour, willingness to pay or eat, acceptance/adoption, and attitudes.

2. Method

2.1. Selection of relevant research papers

A systematic literature review comprises four key features: (a) literature collection; (b) carefully assessing the quality of the literature; (c) establishing a protocol to collate scientific evidence; and (d) ensuring a robust, transparent, replicable and evidence-based selection process (Briner & Denyer, 2012; Mallett, Hagen-Zanker, Slater, & Duvendack, 2012; Petticrew & Roberts, 2008; Waddington, White, Snilstveit, Hombrados, Vojtkova, Davies, et al., 2012).

Following the PRISMA reporting approach (Page et al., 2021), empirical research articles were collated relating to consumer acceptance of foods derived from animals fed insect-derived feedstuffs. A systematic process was applied in identifying, screening and appraising the eligibility of papers, using the PRISMA protocol (Moher, Shamseer, Clarke, Ghersi, Liberati, Petticrew, et al., 2015), (Fig. 1). Only articles published in English were included in the review.

Four databases were searched (Scopus, ISI Web of Science, AgEcon Search and Google Scholar), with the latter two enabling identification of relevant literature (Haddaway, Collins, Coughlin, & Kirk, 2015). Searches were performed using a combination of different search terms specific to each database. Only articles from the past 20 years (1995 onwards) were included, to ensure that the publications were recent, utilised up-to-date methodologies, and were in line with recent relevant policy. Search strings were trialled and refined in a multi-step process, with the face validity of each search addressed by checking search results for key authors identified through an initial search. Boolean searches were performed on title, abstract and keywords in each database, with the following query: (consumer*) AND (“feed” OR “meal”) AND (insect* OR “entomophagy”) AND (accept* OR assess* OR evaluat* OR attitud* OR intent* OR willing*).

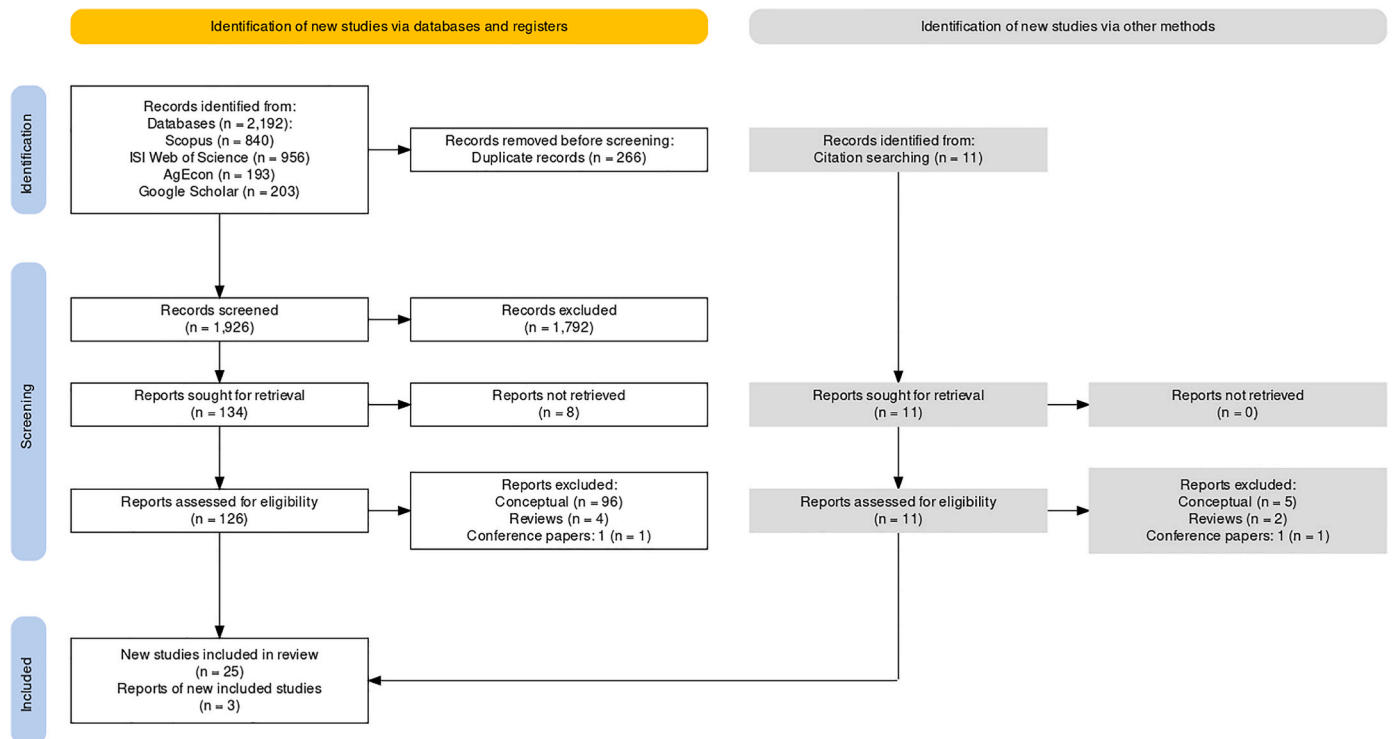


Fig. 1. Flow diagram (Page et al., 2021) of the literature selection process and criteria applied in different steps of the process (Haddaway, Page, Pritchard, & McGuinness, 2022).

The searches generated 840 articles from Scopus, 956 from Web of Science, 193 from AgEcon and 203 from Google Scholar (see Fig. 1). These articles were imported into the EndNote library, 266 duplicates were removed, and 1926 articles were included in the preliminary list. After screening titles and abstracts ($n = 1926$), and excluding reports not retrievable ($n = 8$), 126 articles were assessed against eligibility criteria (Table 1), and 101 were discarded. The remaining 25 peer-reviewed articles were considered eligible for full-text review. Reference lists of included articles were assessed for supplementary literature, which yielded three additional papers (see Table A1 in Appendix I).

2.2. Screening and data extraction

Titles and abstracts were screened using a liberal-accelerated approach (i.e. potentially relevant records were identified by one reviewer and a second independent reviewer screened records excluded by the first reviewer) (Pussegoda, Turner, Garritty, Mayhew, Skidmore, Stevens, et al., 2017). The full-text screening was carried out independently by two of the authors and 5% pilot testing was carried out at both screening levels. In cases of disagreement on the eligibility of an article for inclusion, consensus was reached through discussion and third-party arbitration.

Information extracted from retrieved articles included research design, sample size/country, outcome variables and factors impacting consumers' evaluation (Tables A1 and A2 in Appendix I). The key findings were summarised and tabulated to synthesise existing knowledge on factors predicting consumer acceptance of insects in animal feed.

In terms of the geographical distribution of the data collected in the 28 articles, most focused on Italy (8 articles), followed by Germany (4 papers) and the United Kingdom (3 papers) (Fig. 2a). Two journals, *Journal of Insects as Food and Feed* and *Food Quality and Preference*, were identified as most frequently publishing relevant articles (Fig. 2b).

The majority of research articles identified focused on insect-based feeds for fish and poultry, with some assessing acceptance of insect-based feedstuffs in general (Fig. 3; Table A3 in Appendix I). Percentage acceptance across product categories over aggregated sample sizes of 28 studies is shown in Fig. 4 (for details refer to Table A3 and Table A4 in Appendix I). Overall consumer acceptance of foods derived from animals fed insects was 54%, irrespective of product type (mean acceptance across all product categories). Using insects as feed for laying hens (mean = 75%, std = 13%) and fish (mean = 64%, std = 12%) was more acceptable than using insects to feed cattle (mean = 49%, std = 2%), poultry (mean = 42%, std = 13%) and pigs (mean = 35%, std = 10%). Acceptance when the type of product did not mention the animal being fed insects (General) was moderate and around 60%.

The majority of the articles in the dataset employed a quantitative approach (survey: 23, experiments: 3). One article reported applying

Table 1
Inclusion and exclusion criteria.

Inclusion criteria
<ul style="list-style-type: none"> Articles focus on consumer behaviour or evaluation of insects as feed Articles presenting original results of primary empirical studies, both qualitative and quantitative (e.g. focus group discussions, surveys, experiments) Full-text papers published in peer-reviewed journals Published from January 2008 to November 2022 Accessible full-text papers written in English
Exclusion criteria
<ul style="list-style-type: none"> Articles not discussing consumer attitude/intention/willingness to purchase foods derived from animals fed insects Articles not presenting original empirical data (such as review articles, opinion papers, discussion papers) Conference proceedings, book chapters, unpublished theses and position papers Papers focusing on other aspects of indirect entomophagy (such as production processes, sensory analysis of derived foods, regulations, media coverage) Trends in feed and animal husbandry Physiological aspects of feed developments

qualitative methodology (focus group) and one reported use of mixed methods. As quantitative and qualitative data were included in the analysis and as a large variety of measures and scales were used to measure consumer attitudes, meta-analysis was not possible. Therefore, narrative analysis was conducted following the Economic and Social Research Council (ESRC) narrative synthesis guidelines (Popay, Roberts, Sowden, Petticrew, Arai, Rodgers, et al., 2006). A summary table was initially created to provide an overview of the different articles, enabling the lead author to become familiar with the data prior to coding. This formed the basis of the thematic coding approach applied (Braun & Clarke, 2006; Thomas & Harden, 2008). The data were then analysed using QSR NVivo 10.

At least 12 factors affecting consumer acceptance of foods derived from animals fed insect meal were identified. These were: attitudes, environmental concerns, emotions, demographic differences, knowledge, sensory expectations, perceived risk-benefit, perceived quality, price, product/technology type, traceability and labelling, and cultural values (Fig. 5). Demographics, environmental and ethical concerns, attitudes to, and knowledge about insect feed technology, and emotional responses to the use of insect-based feedstuffs in animal production supply chains were most frequently reported, although this may be a construct of the methodology and analysis applied (see Table A2 Appendix I). Table 2 summarises these factors, which are further elaborated upon in sections 3.1-3.12 (detailed analyses are provided in Table B1 Appendix II).

3. Results

3.1. Attitude and personality traits

Research has shown that attitude is an important determinant of acceptance of novel food technologies and their applications (e.g., Byrka, Kaiser, & Olko, 2017; Frewer, 2003). In the set of articles reviewed in the present study, between 32% and 68% of consumers accepted insects in animal feed, although the figure depended on the type of supply chain assessed (Domingues et al., 2020; Kostecka et al., 2017; Mancuso et al., 2016; Spartano & Grasso, 2021b; Weinrich & Busch, 2021).

Domingues et al. (2020) examined factors influencing consumers' evaluation of products derived from animals-fed insects and reported an association between positive attitudes to the technology and acceptance of use of insect meals to feed poultry, pigs, cattle, and fish. Spartano and Grasso (2021b) found that positive attitudes towards insects as feed increased consumer willingness to try eggs laid by hens fed with insects, while Sogari et al. (2022) observed that attitudes towards the technology predicted intention to purchase farmed duck fed with insects. In contrast, Giotis and Drichoutis (2021) found that respondents exhibited support for innovative sources of food, but were not necessarily willing to consume products derived from these innovations. In an Italian study on consumer acceptance of farmed fish-fed insect meals, positive attitudes exhibited by 90% of respondents were primarily motivated by their general interest in the subject of insect-based animal feedstuffs, while their willingness to purchase fish-fed insect meal was linked to product cost, provided that sanitary standards were followed (Mancuso et al., 2016).

3.2. Environmental and animal welfare concerns

3.2.1. Environmental concerns

Consumer behaviour and evaluation of sustainable novel foods may be influenced by attitudes to the environment (Slade, 2018). Consumer willingness to adopt environmentally friendly behaviours is also influenced by attitudes to the environment, with adoption being more likely to occur if people are more concerned about environmental issues (Byrka et al., 2017). Environmental and ethical concerns may play a role in consumer acceptance of insect-based feedstuffs (e.g., Bazoche &

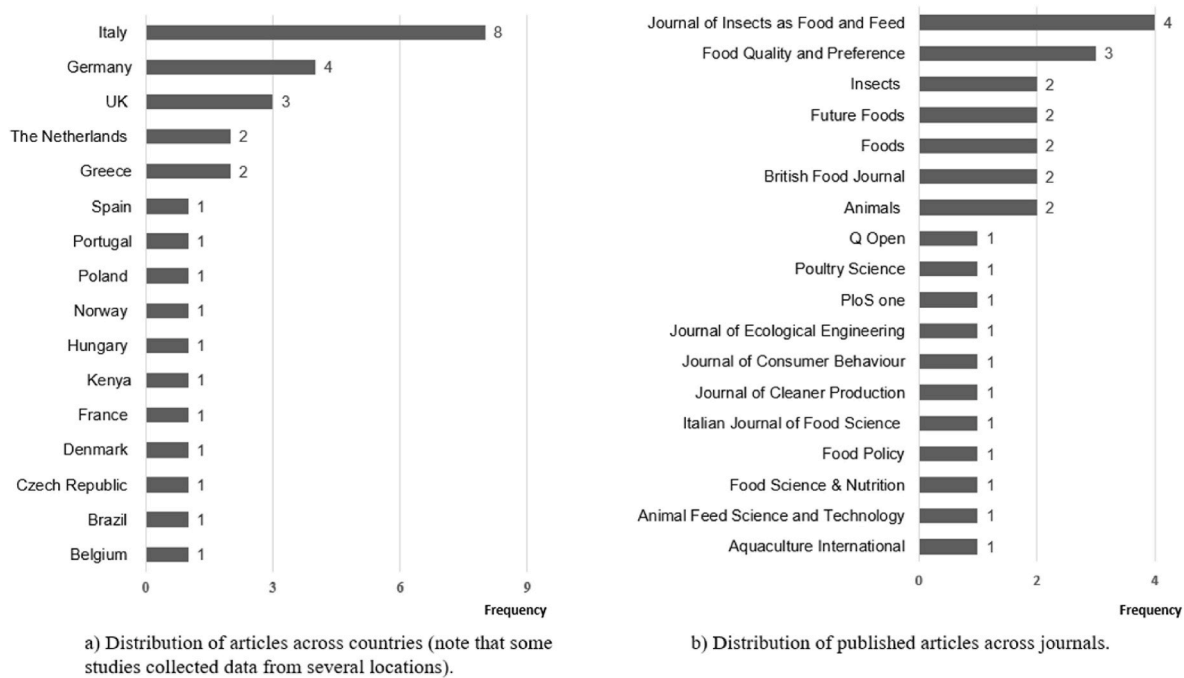


Fig. 2. Geographical location and publication source of retrieved research articles on consumer acceptance of insect-based feedstuffs (n = 28). Note that some studies included samples from more than one country (e.g. Naranjo-Guevara, Fanter, Conconi, & Floto-Stammen, 2021; Ribeiro, Gonçalves, Moura, Varela, & Cunha, 2022).

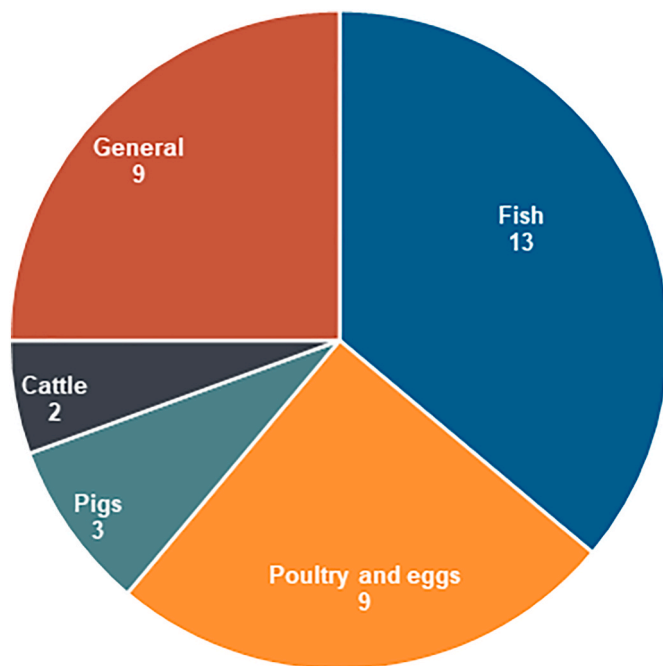


Fig. 3. Proportions of papers with a focus on insect-based feedstuffs in general or on feedstuffs for specific livestock species (total number of papers reviewed was 28, some articles included more than one product). (Figure in color). (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

Poret, 2021; Khaemba et al., 2022; Laureati et al., 2016; Mancuso et al., 2016; Sogari et al., 2022).

Altmann et al. (2022) reported a positive association between environmental awareness and consumer support for sustainable label cues, with less environmentally conscious consumers having more negative attitudes to chicken breasts produced using birds fed with insects

compared to conventional soybean in their feed. Giotis and Drichoutis (2021) found a positive association between environmental sensitivity and consumer acceptance of insects in fish feed, while Lippi et al. (2021) found that the majority of respondents who favoured eggs from hens fed insects expressed environmental concerns and believed that insect-based feedstuffs can help reduce environmental impacts. Consumers with greater levels of environmental concern were also reported to be more likely to eat farmed fish-fed insect meal (Baldi et al., 2021; Bazoche & Poret, 2021; Laureati et al., 2016; Mancuso et al., 2016; Sogari et al., 2022).

Naranjo-Guevara et al. (2021) reported that the majority of respondents supported sustainable development and expressed a preference for environmentally friendly food choices. However, increased environmental concerns were not associated with acceptance. Ankomah-Yeboah, Jacobsen, and Olsen (2018) examined the role of insect-based fish feed in consumer preference for fish attributes and found that consumers showed a higher preference for sustainability attributes associated with trout (e.g. organic labels and Aquaculture Stewardship Council ecolabel) compared to those which were conventionally reared, but that the majority were indifferent to whether or not the fish were being fed insect-based feed. Spartano and Grasso (2021b) found that environmental concerns did not directly affect willingness to try eggs from hens fed insect meal.

3.2.2. Animal welfare concerns

Animal welfare concerns related to laying hens were reported to be associated with a substantial decrease in the likelihood of willingness to try eggs (Spartano & Grasso, 2021b). Respondents with higher concern for hen welfare were found to purchase free-range or organic eggs, but not eggs from hens fed with insects (Spartano & Grasso, 2021b). In comparison with an insect-based production system, free-range hen production was perceived as more animal welfare-oriented and hence was preferred by consumers, although free-range production involves the consumption of insects as a natural dietary component (Szendrő et al., 2020).

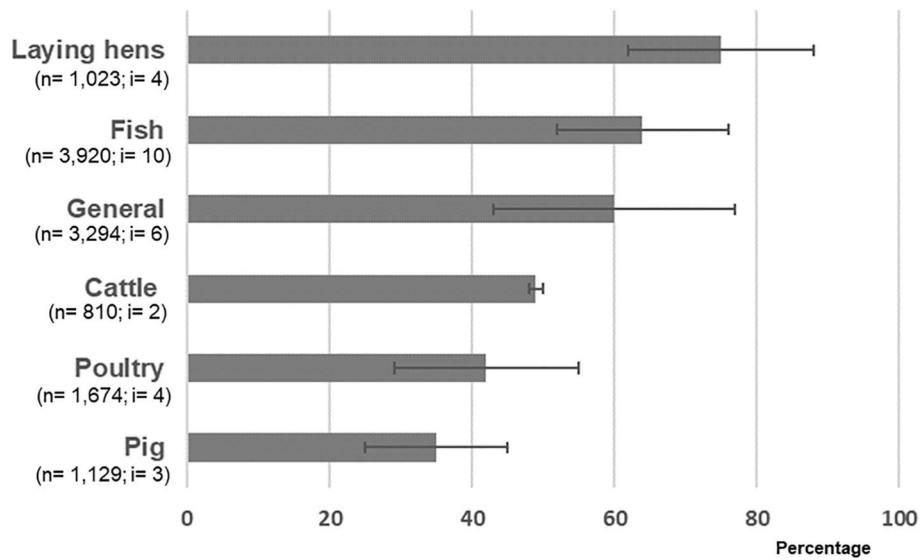


Fig. 4. Overall percentage, consumer acceptance of using insect-based feed for different end product types and aggregated sample size. Total number of participants (n) associated with product categories (i.e. fish, poultry, laying hens, pigs, cattle, and general) across related articles (i) is indicated in brackets. Overall aggregated sample size including all categories was 11,850 and overall acceptance rate was 57% across all 28 papers.

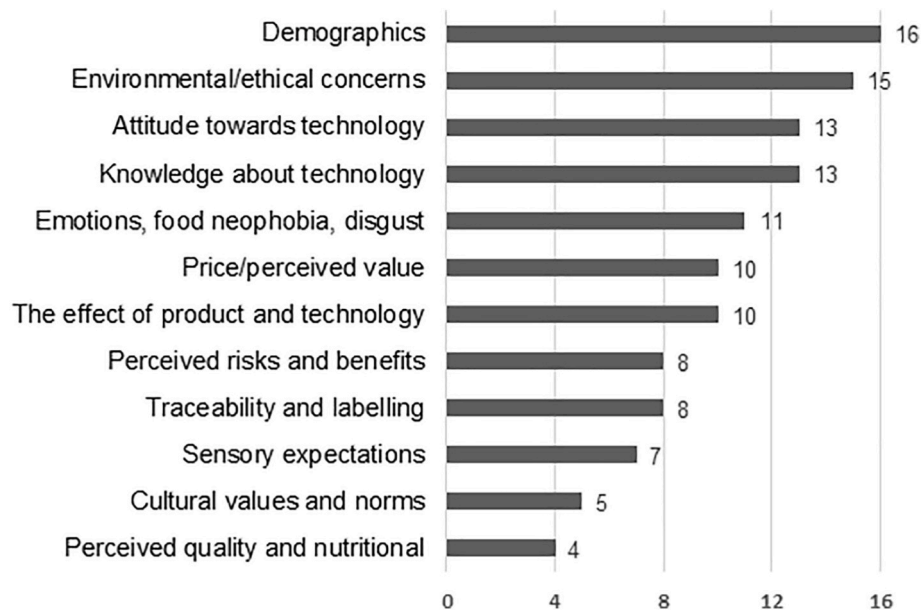


Fig. 5. Frequency of factors examined in the reviewed articles (total papers = 28).

3.3. Consumer emotional responses

Food neophobia and disgust may influence consumer food choices (Henchion et al., 2013; Noppers, Keizer, Bolderdijk, & Steg, 2014; Wood & Moreau, 2006). Food neophobia is associated with consumer aversion to consuming new foods and is linked to culture and risk perceptions (Nezlek & Forestell, 2019; Tuorila, Lähteenmäki, Pohjalainen, & Lotti, 2001). Disgust is defined as a reactive emotion triggered by food-related cues to avoid ingestion of potentially noxious and/or contaminated substances (Curtis & Biran, 2001; Egolf, Hartmann, & Siegrist, 2019; Hartmann & Siegrist, 2018). Individuals with a high degree of food disgust sensitivity are prone to react more severely to cues that imply decay or inedibility (Hartmann & Siegrist, 2018, 2020).

Emotional factors such as food neophobia and disgust were identified as barriers to acceptance of insects as animal feed in many of the articles reviewed (Bazoche & Poret, 2021; La Barbera et al., 2020; Laureati et al.,

2016; Lippi et al., 2021; Ribeiro et al., 2022; Spartano & Grasso, 2021b; Zamparo et al., 2022). Lippi et al. (2021) found that greater expression of food neophobia was negatively correlated with the acceptance of eggs from laying hens fed a diet based on insects. Similarly, Laureati et al. (2016) and Bazoche and Poret (2021) found that less neophobic consumers were more likely to accept foods derived from animals fed with insects.

A recent study by Zamparo et al. (2022), examining the role of food neophobia and food technology neophobia in acceptance of insects in animal feed, confirmed the importance of neophobic feelings, particularly food technology neophobia, in influencing consumer attitudes to insect-based feedstuffs. Similarly, less neophobic consumers have been found to be more likely to accept insects as feed, but some participants experienced a sense of disgust in relation to the idea of eating fish fed insect meal (Bazoche & Poret, 2021). Szendrő et al. (2020) found that consumers were generally willing to eat food derived from insect-based

Table 2
Summary of factors affecting acceptance of food derived from animals fed insect-based diets.

Factor	Impact/evidence	References
Attitude and personality traits	Attitudes to feed production processes influence consumer support for the resultant products	Sogari et al. (2022), Zamparo, Cunico, Vianelli, and Moretti (2022), Spartano and Grasso (2021b), Weinrich and Busch (2021), La Barbera, Verneau, Videbæk, Amato, and Grunert (2020), Domingues, Borges, Ruviano, Gomes Freire Guidolin, and Rosa Mauad Carrijo (2020), Mancuso, Baldi, and Gasco (2016) Verbeke et al. (2015) Giotis and Drichoutis (2021), Lippi et al. (2021), Szendrő, Nagy, and Tóth (2020)
Environmental and animal welfare concerns	Consumers perceive insect-based animal feed to be more sustainable and better for the environment. Consumers who express greater environmental concerns are more likely to accept food derived from animals fed with insects. Animals fed with insects are perceived to be healthier than animals fed conventional feed. Although consumers may express support for healthy and environmentally friendly foods, these concerns do not directly affect their willingness to consume foods produced using insects.	Altmann, Anders, Risius, and Mörlein (2022), Ankamah-Yeboah, Jacobsen, and Olsen (2018), Khaemba et al. (2022), Mancuso et al. (2016) Altmann et al. (2022), Sogari et al. (2022), Baldi, Mancuso, Peri, Gasco, and Trentinaglia (2021), Bazoche and Poret (2021), Giotis and Drichoutis (2021), Laureati, Proserpio, Jucker, and Savoldelli (2016), Lippi et al. (2021) Verbeke et al. (2015)
Emotions	Food neophobia and disgust are barriers to acceptance of foods produced using insect-based feedstocks. Consumers show moderate to high food neophobia and/or disgust to foods derived from animals fed insects, but these reactions are not associated with consumer acceptance or rejection.	Ribeiro et al. (2022), Zamparo et al. (2022), Bazoche and Poret (2021), Giotis and Drichoutis (2021), Lippi et al. (2021), La Barbera et al. (2020), Roma, Palmisano, and De Boni (2020), Spartano and Grasso (2021b), Laureati et al. (2016) Altmann et al. (2022), Naranjo-Guevara et al. (2021)
Demographics	Young males with higher education are more favourable towards insects as animal feed.	Baldi et al. (2021), Ribeiro et al. (2022), Menozzi et al. (2021), Szendrő et al. (2020), Kostecka, Konieczna, and Cunha (2017), Laureati et al. (2016), Mancusom et al. (2016)

Table 2 (continued)

Factor	Impact/evidence	References
	There are no statistically significant differences in acceptance of foods derived from animal fed insects between demographic groups (i.e. gender, education, age, etc.). People who are more willing to try new foods or have more trust in the food actors are more likely to accept insect-based feed processes.	Popoff, MacLeod, and Leschen (2017), Rumbos, Mente, Karapanagiotidis, Vrontzos, and Athanassiou et al. (2021), Spartano and Grasso (2021b), Verbeke et al. (2015) Giotis and Drichoutis (2021)
Knowledge about insect-based feed	Consumers with prior knowledge (awareness) of insect-based feed processes are more receptive to it. Provision of information on the advantages of rearing insects as animal feed results in more support for food derived from animals fed insects. Informed consumers interpret new information about insect-based feeds in alignment with their existing views, which does not necessarily result in increased willingness to consume. Consumers are relatively uninformed about insect-based livestock feed.	Khaemba et al. (2022), Sogari et al. (2022), Baldi et al. (2021), Spartano and Grasso (2021b) Altmann et al. (2022), Bazoche and Poret (2021), Menozzi et al. (2021), Naranjo-Guevara et al. (2021) Popoff et al. (2017), Rumbos et al. (2021)
Sensory expectations	Appearance of foods derived from livestock fed insects is the most important product attribute in food choice Consumers are willing to eat novel food products produced using insect-based feeds as long as the foods do not taste like insects. Consumers with previous tasting experience of insect-based foods produced using entomophagy are more likely to accept food derived from insect-fed animals.	Rumbos et al. (2021), Spartano and Grasso (2021a), Spartano and Grasso (2021b), Weinrich and Busch (2021), Ferrer Llagostera, Kallas, Reig, and Amores de Gea (2019), Popoff et al. (2017) Altmann et al. (2022), Lippi et al. (2021), Roma et al. (2020), Ferrer Llagostera et al. (2019) Mancuso et al. (2016) Bazoche and Poret (2021)
Perceived risk and benefit	There is a high level of concern regarding the health risks associated with foods derived from animals fed insects. Consumers perceive no specific health adverse effects from consuming food from animals fed insect-based feed. Consumers see sustainability and environmental advantages of rearing insects as animal feed.	Sogari et al. (2022), Spartano and Grasso (2021b) Khaemba et al. (2022), Mancuso et al. (2016), Verbeke et al. (2015) Bazoche and Poret (2021), Szendrő et al. (2020) Rumbos et al. (2021), Ferrer Llagostera et al. (2019)

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Table 2 (continued)

Factor	Impact/evidence	References
Perceived quality and nutritional value	Consumers perceive food produced from insect-based feed to be of higher nutritional value. Willingness to pay for insect-based feed is higher among environmentally conscious consumers. Consumers perceive that feeding insect-based feed to animals will lower the price of foods derived from these animals.	Khaemba et al. (2022), Weinrich and Busch (2021), Verbeke et al. (2015) Altmann et al. (2022), Giotis and Drichoutis (2021), Ferrer Llagostera et al. (2019) Khaemba et al. (2022), Bazoche and Poret (2021), Lippi et al. (2021), Spartano and Grasso (2021a), Spartano and Grasso (2021b), Ankamah-Yeboah et al. (2018), Mancuso et al. (2016)
Effect of product/technology type	Insects as animal feed are more acceptable to consumers than insects as human food. Insects as a supplementary ingredient in animal feed are perceived as more acceptable than “complete” insects. On average, consumers are more positive about using insects to feed fish and poultry rather than to feed pigs and cattle.	Ribeiro et al. (2022), Onwezen, Van den Puttelaar, Verain, and Veldkamp (2019), Giotis and Drichoutis (2021) Verbeke et al. (2015) Ribeiro et al. (2022), Menozzi et al. (2021), Kostecka et al. (2017)
Traceability and labelling	Mandatory labelling and certificates of quality are essential for food derived from animals fed insects if the resulting products are to be acceptable to consumers.	Altmann et al. (2022), Khaemba et al. (2022), Giotis and Drichoutis (2021), Lippi et al. (2021), Menozzi et al. (2021), Popoff et al. (2017), Verbeke et al. (2015)
Cultural values and norms	The effects of cultural values and social norms are mixed.	Khaemba et al. (2022), Ribeiro et al. (2022), Naranjo-Guevara et al. (2021), Weinrich and Busch (2021), Onwezen et al. (2019)

diets but that unfamiliarity with new foods and an associated sense of disgust played a significant role in forming a behavioural intention. Acceptance of insects as feed is linked to both food neophobia and feelings of disgust (La Barbera et al., 2020), with experience of neophobia and disgust negatively affecting the intention to eat insect-derived foods (Roma et al., 2020). Giotis and Drichoutis (2021) found that respondents regarded eating duck fed an insect-based diet as ‘disgusting’, but this feeling differed significantly from that in a group which received information about the supply chain, with disgust being more frequently expressed among female participants. However, medium levels of food neophobia have been found to be uncorrelated with consumer acceptance of using insects as animal feed (Naranjo-Guevara et al. (2021). Altmann et al. (2022) observed that research respondents reported experiencing disgust for both insect and algae feedstuffs used in producing chicken feed, but their analysis did not indicate that food neophobia predicted acceptance of novel feedstuffs.

3.4. Knowledge about technology

Research has shown an association between greater knowledge of agri-food technologies and attitudes towards these (Armitage & Conner, 2001; Rollin, Kennedy, & Wills, 2011). Lack of knowledge about food technology and its potential benefits (and risks) may influence consumer reluctance to accept new technologies used in food production (Bhat, Kumar, & Fayaz, 2015; Lusk, Roosen, & Bieberstein, 2014; McCluskey &

Swinnen, 2011).

Llagostera, Kallas, Reig and De Gea (2019) report that respondents revealed moderate objective knowledge regarding aquaculture production systems, while self-reporting higher (subjective) knowledge. Spartano and Grasso (2021b) found that individuals with self-reported knowledge of insects as feed showed a more positive attitude to eggs from hens fed insects and associated less disgust with such eggs.

Providing information can reassure individuals about the environmental impact and safety of insect farming and its end products (Baldi et al., 2021). There is evidence that this increases acceptance of other novel foods, such as insects as human food (e.g. Mancini et al. (2019), genetically modified foods (e.g. Hobbs and Plunkett (1999) and aquaculture products (e.g. Pieniak, Vanhonacker, and Verbeke (2013)). Menozzi et al. (2021) examined the effect of technology information on consumer attitudes to use of insects in poultry feed and found that providing non-technical information on the advantages of insect-based feedstuffs significantly increased favourable attitudes towards ducks reared on insect-based meals and live insects, while also increasing willingness to buy derived products. Similar results were reported in other articles in our dataset (e.g., Baldi et al., 2021; Bazoche & Poret, 2021; Naranjo-Guevara et al., 2021; Verbeke et al., 2015), suggesting the provision of information may result in more favourable attitudes to insects as animal feed.

Weinrich and Busch (2021) identified incongruence in subjective and objective consumer knowledge regarding animal feed options, where the more respondents perceived insects to be environmentally friendly, the higher their acceptance of the derived products. Spartano and Grasso (2021b) concluded that prior familiarity with insects as feed technology can mitigate the negative effects of neophobia and disgust. However, Altmann et al. (2022) found that while providing information increased the positivity of attitudes to insects as feedstuffs, underlying environmental values held by consumers were more influential for their ultimate acceptance of insect feedstuffs in chicken production.

3.5. Sensory expectations

Table 2 summarises the sensory expectations of consumers (derived from hypothetical products) associated with the use of insects as feed (e.g., Altmann et al., 2022; Bazoche & Poret, 2021; Lippi et al., 2021; Spartano & Grasso, 2021b). Altmann et al. (2022) found that chickens fed insect meals had less visibly yellow meat than chickens fed a conventional soybean-based diet, which was preferred by participating consumers. In relation to fish, it has been reported that consumers were generally willing to eat fish fed with insect meal as long as the fish did not taste like insects (Bazoche & Poret, 2021). However, Llagostera, Kallas, Reig, and De Gea (2019) found that consumers expected gilthead sea bream fed insect meal to have poorer sensory properties than wild-caught bream.

3.6. Perceived risks and benefits

Perceived risk-benefit trade-offs have been found to influence consumer acceptance of novel food technologies (for reviews refer to Finucane & Holup, 2005; Frewer, van der Lans, Fischer, Reinders, Menozzi, Zhang, et al., 2013). How consumers perceive food risk (e.g., Magnusson & Koivisto Hursti, 2002; Marette, Roosen, Blanchemanche, & Feinblatt-Mélèze, 2010; Redmond & Griffith, 2004; Siegrist, Stampfli, & Kastenholz, 2009; Webster, Jardine, Cash, & McMullen, 2010; Williams & Hammit, 2001) and how risk is evaluated in comparison to other attributes in relation to food choices (e.g., Loureiro & Umberger, 2007; Van Wezemael, Verbeke, Kügler, & Scholderer, 2011) has been a focus of previous research.

Rumbos et al. (2021) showed that consumers perceived the use of insects in aquafeeds to be a sustainable production technology that improves the ecological footprint of aquaculture. Perceived environmental advantages of insects as feed were also identified in other studies

in the dataset (e.g., Ferrer Llagostera et al., 2019; Verbeke et al., 2015).

A study by Weinrich and Busch (2021) found that participants perceived no specific risks associated with the use of insects as feed for poultry and pigs. Verbeke et al. (2015) found that in addition to improving ecological livestock impacts, consumers believed that insect-based feed can help lower national dependence on imported protein sources, at the same time expressing concerns about microbiological risks associated with insect-based feeds and potential impacts on biodiversity if insects are accidentally released into the environment. Mancuso et al. (2016) found that the majority of their respondents had positive attitudes to farmed fish fed insect meals and expressed a strong intention to purchase these products, assuming hygiene requirements are met. Consumers have been found to be increasingly concerned with food safety throughout the entire food chain (Baldi et al., 2021; Kher, De Jonge, Wentholt, Deliza, de Andrade, Cnossen, et al., 2013; Mol, 2015; van Rijswijk & Frewer, 2008).

3.7. Perceived quality and nutritional value

A significant proportion of consumers in the articles reviewed perceived that foods derived from animals fed insects in their diet were of high quality and rich in nutrients (Khaemba et al., 2022; Verbeke et al., 2015; Weinrich & Busch, 2021). Participants with a negative attitude to consuming fish fed insect meal expressed low trust in the quality and nutritional value of the fish (Rumbos et al., 2021). Verbeke et al. (2015) reported that respondents perceived food from animals fed insect-based feed to be of good nutritional value and healthy, but were concerned about potential allergic reactions (Table 2).

3.8. Price and perceived value

Higher consumer support has been reported for purchasing eggs produced from hens fed black soldier fly larval-based feed regardless of the price (Kahemba et al., 2022). Giotis and Drichoutis (2021) found consumer willingness to pay a higher premium for gilt-head bream fed insect-based feed than for food products containing insects for immediate consumption. On addition, consumer willingness to pay was greater for gilt-head sea bream fed a mixture of insect and vegetable meal rather than a solely insect-based meal (Ferrer Llagostera et al., 2019). However, in contrast, consumers may be price-sensitive to foods derived from animals fed alternative meals (Ankamah-Yeboah et al., 2018; Lippi et al., 2021; Mancuso et al., 2016; Spartano & Grasso, 2021a, 2021b). Choice experiments on three feedstuff alternatives (insect, algae, soy) showed that when priced similarly, chicken fed insect meal was chosen most frequently (48.9% across groups that received information about insect as feed technology and 34.2% for uninformed groups) (Altmann et al., 2022).

3.9. Effect of product technology type

In general, using insects as animal feed has been reported to be associated with greater consumer acceptance than using products containing insects for direct human consumption (Giotis & Drichoutis, 2021; Onwezen et al., 2019). Menozzi et al. (2021) observed a higher willingness to purchase duck fed insect meal compared with duck fed fishmeal or genetically modified (GM) soybean meal, but lower acceptance than for duck fed (non-GM) soybean meal. However, Weinrich and Busch (2021) found higher consumer willingness to purchase poultry and pork fed micro-algae compared with insect-based feed. Popoff et al. (2017) examined the effect on consumer acceptance of the rearing substrate used to produce insects for animal feed and found that vegetable waste was considered a more suitable substrate than animal manure, abattoir waste or human sewage.

3.10. Traceability and labelling

As indicated in Table 2, a substantial number of articles in the dataset evaluated labelling and/or certification as important product attributes linked to information provision about the use of insect-based feed in the supply chain (Altmann et al., 2022; e.g., 2018; Giotis & Drichoutis, 2021; Khaemba et al., 2022; Lippi et al., 2021; Menozzi et al., 2021; Popoff et al., 2017; Verbeke et al., 2015). Lippi et al. (2021) found that labelling was important to consumers with environmental and health concerns and to consumers who were already willing to consume insects in their diets. Popoff et al. (2017) found that the majority of consumers they surveyed wanted product labels indicating whether fish had been fed insects, together with information about the type of waste substrates used to rear the insects. Altmann et al. (2022) reported that the presence of health or pro-environmental labels on food products produced using insect-based feeds significantly and positively influenced consumer acceptance, adding to findings on how sustainability labelling influences consumer food choices (e.g., Grunert, Hieke, & Wills, 2014; Peschel, Grebitus, Steiner, & Veeman, 2016; Van Loo, Caputo, Nayga, & Verbeke, 2014) and how health claims affect consumer decision-making regarding food from animals (Altmann et al., 2022).

3.11. Cultural values and norms

Our results indicate that consumers are relatively receptive towards the idea of using insects as feed and the location of data collection does not play a major role in consumers' choice. Exceptionally, Weinrich and Busch (2021) in Germany and Ribeiro et al. (2022) in Italy observed relatively lower consumer support for this technology. Cultural aspects of food choices were not examined in most of the articles retrieved and evidence of a significant effect of culture on food choice in relation to animals fed insect-based feedstuffs was not identified in those which did (e.g., Naranjo-Guevara et al., 2021) (Table 2). For example, Khaemba et al. (2022) found that the consumption of eggs from hens fed black soldier fly larvae-based feed was not culturally or religiously problematic. In contrast, Weinrich and Busch (2021) found that social norms influenced consumer intentions to buy poultry fed insect meal, but that the impact of attitudes towards the product was considerably stronger. Onwezen et al. (2019) observed that consumers with weak personal attitudes in relation to their own health or the environment were more likely to accept insect-based products positioned with affective clues ('feel good about yourself') rather than cognitive messages ('research shows').

3.12. Demographic factors

The reported effect of demographic factors on evaluation of insects in animal feed was contradictory (e.g., Domingues et al., 2020; Naranjo-Guevara et al., 2021; Ribeiro et al., 2022; Rumbos et al., 2021) (Table 2). Some articles retrieved did not identify an association between sociodemographic factors and acceptance of insect feed (e.g., Naranjo-Guevara et al., 2021; Popoff et al., 2017; Spartano & Grasso, 2021b; Verbeke et al., 2015), but Baldi et al. (2021), Bazoche and Port (2021), Giotis and Drichoutis (2021) and Laureati et al. (2016) all reported a higher likelihood of acceptance for younger males. Domingues et al. (2020) found that higher income was associated with a substantial reduction in the likelihood of accepting insects in aquafeed. Moreover, Giotis and Drichoutis (2021) reported that people who are more willing to try new foods or have more trust in the food actors are more likely to accept insect-based feed processes.

4. Discussion

Understanding drivers of public acceptance is important to the development of insect-based feed technology (Smith & Barnes, 2015; Sogari, Amato, Biasato, Chiesa, & Gasco, 2019). In this systematic

review, we synthesised relevant factors potentially influencing consumer acceptance of insect-based feedstuffs. Three broad themes were identified: a) overall positive consumer disposition towards insects as animal feed, b) knowledge and heuristic cues (such as perceived healthiness and disgust evoked by the unfamiliar technology) as drivers of consumer acceptance and c) effects of environmental and ethical concerns on acceptance.

4.1. An overall positive attitude towards insects as animal feed

Using insects as livestock feed appears to be more acceptable than using insects as human food (e.g., Domingues et al., 2020; Giotis & Drichoutis, 2021; Kostecka et al., 2017; Mancuso et al., 2016; Spartano & Grasso, 2021b; Verbeke et al., 2015). Consumer acceptance of insects as feed may be positively influenced by overall attitudes towards entomophagy (Baldi et al., 2021; Mancuso et al., 2016). This corroborates suggestions by Smith and Barnes (2015) and Sogari et al. (2019) that consumer acceptance will not be a barrier to the use of insect protein in the livestock feed industry. Acceptance of novel foods may start with initial perceptions and attitudes linked to the technology (Albertsen, Wiedmann, & Schmidt, 2020; Fishbein & Ajzen, 2011; Siegrist & Hartmann, 2020). Risk-benefit perceptions influence attitudes regarding the behavioural intention to adopt (perceived benefit) or reject (perceived risk) a novel food technology (Frewer, Howard, & Shepherd, 1998; Pofinhos, van der Lans, Rankin, Fischer, Bunting, Kuznesof, et al., 2014), and hence a willingness to purchase and consume the resulting products (Rogers, Singhal, & Quinlan, 2014; Sogari et al., 2022). The available evidence indicates higher consumer acceptance of rearing insects for feeding fish and poultry compared to pigs and cattle (Domingues et al., 2020; Ribeiro et al., 2022). One explanation is that insects are a natural dietary ingredient for poultry and fish, but not for cattle, pigs and many types of pet (Menozzi et al., 2021; Szendrő et al., 2020), since production processes perceived as more “natural” are more acceptable to consumers (see. *inter alia*, Frewer, Bergmann, Brennan, Lion, Meertens, Rowe et al., 2011; Jin et al., 2022). Similarly, feeding live insects to animals may gain higher acceptance by consumers than feeding processed insect meal, since the former is perceived as “organic” feed (Menozzi et al., 2021). For example, Smith and Barnes (2015) found that the majority of consumers perceive fly larvae to be a suitable source of protein for use in animal feed.

Positive attitudes towards specific food technologies have been found to influence consumer support for products derived from these technologies (Albertsen et al., 2020; Frewer, 2003; Gupta, Fischer, & Frewer, 2011; Ronteltap, van Trijp, Renes, & Frewer, 2007). However, general support for insect-based feed technology does not necessarily mean willingness to consume food derived from such feeds (Giotis & Drichoutis, 2021), as price is also an important consideration (Sogari et al., 2019). Fishmeal is currently a more price-competitive feed source than insect-based feed, but fishmeal prices are predicted to rise in the future because of over-exploitation of fish stocks globally (Fellows et al., 2014; Makkar, Tran, Heuzé, & Ankers, 2014). For insects to be a viable substitute source of protein (particularly for pigs and poultry), the price needs to be lower than that of fish meal (currently 1.75 USD per kg). This price differential is likely to be reflected in food retail prices (Gasco et al., 2021).

In agreement with previous findings on the acceptance of insects as human food (Alemu, Olsen, Vedel, Pambo, & Owino, 2017; Elzerman, Hoek, Van Boekel, & Luning, 2011; Hartmann, Shi, Giusto, & Siegrist, 2015; Hartmann & Siegrist, 2016; Megido, Gierts, Blecker, Brostaux, Haubruge, Alabi, et al., 2016; Tan, van den Berg, & Stieger, 2016), the articles reviewed suggested that the composition and level of processing of insect feed can affect consumer responses. Megido et al. (2016) argue that the commercialisation of insect-based products should begin with the incorporation of powdered or minced insects in the feed, rather than whole visible insects. Similarly, Verbeke et al. (2015) found that consumers are more receptive to insects as supplementary ingredients in

animal feed than as substitutes for conventional animal feeds. Therefore, processing of insect-based products so that whole or recognisable insects cannot be identified following processing is associated with a higher level of consumer acceptance (Lippi et al., 2021; Onwezen et al., 2019), although consumers are less sensitive to insect composition and presentation in indirect entomophagy (Sogari et al., 2019; Spartano & Grasso, 2021b). Moreover, socio-demographic factors were not found to be a significant predictor of consumers' acceptance of insects as feed which is in contrast with findings related to acceptance of insects as food (e.g., Alhujaili, Nocella, & Macready, 2023).

4.2. The role of risk perception, knowledge and heuristic cues

Consumers are becoming more aware of food safety and sustainable food production processes (Baldi et al., 2021; Kher et al., 2013; van Rijswijk & Frewer, 2008). Insects are very effective in turning low-quality biomass into a rich-protein feed output and promoting a circular economy (Doi, Gałęcki, & Mulia, 2021; Naranjo-Guevara et al., 2021; Rumpold & Schlüter, 2013a). Positive impacts of insect-based animal feed on animal health, digestive performance and end-product quality have been reported (For a review refer to Sogari et al., 2019). Although rearing insects for food and feed does not result in a product which is free from pathogens, it is believed that the use of insects in this way poses a low risk of transmitting zoonotic diseases (Cao, Ye, & Han, 2015; Chia, Macharia, Diro, Kassie, Ekesi, van Loon et al., 2020; Doi et al., 2021; Lalander & Vinnerås, 2022; Van Huis, 2020). Thus while consumers may perceive rearing insects for animal feed as a sustainable technology with environmental advantages (e.g., Ferrer Llagostera et al., 2019; Rumbos et al., 2021), substantial consumer food safety concerns remain and may act as a barrier to commercialisation (Baldi et al., 2021; Mancuso et al., 2016; Verbeke et al., 2015). This emphasises the importance of providing detailed information to the public regarding food safety issues and their other concerns.

One issue identified as contributing to risk perception was consumer concern about the substrates used for insect rearing. Consumers consider vegetable waste to be a more suitable substrate on which to rear insects than other potential substrates such as animal manure, mixed food waste, abattoir waste and human sewage (Lalander & Vinnerås, 2022; Popoff et al., 2017). Risk communication could thus usefully focus on substrate safety issues. For example, insects for feed reared on vegetable-based substrates do not represent a microbiological or chemical hazard to humans and this information might be the focus of risk communication (EFSA, 2015). According to Altmann et al. (2022), labelling of production methods and feed ingredients reduces information asymmetry and leads to increased product acceptance. This raises the question of whether mandatory labelling is desirable for foods derived from animals fed an insect-based diet and how this might affect consumer acceptance (Altmann et al., 2022; Menozzi et al., 2021).

Some consumers lack knowledge of animal nutrition and entomophagy (Ferrer Llagostera et al., 2019; Popoff et al., 2017; Rumbos et al., 2021; Spartano & Grasso, 2021a, 2021b), which may reduce acceptance (Cardello, Schutz, & Lesher, 2007; Rollin et al., 2011). Providing information about the nutritional benefits of insects as animal feedstuff may increase acceptance (Bazoche & Poret, 2021; Laureati et al., 2016; Szendrő et al., 2020). Familiarity with the underpinning technology has the potential to alleviate disgust and even lower the impact of neophobia, although affective emotional reactions are only marginally changed by awareness and provision of information (La Barbera, Verneau, Amato, & Grunert, 2018; Looy & Wood, 2006; Verneau et al., 2016).

It is not clear whether a lack of consumer knowledge about animal nutrition and entomophagy has a direct impact on food choices concerning animal products produced using insect-based feeds, but the provision of information about food production processes is likely to have little impact on affective reactions (Hartmann & Siegrist, 2017; Rollin et al., 2011). Lack of knowledge of novel and emerging food

technologies, in general, can act as a significant impediment to consumer acceptance (Cardello et al., 2007; Rollin et al., 2011). Moreover, lack of transparency in supply chains as a result of failure to provide information about food technology production technologies would potentially lower trust in both the food industry and food regulators, and should thus be avoided (Earle, 2010; Wu, Zhang, van Klinken, Schrobback, & Muller, 2021).

Consumers often refer to labels, in particular in relation to credence attributes such as environmental advantages and health impacts (Fernqvist & Ekelund, 2014). Environmentally conscious consumers may use these information cues (e.g. eco-labels) to seek novel feed alternatives, but among less environmentally concerned consumers such information might raise concerns about unfamiliar effects and hence induce negative responses (Altmann et al., 2022). It has been shown that the provision of information may evoke negative associations, such as disgust and fear, about novel foods derived from algae and insects (Menozi, Sogari, Veneziani, Simoni, & Mora, 2017; Schouteten, De Steur, De Pelsmaeker, Lagast, Juvinal, De Bourdeaudhuij et al., 2016). Health labels (e.g. omega-3 health claims) may have a positive impact on consumer willingness-to-accept insect feed-derived products (Altmann et al., 2022), suggesting that perceived positive health attributes have a stronger impact on consumer acceptance than positive environmental attributes (e.g., De Marchi, Caputo, Nayga, & Banterle, 2016; Van Loo et al., 2014).

Our results indicated that studies on evaluation of insects as feed employing discrete choice experiments indicated lower levels of consumer acceptance towards insects feed technology than surveys (see Altmann et al., 2022; Ferre Llagostera et al., 2019; Onwezen et al., 2019). However, experimental research is underrepresented in the literature (3 discrete choice experiments versus 23 surveys, see Table A1-A3 in Appendix I).

4.3. Effects of environmental and ethical concerns

This review showed that providing information on the environmental advantages of adopting insect-based feed positively affects consumer perceptions, corroborating and extending previous findings that distributing information on the advantages of entomophagy technology positively influences consumer attitudes (Hartmann & Siegrist, 2016, 2018; Megido et al., 2016; Tan et al., 2016; Verneau et al., 2016). However, there is less evidence available regarding the relationship between the environmental benefits of the technology and willingness-to-eat for products produced using it. Inconsistency between environmental risk attitude and pro-environmental tendencies has been observed elsewhere (e.g., Lacroix & Gifford, 2018; Zeng, Jiang, & Yuan, 2020).

Research has shown that the framing effect can explain decision anomalies, where people seem to deviate from consistent choice behaviours (Dolgoplova, Li, Pirhonen, & Roosen, 2022). For example, the willingness to pay for insect-based feed by smallholder farmers was influenced by the way the information was presented to them, with a positive framing leading to higher willingness to pay (Chia et al., 2020). Similar results have been found in the evaluation of insect-based foods (Kröger et al., 2022). However, the impact of attribute framing on acceptance of food derived from animals fed insect-based feed is an underexamined research area.

4.4. Future research

Knowledge about consumer perceptions of different methods of insect farming is currently limited. Variations in how people perceive the risks connected to different production methods for a particular novel food have been identified, although this issue has not been considered in relation to insect food production technology (Delwaide, Nalley, Dixon, Danforth, Nayga Jr, Van Loo et al., 2015; Frewer, Howard, & Aaron, 1998; Onyango, Govindasamy, Hallman, Jang, & Puduri, 2006;

Onyango & Nayga, 2004). There are four main insect-rearing approaches: xiroculture (insects reared on dry substrates, e.g. in dry containers), hygroculture (insects reared in a humid environment, e.g. on waste vegetables and animal-based biomass), aquaculture (insects reared in tanks or semi-aquatic conditions) and xyloculture (insects reared on wood logs or sawdust) (Grabowski, Abdulmawjood, Acheuk, Barragán Fonseca, Chhay, Costa Neto et al., 2022). There may be differences in whether consumers perceive these to be natural or risky, which may in turn affect product acceptability. In addition, different insect species may generate different levels of disgust and risk perception, an issue that merits further investigation (Hartmann & Siegrist, 2017). Innovations in the area of insects as feed is not static. New applications including the use of insect fats in rabbit diets (Gasco, Dabbou, Gai, Brugiapaglia, Schiavone, Birolo, et al., 2019) or as cooking oil (Tzompa-Sosa, Dewettinck, Gellynck, & Schouteten, 2022) that are currently being developed warrant further research from a consumer acceptance perspective.

Insect rearing can be performed at different scales (e.g. multinational corporations, micro-enterprises, small-scale local farming) depending on substrate availability, technological advances or market demand (Barragán-Fonseca, Barragán-Fonseca, Verschoor, van Loon, & Dicke, 2020; Chia, Tanga, van Loon, & Dicke, 2019). Smaller-scale farming approaches may be more acceptable than larger-scale 'intensive' activities (Sogari et al., 2022). Other barriers to insect production may exist within the supply chain. Future research should consider the price implications for consumers and other stakeholders, such as feed producers and farmers, of commercial-scale development of insects as feed (Sogari et al., 2022). It is not clear whether supply chain actor perceptions of consumer requirements can act as a catalyser of innovation in this sector.

Moreover, consumers are increasingly concerned about animal welfare in food production from animals. The impact of insect-based feeds on consumer perceptions of animal welfare is not considered in depth in the existing literature. At present, insect farms apply heat to kill insects when producing insect meals, but there is increasing consensus that insects have pain receptors (nociceptors), so other methods of production (e.g. freezing) need to be examined (Van Huis et al., 2013). The impact of the insect slaughter method on consumer perceptions has not been assessed.

Finally, there is a gap in the literature regarding cultural differences in the evaluation of insects as human food and as feed for animals. Insects are an integral dietary component estimated to be included in the diet of over 2 billion people worldwide, but the concept of eating insects is still new to Western culture (Bessa, Pieterse, Sigge, & Hoffman, 2020; de Carvalho, Madureira, & Pintado, 2020; Yen, 2015). Thus, consumer research has tended to focus on the inclusion of insects in "Western" diets. Consumer acceptance of insect feed in the context of the global food system is a topic worthy of future research.

4.5. Policy implications

First, there is a need for policy interventions (e.g., labelling) to make transparent and provide information about the quality and safety standards of insect-based feed to increase consumer trust in the product. Second, policy initiatives that incentivize the production of insect-based feed could help to industrial-scale development, leading to increased production and lower costs. Finally, there is a need for regulations that ensure the responsible and ethical treatment of insects used for feed production, to address any potential ethical concerns regarding the use of insects as a novel sustainable source of protein. Further research is needed to address these concerns with multi-stakeholder perspective techniques such as systems mapping and systems thinking (for a review refer to Dentoni, Cucchi, & et al., 2022-a).

6. Conclusions

Overall, this systematic review identified relatively high consumer support for using insect meal as an animal feed component, particularly for fish. Several major interconnected themes acting as determinants of consumer acceptance of insect-based animal feed emerged in the body of literature reviewed. Important factors included knowledge and general attitude to technology, environmental and ethical concerns, heuristic cues (e.g. perceived risks, perceived quality, disgust evoked by unfamiliar technology), cultural values, labelling, price and sensory appeal. Among these, knowledge, perceptions and heuristics seem to play a more salient role than environmental and ethical concerns. Disgust and food neophobia increase consumer reluctance to eat foods derived from animal fed insects as part of their diet.

Declarations of competing interest

None.

Data availability

Data will be made available on request.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.tifs.2023.05.018>.

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