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Consumer acceptability of plant-based, seaweed-based and insect-based foods as alternatives to meat: A critical compilation of a decade of research

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26 **Abstract**

27 There is a growing criticism of meat-based products over environment, animal welfare, and
28 public health. Meat lovers are keeping and adapting their habits, while other consumers are
29 increasingly shifting towards meat alternatives considered as healthier and more sustainable
30 options to replace the animal-based products. This transition gives room in the market to plant-
31 based, seaweed-based, and insect-based meat products. Nevertheless, these emerging markets
32 are still facing the challenge of consumers' acceptance and the uncertainty in terms of
33 preferences. This paper focuses on in-depth understanding of consumer perception and
34 acceptability of plant-, seaweed-, and insect-based meat products to get insights on their current
35 situation and future implementation. The main factors and motives influencing the consumer
36 perceptions towards meat alternative products are reported. Further, the consumers' motives and
37 drivers to consume alternative products were highlighted. This review, provides a better
38 understanding of motives and drivers of consumers' acceptance to improve the acceptability of
39 meat alternatives, considering product and country origin of the consumers of meat alternative
40 foods.

41 **Keywords:** Meat alternatives, Novel foods, Consumer acceptance, Habits and Preferences, Food
42 innovation.

1. Introduction

Meat is an important source of nutrients, *e.g.*, proteins, iron, and vitamins, with beneficial effects on human health (Gagaoua & Picard, 2020). Meat consumption has been increased since the era 60s, but particularly from the era 80s decade to nowadays (González et al., 2020), which can be attributed to increased population and income. As such, the meat industry is facing a challenge to meet the growing consumer extractives for meat products. With a growing world population expected to reach about 9 billion by 2050 (United Nations, 2019), the demand for meat and meat products is projected to double by 2050. The situation is alarming for a certain category of population as more meat production means for them more gas emission and carbon footprint, especially for red meat. For example, livestock production results in greenhouse gas emissions, about 14.5% (Gerber et al., 2013) and uses considerable amounts of freshwater (Gerbens-Leenes et al., 2013). Several studies reported that excessive consumption of red and processed meat products can be related to adverse health effects (Bouvard et al., 2015; Godfray et al., 2018). Furthermore, farm animal suffering is a major ethical concern in many developed countries since appeals for animal welfare has got less attention as compared to the human health (Mathur et al., 2020). For instance, the animal welfare in Sweden is still a debate, where animals are not considered as sentient creatures but as production factors and commodities for economic benefit (Schwartz, 2020ref). Food production systems were reported to be harmful to animals at different degree depending on the type of harm caused (Hampton et al., 2021). Four types were identified: i) keeping animals in captivity; ii) causing deliberate harm to animals through slaughter, fishing, or hunting; iii) causing direct but unintended harm to animals such as vehicle collisions; and iv) negatively affecting the welfare of animals indirectly by disturbing ecological systems (Hampton et al., 2021; Poore & Nemecek, 2018). This contributed into the criticism of meat products from environmental, animal welfare, and public health perspectives.

Replacing animal meat with sustainable alternative proteins such as plant-based meat products was suggested as a promising approach to satisfy the consumers' needs and in certain cases to reduce meat consumption. In recent years, substantial investment in plant-based and lab-grown meat has been pumped from private and public sectors. As a result, alternative plant-based meats hold an important share of the global market and made available in popular franchises like McDonald' and Burger King. The global meat alternative market size was valued at \$4,512.1 million in 2019, and is projected to reach \$8,823.6 million by 2027, exhibiting a compound annual growth rate of 7.2% from 2021 to 2027 (Chouhan et al., 2021). Growing niches, *i.e.*, vegetarians, vegans and flexitarians, are a key segment driving the boom as their gateway for a

more sustainable and healthier meat substitute (Boukid, 2021). Furthermore, changes in food habit during the COVID-19 outbreak boosted the raise of alternatives products as consumers were seeking healthier and more functional foods (Ayivi et al., 2021; Profeta et al., 2021a). The changes in food habit during the COVID-19 outbreak were driven by two main factors. First, staying at home which led to changes in the amount, quantity and quality of food. Second, stockpiling food that is impacted by food availability in groceries (Di Renzo et al., 2020). In addition, social media reporting continuously about the COVID-19 might be another cause of stress leading consumers to be careful about their meals. It was reported that people decreased the junk food (snacks and products rich simple sugars) consumption during the lockdown (Di Renzo et al., 2020) as foods associated with increased risks of cardiovascular diseases. For the same reasons, proteins from non-animal sources gained traction as an alternative to meat products due to their low fat content and saturated fatty acids and thus lower cholesterol. For instance, COVID-19 outbreak boosted the raise in veggie burgers and a drop in meat burgers launches during 2019 in Europe (Boukid & Castellari, 2021). In the USA, the sales of plant-based meat alternatives increased by almost 200% in 2020 compared to 2018.

Sensory attributes of meat products such as flavour, texture, and appearance are important factors for the acceptance and eating behaviour (Brückner-Gühmann et al., 2019; Hartvig et al., 2014). The partial or total replacement of meat by plant-based, seaweed-based, and insect-based foods could be a healthier or/ and more sustainable alternative (Gullón et al., 2020a; Lee Hyun Jung Yong Hae In, 2020; Sadler, 2004); however, consumers remains often hesitant towards new or unfamiliar foods (Tan et al., 2016). Therefore, consumers' preferences for alternative and novel meat products are still unknown and uncertain due to the multifactorial decision. For example, several factors might impact the acceptance of consumers including sex, gender, income, geography and cultural habits, and product type. Therefore, this review aimed to gather the current knowledge about consumer perception and acceptability of meat alternatives (*i.e.*, plant-, seaweed-, and insect-based foods) and enable recommendations for future implementation and action in this sector. To do so, the literature was searched in Pubmed, Scopus and Google Scholar databases to gather all the papers published in the field of plant-, seaweed-, and insect-based products for human food consumption since 2010 upon June 2021. We used the keywords “perception*consumers*plant-based*food, perception*consumers* Insect-based*food, perception*consumers*seaweed* based products, perspective* consumers*plant-based*food, perspective*consumers*insect-based*food, and perspective* consumers* seaweed*based*food” to identify the related articles.

A total of 11 150 articles were retrieved in the first step with 7367, 247 and 2541 articles identified for plant-, seaweed-, and insect-based products, respectively. The articles that do not belong to agricultural and biological sciences, environmental sciences, economic and business, social sciences, and chemistry were excluded. A total of 7264 articles (6308, 148, and 808 articles, respectively) were retained in the second step. The review was limited to peer-reviewed research articles published in English during the last decade (2010 to 2021) and focusing on consumer preferences, perceptions, acceptance and behavior. A total of 519 articles (431, 13, and 75 articles) were selected. From these, 442 papers were excluded because the studies were not strictly related to consumer research for products as meat substitutes. Finally, 85 research articles were retained as eligible (see **Table S1** and **Figure S1** for the full list of the papers and the flowchart highlighting the selection process of the articles, respectively).

The selection process meant to select peer-reviewed articles related to the topic of this review. The selected articles have the country where the review was conducted and the plant-, seaweed- and insect-based products investigated. The criteria of selection of the articles were briefly summarized in **Table S2**. In terms of methodologies, in brief, the data in the 85 eligible research articles were collected by quantitative approaches using interviews, questionnaires, online surveys, or choice experiments (sensory testing) and conjoint analysis. Qualitative approaches such as focus groups were in certain of the studies used to investigate if the trends of consumptions by consumers are linked to the perceptions of the new proposed products. The factors influencing the preference, perception, and acceptance of the consumers related to the products and the motives behind consumption were identified and commented accordingly (**Tables 1, 2 and 3**). In this review, consumer perception of alternative products (plant-based, seaweed-based, and insect-based) were discussed to understand the consumer behavior and the motives influencing the perception and acceptability. Furthermore, this review explored the factors influencing the acceptability of these products considering country as a variable.

2. General findings

General findings are described first regarding the retrieved studies with a focus on the main factors and motives influencing the consumer perceptions, the meat alternative products (plant, seaweed-, and insect-based products) and countries related to the impact on the acceptability. Therefore, this review reviewed the main factors driving consumer acceptance of plant-, seaweed-, and insect-based products – for example, food choice motives (Onwezen et al., 2021; Vainio, 2019), consumer attitudes towards alternative proteins (Lemken et al., 2017), and

familiarity with meat alternatives (Palmieri & Forleo, 2020; Schlup & Brunner, 2018; Verbeke, 2015).

This review revealed that the consumer studies related to meat alternatives increased rapidly as most of them were published in the last five years (during 2016-2021). For the plant-based meat products, the studies are mostly conducted during the period 2016-2017, while the insect-based meat products are very recent and conducted during the last two years (2020-2021). These indicate that the studies related to plant-based products are currently booming as a commodity of meat product alternatives. There were 40 studies related to the insect-based meat products found in the literature search with variety of products, but the insect sources are mostly obtained from cricket and mealworm. Only few studies related to seaweed products are found. However, seaweeds as natural sources containing higher proteins have a great potential to be used as meat alternatives, for the design of functional meat products based on seaweeds and their extracts or to reformulate new meat products enhancing their healthy attributes (Gullón et al., 2020a).

Several of the consumers' acceptance studies have focused on specific cases of alternative proteins such as insects (Adámek et al., 2018; Balzan et al., 2016; Bartkiewicz et al., 2017; Caparros Megido et al., 2014), plant-based meat alternatives (Michel et al., 2021; Vainio, 2019; van Loo et al., 2020; Wang & Scrimgeour, 2021a), edible seaweed (Palmieri & Forleo, 2020), burgers (Schouteten et al., 2016; Slade, 2018), etc. Considering the country as discriminative factor, European countries dominated research studies on meat alternatives from plant- or insect-based products. Specifically, Germany (Hartmann et al., 2015), Denmark (Verneau et al., 2016), and The Netherlands (Lensvelt & Steenbekkers, 2014) focused on plant-based products, while The Netherlands (House, 2016; Marberg et al., 2017; Pascucci & de magistris, 2013), Belgium (Bryant & Sanctorem, 2021) and Italy (Cicatiello et al., 2016; Verneau et al., 2016) were interested on investigating the insect-based meat products. The U.S.A., China (Hartmann et al., 2015; Wang & Scrimgeour, 2021a), New Zealand (Wang & Scrimgeour, 2021b) and Australia (Lensvelt & Steenbekkers, 2014) have also focused on this topic. On another hand and as stated above, these studies were conducted *via* structured surveys and questionnaires, which are common methods to understand the consumer perceptions. These methods are proved to be effective to gain high numbers of participants enabling high accuracy of the results regarding the response of participants to these meat alternatives. Indeed, more than a thousand participants were involved in about 25% of the retrieved studies.

3. Motives influencing the consumers' perception on new meat alternatives

Motivations behind consumer acceptance can be related to conventional drivers (sensory, taste, cost, and convenience) or/and emerging drivers (health and wellness, safety, environment, animal welfare and familiarity) (Boukid, 2021; de Boer et al., 2013; Schösler et al., 2012; Siegrist & Hartmann, 2019). Based on the retrieved studies (**Tables 1, 2 and 3**), the main product-related drivers are healthiness, taste (de Boer et al., 2013), convenience, environmental benefits (de Boer et al., 2013; Vainio, 2019), and appearance (Bryant & Sanctorem, 2021). These factors are of high relevance to make purchase decisions.

The motives over environmental concerns are the most influential factors for the consumers to change their eating behavior and shift toward consuming more meat alternatives as a more sustainable manner to those based on solely meat (de Boer et al., 2013; Schösler et al., 2012; Siegrist & Hartmann, 2019). Even though environmental impact is underestimated (or misunderstood) in few countries, like Switzerland (Hartmann & Siegrist, 2017; Lazzarini et al., 2017), tailored marketing strategies promoting plant-based foods and insect foods as sustainable options to conventional meat increased the willingness to buy or to consume type of products in different countries (Circus & Robison, 2019; Imm et al., 2021). These category of consumers can be considered as “environmentally conscious” (Hoek, 2010; Schösler et al., 2012). The pro-environmental behavior is truly personal because of the underlying moral attitudes and values. The motivation for dietary change depends then on the involvement of consumers with “green” background *e.g.*, reducing environmental impact (de Boer et al., 2013) and sustainability (Hoek et al., 2017). Indeed, sustainability and environmental benefits of seaweed have been mentioned by in few papers to have a positive influence on the consumption of seaweed-based products (**Table 2**).

Regarding health and nutrition benefits, (Verbeke, 2015) argue that when there is a relation between functional ingredients and the health benefits of the products in consumer insights, the products would be perceived positively by consumers as further confirmed in other studies (de Boer et al., 2013). Consumers' awareness over the health benefits of the plant-based products leads to the willingness to consume thereby to change their eating behavior (Biondi & Camanzi, 2020). Also, the seaweeds containing bioactive compounds are conferred to have health properties (Gullón et al., 2020a) and can be used to reformulate new functional foods (Nadeeshani et al., 2021) or meat products judged by some consumer as “bad” to improve certain of their nutritional aspects (Gullón et al., 2020b). (Schouteten et al., 2016) reported increased

demand of insect burger due to targeted campaign on insect food benefits. The knowledge about the content of the meat alternatives also contributes into the change of eating behavior of the consumers. The font-of-pack labeling is the tool that can help consumers to make informed choice while purchasing a food product. Nutritional labeling is also very important to enable a further understanding of the healthiness of the alternative products compared to conventional ones through the list of ingredients, nutritional facts, health claims, nutrient content claims and allergens.

The concern over animal welfare was found to be psychologically increased for many people. For example, (Wang & Scrimgeour, 2021a) reported that animal welfare is the main motive for people in New Zealand to consume plant-based products because of their low affinity to animal-based foods. In another report (Graça et al., 2015), it was reported that the willingness to change eating behavior to plant-based foods to minimize animal suffering.

Besides the above-mentioned factors, price, taste and appearance are also relevant factors that can influence consumer willingness to buy alternative meat products (Boukid, 2021; de Boer et al., 2013). The challenges that meat alternatives still facing are the ignorance about their composition, molecular interactions, nutritional benefits, and sensory attraction including off-flavor (Bahmid et al., 2020; Brückner-Gühmann et al., 2019; de Boer et al., 2013; Haard, n.d.; Hoek, 2010; Pagliarini et al., 2021; Schouteten et al., 2016). Many non-consumers of meat alternatives agree that the meat alternatives would be more attractive if their price is lowered and their nutritional composition is improved compared to meat and meat products. Indeed, current meat alternatives have lower protein and higher fat, carbohydrates and sugar contents compared to their meat-based counterparts (Boukid & Castellari, 2021). Appearance is of great importance but innovative technologies for alternative proteins texturization are rapidly growing aiming to improve this aspect and reach a meat-like experience and properties (Ismail et al., 2020). In this perspective, several challenges and limitations must be overcome to improve the flavor profiles, for instance, of plant-based proteins (Karolin Mittermeier-Kleßinger et al., 2021).

According to (Renner et al., 2012a), the environmental aspect is only perceived by the consumers as additional benefits and is not the only driving factor for deciding about the food alternatives. Hedonic factors, like price, appearance and taste are still the most important factors (Siegrist & Hartmann, 2019). For the seaweed products, sensory and composition characteristics, like taste and ingredients, are important drivers (Palmieri & Forleo, 2020). For example, (Lazzarini et al., 2017) suggested that it is important to improve the texture, taste, appearance

and price of the meat substitutes when sensory is the dominant driver (van Loo et al., 2020), whereas health claims are more persuasive when health benefits are the main consideration (Biondi & Camanzi, 2020).

Some studies reported cultural and social issues *e.g.*, value, emotion, experience, knowledge, and feeling also influence the consumers for decision to consume plant-based products. (Hoek, 2010) found that the main reason for plant products preference is familiarity and experience. Certain consumers accept bean-based products as meat alternatives, like insect burgers with high protein content because of the previous experience to consume such products (Aschemann-Witzel & Peschel, 2019a; Schouteten et al., 2016). Neophobia is an issue for many consumers having fear of eating unfamiliar products such as those made with insects and seaweed (Caparros Megido et al., 2016; Hartmann et al., 2015; Verbeke, 2015). (Hoek et al., 2011) found also compared to muscle foods, the meat substitutes are more ethical, but due to the absence of a strong ethical orientation, meats are selected over meat alternatives. In addition, the situation where meat substitutes are consumed and under which social norms may also have an influence on perceived feasibility. In this context, a study of attitudes has shown that people tend to adjust their eating behavior according to their colleagues' eating behavior (Higgs & Thomas, 2016). As an example, hosts serving vegetarian foods to their colleagues have more awareness, alternative, health awareness, and concern to animal welfare than hosts serving meat foods (Funk, Sütterlin, & Siegrist, 2020). Therefore, the eating situation could also influence the acceptance of meat substitutes.

Versatility of the products as meat alternatives to fulfil the consumer needs could be an advantage as well. For example, in Belgium, the consumers have the pleasure to consume different products from myriad sources such as legumes, pulses, cereals, insects, and seaweeds (Bryant & Sanctorem, 2021). Such a rich product portfolio is considered as the market establishment for the meat alternatives. Even though, these factors can have an influence on the consumer preference, other factors like taste and healthiness still have a more pronounced impact on the overall consumer perceptions (Hoek et al., 2017). In relation to the social issues, the quality of the food alternatives should be guaranteed to maintain the market, because the bad experience in the first consumption of the meat alternatives leads to an ignorance to the forthcoming consumptions (Hartmann & Siegrist, 2016, 2017). Product standardization and quality stability and tractability are deemed keys factors for investors to maintain or to expand the alternative products market.

4. Product related consumers' acceptability

4.1. Plant-based meat (nugget, burger, etc)

Steak patterns differ significantly from alternative meat products and processed meat products (Michel et al., 2021). The processed meat products, *e.g.*, chicken and vegetarian nuggets or beef and vegetarian burgers have similarities in terms of form, processing steps and ingredients such as starches, soy proteins, emulsifiers and hydrocolloids (Boukid & Castellari, 2021). Nevertheless, there is no logical evidence or sense to compare a meat substitute to a steak. Nevertheless, it is important to mention that both research and market for the replacement of processed meat products *e.g.*, chicken nuggets or beef burgers with plant-based substitutes are increasing and promising, respectively (Faber et al., 2020). In terms of consumers acceptability, Belgian and Dutch respondents, for example, perceived the term “plant-based diets” more attractive than vegetarian (Faber et al., 2020). (van Loo et al., 2020) investigated the consumer preference in USA and identified that 16% of people prefer consuming plant-based burgers, compared to the growing-lab meat with only 7%. The percentage of preference of the consumers is to some extent and was established to be around 21% (Slade, 2018). In the United Kingdom, 90.6% of surveyed participants would consume plant-based substitutes (Circus & Robison, 2019). The information related to insect food benefits, is however, increasing the demands to insect burgers (Schouteten et al., 2016). Overall, the motives of consuming alternative burgers are mainly related to the environmental impact, health and animal welfare, but consumers are perceiving that plant-based meats should have a similar appearance to that of meat-burger. (Peschel et al., 2019) also reported that the mention “minimally processed” food has benefits in terms of sustainability and environment.

4.2. Oil seeds and legume products

Tofu and Tempe for example have been known for long time, but meat lovers are not interested on the soybean products because of the taste, flavor (mainly off-flavor as mentioned above) and other sensory attributes (Hoek et al., 2017). The vegetables (or legumes) are of interest because of the health, and environmental benefits and innovation in this sector is opening plenty of opportunities to emerging sources such as peas, chickpeas, and lentils especially after Food and Agriculture Organization of the United Nations declaring 2015 as the year of pulses (beans, lentils, and peas) (Lemken et al., 2017). On the other hand, soybeans have used historically as food ingredients. Nevertheless, they have a poor reputation since soybeans are one of the most widely used genetically modified organisms (Aschemann-Witzel & Peschel, 2019a).

Generally, participants in certain surveys addressing this specific point agreed that they would avoid soy protein, as soy has been documented as a health risk (e.g., ‘soy is allergic’) (Aschemann-Witzel & Peschel, 2019a). Given this critical stance, it may not be advisable for food manufacturers to invest in extracting proteins from plants that are considered unhealthy.

4.3. Snack from seaweed and edible seaweed

The edible seaweeds have an interesting possibility to be a meat alternative, because of the nutrients and healthy compounds with myriad functionalities (Gullón et al., 2020b; Milinovic et al., 2021). For example, (Palmieri & Forleo, 2020) found that 76% of participants have a willingness to eat seaweed. Around 12% over a thousand participants prefer consuming snack from seaweeds, which was higher than insect-based snacks (de Boer et al., 2013). The seaweed consumers mostly are young males (Milinovic et al., 2021). In addition, most of seaweeds consumers are those who tend to eat fish (de Boer et al., 2013). Similarity of flavors between seaweeds and fish gives a feeling a familiarity to consumers, which might reduce neophobia. Accordingly, familiarity has an influence since 57% respondents had an experience eating the seaweed in the past (Losada-Lopez et al., 2021).

4.4. Edible insects

Strong disgust responses and aversion are still relevant obstacles for the consumers’ acceptance to edible insects (Circus & Robison, 2019; la Barbera et al., 2018, 2021). Edible insect as a food ingredient is still not really understood, but insect foods could be a future dish on European tables as new source of proteins (Mancini et al., 2019; Moruzzo et al., 2021). Some studies proposed for example to use insect proteins as additives or supplements in bread, but the findings of the survey conducted by the authors revealed that most participants were unwilling to try such bread (Ribeiro et al., 2021). Thus, sensory properties need to be evaluated to increase the willingness of consumers to purchase new insect-based meat products. The promotion of the healthiness of the edibles insects needs to target all consumers (Imm et al., 2021; Possidónio et al., 2021). (Schouteten et al., 2016) reported that Western consumers have more willingness to consume insect burgers. Another product, like mealworms and house crickets, associated with known flavors and crispy textures were appreciated better (Caparros Megido et al., 2014). Although differences might exist between genders, the nutritional information, benefits and sensory quality affect emotion and willingness of the consumers, so it is important to improve the sensory quality and provide information related health benefits consuming the insect

products. Therefore, informative nutritional labeling can play key role in the purchase decisions especially for label readers.

5. Country related consumers' acceptability

Country has an influence on the perception and motives of consumers for each country since differences exist in the cultures, habits and behaviors (Lazzarini et al., 2017).

In Western Europe, the positive response to plant-based products for Mediterranean countries is related to the long-term importance of these staple foods in their diets (González et al., 2020). Dutch and Belgian people have initially negative responses to plant-based meat products, knowledge related to the benefits of the products increases the acceptance of the products (Faber et al., 2020). The acceptance of the insect-based products in the Netherlands is some extent high, which 45% of participants have an interest to try the insect foods (Mancini et al., 2019). In Belgium, people have still negative response to meat alternatives. However, there is a possibility to market new meat alternatives. Around 43% females and young consumers in Northern Flanders respond positively to plant-based products. The information related to the benefits of the insect food increases the interest of Belgian to consume such food (Schouteten et al., 2016). The satisfaction of Belgian as an example to toward meat alternatives increased from 44 % (2019) to 51% (2020) (Bryant & Sanctorum, 2021), which can be attributed to the quality improvement of plant-based products and the increase of awareness towards animal welfare and environmental issues during these years. Similar trend was also observed in France, where nutritional information and environmental benefits are significantly driving consumer willingness to purchase meat alternatives (Bryant & Sanctorum, 2021; Saint-Eve et al., 2021). Italian consumers (almost 70% from 600 individuals) consider convenience of plant-based foods as key factor to improve their diet (Contini et al., 2020).

In Germany, the plant-based meat products replace the muscle foods when the processed plant meat foods resemble in texture and taste and are offered at affordable prices (Michel et al., 2021; Saint-Eve et al., 2021). Females prefer consuming more plant-based foods because of the animal welfare and environment concerns, while males consume the alternatives due to the taste and price. For the insects, most people in the Western Countries prefer eating the processed food compared to edible insects because food neophobia was a barrier for people in the Western countries (Hartmann et al., 2015).

The meat consumption in Switzerland is categorized high (Hartmann & Siegrist, 2017). To increase the meat alternatives consumption, ensuring a meat like experience can attract meat lovers to consume alternative products having similar appearance and taste compared to meat (de Boer et al., 2013). Information related to the environmental impact might not be effective, since the awareness to the environmental issue is relatively low (Hartmann & Siegrist, 2017)

People in Denmark and Finland prefer the foods containing high protein content derived from plants. Plant-based products are mainly considered healthier, more environmental friendly, and as sustainable options than meat products (de Boer et al., 2013; Niva & Vainio, 2021). People do not change to meat alternatives only due to the ethical issue (Hoek, 2010). Danish people have also negative response to plant-based food products. Prices of food beverages in Denmark are relatively higher than other European countries. Therefore, Danish consumers tend to prefer locally produced foods when choosing plant-based products (Aschemann-Witzel & Peschel, 2019a). However, the acceptance of the meat alternatives is possible, if consumers know more about alternative products. The females have more preference to consume the meat alternatives than do the males. The low interest of plant-based food sensory and taste, the higher rate in price prevent people to change the behavior to consume meat alternatives (Bryant & Sanctorem, 2021; Hoek, 2010). People with higher education have also more preferences because they have more information about the benefits of the meat alternatives and the health concerns excessive overconsumption of meat products (de Boer et al., 2013; Hoek, 2010; Schösler et al., 2012). In Finland, consumers plan to increase the consumption of plant and insect-based products (26% and 24%, respectively) in the future (Niva & Vainio, 2021). However, in UK, 90.6% are willing to consume plant-based products, while very few of them are willing to consume insect-based meat products.

In USA, the market potential of the plant-based foods is growing very quickly and can be estimated to around or more than 17% (van Loo et al., 2020). Vegetarian, male, young, and with high education individuals have strongly to consume meat alternatives. For the Chinese consumers, they mainly reject or decline to consume plant-based foods because they have a strong insight on meat as a pleasure (hedonism) (Qi & Ploeger, 2021). They historically assume that food containing higher protein and fat is a pleasure (Qi & Ploeger, 2021). It does not mean that the Chinese do not want to consume plant-based foods. It is important to consider that most Chinese dishes are indeed plant-based foods due to their habits and culinary culture mostly involving several plants and vegetables (Wang & Scrimgeour, 2021b). For the insect foods, Chinese have a higher willingness to eat them, either processed or edible insects since it is

already a part of their food repertoire and culture (Gmuer et al., 2016). Verneau et al., (2021) conducted an Entomophagy Attitude Questionnaire (EAQ) towards assessing the intention to eat insects for the Chinese. Results showed that more positive interest or attitude to consume the edible insects compared to non-insect eaters' intention influenced by the role of disgust.

In South America, although people in Chile are categorized as non-insect eaters, they have intention to try insect foods, even to adopt the insect foods into their own' meat or foods (la Barbera et al., 2021). However, the visibility of insects influence their willingness to try since the consumers are more reluctant to direct entomophagy (la Barbera et al., 2021; Verneau et al., 2021). On the other hand, in many African countries, insects' consumption is regarded as a traditional practice (Grabowski et al., 2020). For example in South Africa, most people consume insects as a nutritious food and this emphasizes the important role of insects for people's livelihoods in rural areas (Hlongwane et al., 2021). Acculturation and insect availability could decline entomophagy and become a challenge for insects' consumption in Africa (Hlongwane et al., 2021).

Meat consumption in New Zealand is relatively routine since meat is acknowledged as a traditional diet. However, the influence of Western people is very strong, which might affect the habits of meat consumption in the country (Wang & Scrimgeour, 2021b). In Australia, a study of meat alternatives perception revealed that Australian consumers feel no benefits from eating the plant-based foods. As a result, the Australian was not ready to change the eating behavior toward the consumption of meat alternatives (Hoek et al., 2017).

6. Consumers perceptions to insect-, seaweed- and plant-based products

A transition to consider meat alternatives offers new interest on vegetables and grains (Holm & Møhl, 2000). Several studies reported meat reducers (flexitarian and plantarian) and meat avoiders (vegetarians and vegans) (Kanerva, 2013; Possidónio et al., 2021). For example, 37% of consumers in Finland consume beef, and there are no consumptions of insect- or plant-based protein products (Niva & Vainio, 2021).

The strong relationship between healthy and sustainable food perceives a clear relationship between attitudes and behaviors. Consumers reducing meat consumption have higher perceptions of the environmental effects, health awareness, and lower disgust sensitivity, and they are in general younger, females, and more educated (Bryant & Sanctorem, 2021; Graça et al., 2015). Health awareness, gender, education, income, and age positively affect the trend of

plant-based foods consumption in European Countries. The better consumer understanding on the environmental effect attract more consumption on sustainable food. These results agree with the statements by (de Boer et al., 2013) who reported that consumers who value nature are also more willing to switch to meat-free diets. Therefore, switching to a plant-based product is regarded as a behavior giving more attention to healthy and sustainable consumption.

Meat alternatives are expected to have similar texture, taste, and ease of preparation to muscle foods (Faber et al., 2020; Michel et al., 2021). In terms of social issue and regarding different consumption situations, meat alternatives are considered more appropriate to be consumed alone or with family or friends (Michel et al., 2021). However, consumer preferences are not yet fully understood since they are dynamic and not stationary. In line to this, (Bekker et al., 2017) reported that attitudes can be changed with marketing campaigns, or social norms can influence the willing of consumers to eat plant- or insect-based products (Banovic & Otterbring, 2021). In addition, most consumers do not believe than plant based-burgers have similar taste to that of conventional meat. It is important to produce a plant-, seaweed-, and insect-based burger with a convincing taste as muscle beefs' tastes to obtain or secure a higher market share.

7. The drivers to increase the acceptance of meat alternatives

Consumers do not often realize environmental and health effects of muscle meat and do not have a willingness to change their meat consumption habits (Hartmann et al., 2018; Hartmann & Siegrist, 2017). With consideration of more sustainable foods' transitions, it is important to have a better understanding of consumers' motivators/demotivators and establish interventions to improve the consumer acceptance toward meat alternatives.

Combining sensory evaluation with instrumental results could be beneficial to optimize the ingredients and/or to modify the sensory characteristics and to improve the final product, hence increasing the consumer acceptance. Meat alternatives can successfully replace meat when taste and texture are very similar to those of processed meat products at competitive prices (Graça et al., 2015). Meat alternative producers are recommended to focus on replicating the processed meat products instead of imitating the meat like escalope or steak. Under certain conditions, such as plant-based burgers, even though consumers are conveyed that all burgers has the same taste, the preferences for beef burgers are still noticed. As an example, women prefer to purchase the plant-based burgers, but less possibility to purchase the cultured meat burgers (Bryant & Sanctorem, 2021; Hoek, 2010). For the insect foods, the incorporation of insects as ingredients into familiar foods can reduce the negative attitudes and neophobic reactions (Hartmann et al.,

2015). In opposite of the plant-based products, males are over 2 times more acceptable than females (Verbeke, 2015).

Communication such as targeted marketing campaigns and social media influencers play an important role, so an efficient campaign related to the meat alternatives must be to the point and well-delivered to the targeted consumers. The campaigns should focus on the most important message that the costumers need to know about the meat alternatives products (Schiano et al., 2020; Schouteten et al., 2016). Thus, it may be useful to reinforce the motive for selecting the plant-based food products due to health concerns against muscle foods and meat (Hoek et al., 2017; Schouteten et al., 2016). In addition, it may be important to highlight the sustainability aspect of the product. Another way might give a concern towards meat substitute ingredients by changing the product from animal-based ingredients. This perspective improves the lists of ingredients by increasing transparency and focusing on the familiar and harmless ingredients (Aschemann-Witzel & Peschel, 2019b; Onwezen et al., 2021). Therefore, the health aspect must be considered when the plant-based foods are communicated as the main motive. The "healthy" code scored highly on all measures of centrality. The trend of clean labels (Rondoni et al., 2020) and high processing rates of plant-based products need to be underlined and are the main challenges of plant-based foods (Dickson-Spillmann et al., 2011; Peschel et al., 2019). In terms of managerial implications, rewarding a product by enhancing its health-concerning properties, supported with an effective communication, would seem more potential in consolidating the alternative market. As an example, producing products containing high-quality ingredients and/or no additives (Brückner-Gühmann et al., 2019), instead of preserving the products by using high-pressure treatments, may respond to the health concerns wanted by the market (Barba et al., 2015). In addition to providing information, non-informational approaches where consumers are encouraged to healthier and more sustainable behaviors are gaining interest (Profeta et al., 2021b; Reisch et al., 2017).

8. Future implementation and action to support insect-, seaweed-, and plant-based products as alternatives to meat and meat products

The motive to opt for hedonic food is preferred for the future when ideological drivers of consumer are not strong and the willingness of consumers to change their behavior (Bryant & Sanctorem, 2021). An example of the behavior might be reducing animal product consumption and increasing meat alternatives, *e.g.* plant- and insect based products. Besides the cooking skills and healthiness, the satisfaction and taste are regarded as main barriers to keep the consumption

of muscle foods (Hoek, 2010; Niva & Vainio, 2021; Schösler et al., 2012). This barrier does not only affect the communication strategy, but also the policy implementation and other industry actions. As an example, a new dietary guidelines is established by considering not only health and environment, but also palatability aspects. Similarly, reformulation of food products should be based on consumer acceptance while combining sustainability and health criteria (Dötsch-Klerk et al., 2015).

Public sectors are required to give a training for the consumers to conduct an assessment quality of information related to food product innovation (Vainio, 2019) Consumers consuming meat-based products have a scepticism of scientific evidence, due to less willingness and ability to evaluate and filter information. Many scientific evidence are focused on healthy diet pattern, providing a framework for food policies and strategies to support consumers eating the healthy food products (Hawkes et al., 2013). These strategies include interventions in school environment, economic instruments (taxes and subsidies), and food labeling (Lazzarini et al., 2017). The global and important policy proposed by the governments are food-based dietary guidelines (Hawkes et al., 2013), offering recommendations for types, amounts and number of food that should be consumed to keeping health and prosperity. These recommendations should also be of great help to consumers to make the purchase decision. Even though the global dietary guidelines is focused only on health aspects, a growing number of nutritionists and public health experts suggest that the future dietary guidelines must include also environmental and nutritional aspects (van Dooren et al., 2014). Nowadays, the USA Dietary Guidelines Advisory Committee (February 2015) reports that the environmental impact should be included in the Dietary Guidelines for Americans (USDA, 2015). In Sweden and The Netherlands, dietary guidelines have been launched, in which the environmental aspects are included.

Knowledge related to the food products may not have a positive implication automatically on consumer' food behaviour. However, it is proven that the nutritional knowledge is associated with consumer behaviour on healthier food consumption (Hartmann & Siegrist, 2017; Michel et al., 2021; Siegrist et al., 2007). The environmental effects of foods perceived by consumers affect consumer food behaviour. The increasing knowledge of the general public about the environmental impacts of a variety of food products can give positive effects on the sustainability of the consumer choices. Consumer decisions are influenced by a wide variety of factors as previously explained (Renner et al., 2012b). Consequently, it is difficult to improve the sustainability as a driver of food choices, so steps of action are required. For example, the provision of knowledge related to environmental consequences from the food choices can be

included among the information on product label. This action could not change each consumer behaviour, but some consumers still have a willingness to change their behaviour to consume meat alternatives.

9. Conclusion and prospects

The demand for meat and meat products will continue increasing as population and per capita income is increasing throughout the world. As such, the replacement of meat-by-meat substitutes could be a valuable alternative to reduce the burden of meat production from ethical, environmental and nutritional perspectives. However, the acceptance of meat alternatives is still controversial. Therefore, it is important to understand the consumers' preference and upgrade the quality of meat alternatives to deliver similar experience in terms of taste and texture to that of meat. This review provides insights to better understand the consumer perception and acceptance of plant-, seaweed-, and insect-based foods. Depending on the type of meat alternative, consumers' acceptance significantly varied. For instance, consumers showed more acceptance to plant-based meat alternatives compared to those insect-based. Different factors such as healthiness, taste, familiarity, attitudes, social norms, food neophobia, and digestion are related to consumer acceptance of alternative meat products.

To attract more flexitarian consumers and/or non-vegetarian, it is crucial improving the nutritional the quality of alternative meat products through the incorporation of functional ingredients and generating meat-like sensory attributes. Future studies need to understand the key attributes that are more related to consumer acceptance of the alternative meat products. Hedonic test (e.g., 9-point hedonic scale) is useful to evaluate the overall consumer acceptance and to determine the individual sensory attributes such as aroma, texture, appearance, overall liking, etc. On the other hand, descriptive analysis will help to determine both qualitative and quantitative results of the products' sensory profiles. Likewise, instrumental analysis and high throughput omics methods are necessary to determine the texture, color, and to identify the important aroma-active and other macromolecules compounds. Then, combining sensory evaluation with instrumental results could be beneficial to optimize the ingredients and/or to modify the sensory characteristics and to improve the final product, hence increasing consumers' acceptance. Future studies also need to consider multiple factors (e.g., comparison across countries, consumer segmentation, and different alternative meat products) to understand what are the primary attributes or factors governing the consumer liking and/or acceptance of alternative meat products.

Conflict of Interest

The authors declare no conflict of interest.

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Table 1. Overview of motives and consumers responses for plant-based products as alternatives to meat.

No	Product	Country	Sample (N); Design Data selected	Motives and response of consumers					Other information	Reference
				Sensory properties	Environment	Animal welfare	Health	Physical and chemical characteristics		
1	Snacks	Netherlands	1083; Surveys		Protein with more environmentally benefits					(de Boer et al., 2013)
2	Burger	Unknown	533; Surveys					Organic and natural		(Slade, 2018)
3	Plant-based meat substitutes	UK		Aesthetic appeal				Preference for replacement of other proteins		(Circus & Robison, 2019)
4	Potato protein	Denmark	495; quantitative and qualitative online survey	The protein origin has favourable perception				Particularly favorable in quality dimension and freely associated with starch as a texture agent	- Different single protein ingredients cause different perceptions - Single ingredient descriptors can be employed on product- category level	(Ascheman n-Witzel & Peschel, 2019b)
5	Protein origin									
6	Non-dairy yoghurt alternatives, with oat protein concentrate	Germany	102; consumer test	Sensory attributes play major role				Extrinsic attribute information play important role	Combining good textural properties & nutritional benefits	(Brückner- Gühmann et al., 2019)
7	Plant-based dairy alternatives	United States	23 groups and >11.000 consumers for 2 online surveys		More sustainable than dairy products & important for consumer sustainability perception				Cognitive overlap among ethics, sustainability, healthiness and natural terms	(Schiano et al., 2020)
8	Tofu and vegan diets	Portugal	1138; An integrative bottom-up approach				Healthier options compared to red meat			(Possidóni o et al., 2021b)
9	Legumes						Coincided with legumes regarding to health and taste			

10	Plant-based meat	Belgium	1001 for the year 2019 and 1000 for the year 2020; Online survey		54.1% selecting for environment issue	54.3% for animal welfare issue	82% for health issue		Increasing satisfaction with meat substitutes and increasing concern for environmental impact of food	(Bryant & Sanctorum, 2021)
11	Pea-food products	France	240; Experimental sessions	The consumption is based on the sensory characteristics and desirability	Significant increase for environmental benefits			Significant increase for Nutritional benefits		(Saint-Eve et al., 2021)
12	Plant-based meat alternatives (tofu, vegetarian nuggets & sausage)	Germany	1039; Online survey	Positive impacts in terms of taste and variety for males	Females have concerns about the environment	Females have concerns about animal welfare				(Michel et al., 2021)
13	Plant-based meat alternatives	US	1830; Survey		Positive effect on preferences	Positive impact on acceptance				(van Loo et al., 2020)
14	Almond milk	Caucasian (69.6%) and African American (19.2%).	999; Online conjoint survey		Less perception for the environment	Less animal products and beliefs about animal mistreatment	Maintaining a balanced diet and healthy lifestyle	Lactose free		(McCarthy et al., 2017)
15	Swiss products (e.g., apple, pepper, and peppermint tea)	Germany speaking swiss	305; Online experiment		The perceptions on social sustainability and environmental impacts partly impacted					(Lazzarini et al., 2017)
16	Plant-based food products	Denmark	90; Focus groups, concept maps of the consumers and text mining		Higher complexity with the environmental impact and the authenticity of the product		More complex networks with product properties, e.g., processing degree and nutrition	Plant-based ingredient used as a substitute in animal-based ingredients	<ul style="list-style-type: none"> - Health and sustainability framings cause more complex associations - Health causes product-centered associations on chemicals and nutritional quality 	(Peschel et al., 2019)

17	Spirulina-filled pasta	Germany, The Netherlands, and France	139 in Germany, 137 in the Netherlands and 144 in France (Consumer test)	All sensory attributes were affected		Lemon-basil flavor over tomato and beet-ginger flavours were appreciated	(Grahl et al., 2020)
18	Athletic abs or big bellies	Denmark, Germany, Spain, and the UK	959; Experimental and cross-national studies			Increased arousal levels among consumers exposed to health-related content	(Banovic & Otterbring, 2021)
19	Plant-based products	U.S	41; Interviews	A social interest in advertisement improves consumers' preference		Information on social costs leads to feelings of ambivalence toward meat consumption, making plant-based foods more attractive	(Ye & Mattila, 2021)
20	Legumes	California University	118; Survey	Higher level of spicy heat increased the consumer perception of flavor complexity		A mixture of legumes and vegetables is highly recommended	(Spencer et al., 2018)
21	Foods with increased protein content	Denmark, Finland, Germany and Romania	52; Qualitative focus group approach	Products judged as 'healthier' more environmentally friendly and sustainable	<ul style="list-style-type: none"> - Elderly were sceptic about health - Mixed age had a relatively positive attitude towards health effects 	Matching proteins, as ingredients, to the 'right' food carriers close to conventional - inherently protein rich products could further use and acceptance of the higher protein containing foods.	(Banovic et al., 2018)
22	Phenol-rich plant-based foods	Northern, Central and Southern Italy	1198; questionnaire	Food choice tend to be associated with taste.			(Pagliarini et al., 2021)
23	Plant based foods	New Zealand and China	1185; Online survey			Attitudes and environmental concern affect willingness to adopt plant-based diet.	(Wang & Scrimgeour, 2021a)

24	Green food	China	1412; Online questionnaire	The sensory and price attributes strongly influence hedonic attitudes		Perceptions of nutritional content have strong effects		(Qi & Ploeger, 2021)
25	Plant-based foods	Australia	26; Online interview		An acceptable idea of healthy and environmentally friendly foods.	Health should remain the overarching principle for policies and actions concerned with shifting	Positive attitude for less processed and packaged foods and negative attitude for excessive packaging and ‘chemicals’ in foods.	(Hoek et al., 2017)
26	Plant -based diets	Finland	1279; Questionnaire		Environmental issue positively associated with commercial sources.	Health motive positively associated with perception		(Vainio, 2019)
27	Plant based meat	Portugal	410; Open and closed questionnaire				A pattern of disgust towards meat affects willingness to change habits	(Graça et al., 2015)
28	Soy-based meat	Swiss speaking Germany and French	5586; Secondary data from Swiss food panel		Increasing environmental knowledge impact leading to more sustainable food consumption	High health consciousness and female people considered high possibility to consume plant products		(Siegrist & Hartmann, 2019)
29	Plant-based diet	Belgium, Denmark, the Netherlands and Spain.	438; Online survey	Tasty and enjoyable diets as main drivers				(Faber et al., 2020a)
30	Plant-based protein	Finland	1000; Survey		Sustainability plays role on beef-avoiding plant protein increasers and	Health plays role on beef-avoiding plant protein increasers and	26% planned to increase the consumption	(Niva & Vainio, 2021)

alternative
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increasers

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Table 2. Overview of motives and consumers responses for seaweed-based products as alternatives to meat.

No	Product	Country	Sample (N)	Consumer perceptions/motives					Other information	Reference
				Sensory properties	Environment	Animal welfare	Health	Physical and chemical characteristics		
1	Snack	Netherlands	1083; Survey		Environmentally friendly proteins					(de Boer et al., 2013)
2	Seaweed-based dishes	Spain	50; A survey and a sensorial tasting session				Excellent health or well-being properties	Promotion of wellness and natural attributes draw the attention of consumers	Not influenced by neophobia	(Losada-Lopez et al., 2021b)
3	Edible seaweed	Italian	257; Survey	Organoleptic characteristics should be at the centre of any marketing tools	More sustainable food alternatives		Healthy options	Seaweed properties and availability are important drivers	76% are willing to eat seaweed	(Palmieri & Forleo, 2020)
4	Edible seaweed	Denmark, Finland, Germany, and Romania)	26; Focus group					Preference for plant proteins as additional ingredients		(Banovic et al., 2018)
5	Seaweed foods	Sweden	120; Interview				Positive attitude towards snacks regarded as healthy foods.			(Wendin & Undeland, 2020)

Table 3. Overview of motives and consumers responses for insect-based products as alternatives to meat.

No	Product	Country	Sample (N)	Consumer perceptions/motives				Physical and chemical characteristics	Other information	Reference
				Sensory properties	Environment	Animal welfare	Health			
1	Edible insects	UK	Interviews and an online survey	Aversion: strong, instinctual response	Environmental friendliness	Easy to grow, rear and manage				(Circus & Robison, 2019)
2	Edible Insects	Portugal	1138; an integrative bottom-up approach				Rated as the least appetising, healthy, edible, caloric, and ethical, but also the least expensive.			(Possidónio et al., 2021b)
3	Insect-based food	The Netherlands	33; Semi structured interviews		Explicitly connected for the environment and lifestyle choices		Conscious efforts to consume enough nutrients and proteins			(House, 2016)
4	Insect-based products: pasta, cookies & chocolate bars	Italy	200; Analysis of a non-hypothetical willingness to pay, and experimental design.						Negative beliefs and attitudes toward insects and high levels of neophobia negatively affect the willingness to purchase the products	(Lombardi et al., 2019)
5	Edible insects (mealworms and house crickets)	Belgium	189; hedonic test	Needs to associate them with familiar flavours						(Caparros Megido et al., 2014)
6	Insect-based burgers	Western countries	159; questionnaire and survey	Differences between genders. Impact of burger taste and appearance. The acceptability of insect-derived products is related to food sensory attributes: taste,						(Caparros Megido et al., 2016b)

				appearance, and odor				
7	Pizza containing protein derived from insects	The Netherlands	1083; questionnaire	Gender (male) and taste oriented food choice motives				(Schösler et al., 2012)
8	Snacks, Tortilla chips	Switzerland	428; Online survey		Disgust, dissatisfaction, and positive emotion		Negative emotional experiences	(Gmuer et al., 2016)
9	Insect-based foods	Germany and China	945; questionnaire	More favourably with regard to taste for Chinese		Higher preferences to processed insect-based foods	Compared with the German, the Chinese for insect-based food are more favourable regarding nutritional value, familiarity and social acceptance	(Hartmann et al., 2015)
10	Insect-based food products	Germany speaking Switzerland	107; Experimental studies and surveys				Contaminants and disgust affect willingness to consume insects. Processed insect products increased the preference	(Hartmann & Siegrist, 2016)
11	Insect-based burgers	Belgium	97; Questionnaire	Specific sensory characteristics	Perceived as more nutritious			(Schouteten et al., 2016)
12	Beef burger patties	The Netherlands	103; Questionnaire	Sensory experiences play a necessary role in the acceptance			Food neophobia influenced willingness to eat.	(Tan, Fischer, et al., 2016b)
13	Insect-based products	The Netherlands	1057; Survey	Mainly affected by taste familiarity and individual traits			<ul style="list-style-type: none"> - Acceptance is influenced by appropriateness of carrier-mealworm combination - Negative effects of food neophobia, sweet preparations received lower acceptance, and no effect of flavour origin. 	(Tan, van den Berg, et al., 2016)
14	Insect-based food	Belgium	221; Survey		Aware of the concept		Negative towards the idea of protein-intake	(Vanhonacker et al., 2013)

					'ecological footprint'	through insects consumption	
15	Insect foods	Belgium	368; Survey	Eating insects was 2.6 times higher likelihood	More sustainable		(Verbeke, 2015)
16		Denmark and Italy	282; short questionnaire			A long-established reputation for combining gastronomic and nutritional qualities	Males and people that are familiar to the foods have more positive appreciation (Verneau et al., 2016)
17	Cricket flour	American and Czech	Survey and simple electronic nose	Taste and smell			80% of consumers have willingness to eat the prodcuts (Adámek et al., 2018)
18	Edible insects	Italy	32; Explorative study	Significant determinants related to appearance, farming and sustainability.			(Balzan et al., 2016)
19	Edible insects	Tri-city	788; Survey	-Appearance is the biggest barrier preventing consumption (80,2%). -Taste features as consumption-encouraging factors			(Bartkowicz et al., 2017)
20	Insect-based burgers	Belgium	159; Surveys	Burger appearance and taste as important factors.			(Caparros Megido et al., 2016a)
21	Edible insect	Italy	201; Questionnaire				Consumer attitudes are influenced by higher education, familiarity, and gender (male) (Cicatiello et al., 2016)
22	Edible insects	The Netherlands	150; Surveys				- Consumers with experience of previous insects consumption show more willingness to eat insects. - A (negative) effect of general disgust and (Tan, Fischer, et al., 2016b)

								affective attitude component on willingness to eat a specific insect.	
23	Edible Insects	Hungary	400; A web-based survey				Focus on insect-based food ingredients in processed foods and on a familiarity of product category or flavor profile	A new food choice options to reduce meat intake	(Gere et al., 2017)
24	Snack	Switzerland	428; Online surveys				Impact of processing degree of insect ingredients	Various negative emotional expectations and disgust	(Gmuer et al., 2016)
25	Insect foods	Switzerland	1215; Online survey		Perceived as environmentally friendly	More health-conscious		Brave, knowledgeable imaginative, and interesting	(Hartmann et al., 2018)
26	Spring rolls and buttermilk containing mealworms	Denmark	251; Survey					- Perceived insect eating norm emerged as a significant predictor of insect tasting behavior - Social norms have a substantial role in (un)willingness to eat insects	(Jensen & Lieberoth, 2019)
27	Insect-based food	Portugal	210; Survey		Reduce environmental problem		Use of insect biomass from natural ecosystems		(Kostecka et al., 2017)
28	Insect foods	Western Countries	160; behavioural economics experiment					Disgust affects willingness to eat	(la Barbera et al., 2018)
29	Insect foods	Italy	441; Questionnaire		Sustainability issues did not affect acceptance		Environmental and nutritional advantage had marginal but positive effect	Not ready to accept insects as food	(Laureati et al., 2016)
30	Insect-based products	France	100; Individual single tasting	Positive scores and no difference for preference					(le Goff & Delarue, 2017)

31	Insect foods	Australia and The Netherlands	209; Survey					Price and quality, benefits, risks, naturalness, culture, trust, and attitude, and fit with consumer willingness have an influence on preference	(Lensvelt & Steenbekkers, 2014)
32	Edible foods	The Netherlands	19; In-depth, semi-structured interview		A natural solution to social and environmental problems				(Marberg et al., 2017)
33	Novel foods	Italy	109; Online surveys	Intention is the main predictor of eating insects-based food.	Positive effects on environment and health influence intention				(Menozzi et al., 2017)
34	Insect-based products	The Netherlands	122; Surveys	Visualization of insects on the products affects eating insects as meat-substitutes	Positive environmental and social effects of eating insects as meat-substitutes	The use of logo and health claims impact eating insects as meat substitutes			(Pascucci & de magistris, 2013)
35	Insect food	Finland, Sweden, Germany, and the Czech Republic	887; Consumer survey		Conservation aspects have negative association with food-related novelty and positive association with security across German			A more positive attitude by consumers in Northern Europe towards insect food, compared to Central Europe	(Piha et al., 2018)
36	Insect food	Switzerland	542; Survey	Convenience orientation		Expected food healthiness		Neophobia is not the key predictor of willingness to insects consumption	(Schlup & Brunner, 2018)
37	Edible cricket		354; online questionnaire	Appearance and texture as primary disgust elicitors			Processing is an important step for acceptance	Social role affects disgust of consuming crickets	(Sheppard & Frazer, 2015)
38	Cookie made from cricket	Italy	109; short, structured questionnaire	Appearance and form of the food products are important			Insects can be either visible or unrecognizably processed as ingredients.	- Curiosity is the main factor of willingness to eat insect-based cookies. - Negative perspectives of family members and colleagues and the	(Sogari et al., 2017)

							disgust issues influence Western consumers to prevent eating insects	
39	Processed and unprocessed insect foods	Italy	88; questionnaire	Appearance and Textural properties of the insects are stronger barriers than taste			The positive experience of consumers to consume the products cause to reconsider their initial negative attitude and expectations towards entomophagy.	(Sogari et al., 2018)
40	Edible insects	Italy	46; short questionnaire		Environmental benefits & curiosity are the main factors		Negative perspectives might represent a barrier to introduce edible insects in Western food	(Sogari, 2015)
41	Insect-based protein	Finlands	1000; Survey		Sustainability plays important role on beef-avoiding plant protein increasers and alternative protein increasers	Health plays important role on beef-avoiding plant protein increasers and alternative protein increasers	4% planned to improve the insect-based protein usage	(Niva & Vainio, 2021)

Appendix A. Supplementary Materials

Table S1. List of the articles (from 2008 to 2021) considered in the review.

No	Authors	Year	Titles	Journals
1	Adámek, M., Adámková, A., Mlček, J., Borkovcová, M., & Bednářová, M.	2018	Acceptability and sensory evaluation of energy bars and protein bars enriched with edible insect	Potravinárstvo Slovak Journal of Food Sciences
2	Aschemann-Witzel, J., & Peschel, A. O.	2019	Consumer perception of plant-based proteins: The value of source transparency for alternative protein ingredients	Food Hydrocolloids
3	Aschemann-Witzel, J., & Peschel, A. O.	2019	Consumer perception of plant-based proteins: The value of source transparency for alternative protein ingredients	Food Hydrocolloids
4	Balzan, S., Fasolato, L., Maniero, S., & Novelli, E.	2016	Edible insects and young adults in a north-east Italian city an exploratory study.	British Food Journal
5	Banovic, M., Lähteenmäki, L., Arvola, A., Pennanen, K., Duta, D. E., Brückner-Gühmann, M., & Grunert, K. G.	2018	Foods with increased protein content: A qualitative study on European consumer preferences and perceptions	Appetite
6	Banovic, M., & Otterbring, T.	2021	Athletic abs or big bellies: The impact of imagery, arousal levels, and health consciousness on consumers' attitudes towards plant-based protein products.	Food Quality and Preference
7	Bartkowicz, J., Morska, A., & Gdyni.	2017	Tri-City Consumers Attitudes towards Eating Edible Insect as an Alternative Source of Food	Handel Wewnętrzny
8	Biondi, B., & Camanzi, L.	2020	Nutrition, hedonic or environmental? The effect of front-of-pack messages on consumers' perception and purchase intention of a novel food product with multiple attributes	Food Research International
9	Brückner-Gühmann, M., Banovic, M., & Drusch, S.	2019	Towards an increased plant protein intake: Rheological properties, sensory perception and consumer acceptability of lactic acid fermented, oat-based gels.	Food Hydrocolloids

10	Bryant, C., & Sanctorum, H.	2021	Alternative proteins, evolving attitudes: Comparing consumer attitudes to plant-based and cultured meat in Belgium in two consecutive years.	Appetite
11	Caparros Megido, R., Gierts, C., Blecker, C., Brostaux, Y., Haubruge, É., Alabi, T., & Francis, F.	2016	Consumer acceptance of insect-based alternative meat products in Western countries	Food Quality and Preference,
12	Caparros Megido, R., Gierts, C., Blecker, C., Brostaux, Y., Haubruge, É., Alabi, T., & Francis, F.	2016	Consumer acceptance of insect-based alternative meat products in Western countries	Food Quality and Preference,
13	Caparros Megido, R., Sablon, L., Geuens, M., Brostaux, Y., Alabi, T., Blecker, C., Drugmand, D., Haubruge, É., & Francis, F.	2014	Edible Insects Acceptance by Belgian Consumers: Promising Attitude for Entomophagy Development.	Journal of Sensory Studies
14	Cicatiello, C., de Rosa, B., Franco, S., & Lacetera, N.	2016	Consumer approach to insects as food: barriers and potential for consumption in Italy.	British Food Journal
15	Circus, V. E., & Robison, R.	2019	Exploring perceptions of sustainable proteins and meat attachment.	British Food Journal
16	Contini, C., Boncinelli, F., Marone, E., Scozzafava, G., & Casini, L.	2020	Drivers of plant-based convenience foods consumption: Results of a multicomponent extension of the theory of planned behaviour.	Food Quality and Preference
17	de Boer, J., Schösler, H., & Boersema, J. J.	2013	Motivational differences in food orientation and the choice of snacks made from lentils, locusts, seaweed or “hybrid” meat.	Food Quality and Preference
18	Faber, I., Castellanos-Feijoó, N. A., van de Sompel, L., Davydova, A., & Perez-Cueto, F. J. A.	2020	Attitudes and knowledge towards plant-based diets of young adults across four European countries. Exploratory survey.	Appetite
19	Faber, I., Castellanos-Feijoó, N. A., van de Sompel, L., Davydova, A., & Perez-Cueto, F. J. A.	2020	Attitudes and knowledge towards plant-based diets of young adults across four European countries. Exploratory survey.	Appetite
20	Gere, A., Székely, G., Kovács, S., Kókai, Z., & Sipos, L.	2017	Readiness to adopt insects in Hungary: A case study.	Food Quality and Preference,
21	Gmuer, A., Nuessli Guth, J., Hartmann, C., & Siegrist, M.	2016	Effects of the degree of processing of insect ingredients in snacks on expected emotional experiences and willingness to eat.	Food Quality and Preference

22	González, N., Marquès, M., Nadal, M., & Domingo, J. L.	2020	Meat consumption: Which are the current global risks? A review of recent (2010–2020) evidences.	Food Research International
23	Graça, J., Oliveira, A., & Calheiros, M. M.	2015	Meat, beyond the plate. Data-driven hypotheses for understanding consumer willingness to adopt a more plant-based diet.	Appetite
24	Grahl, S., Strack, M., Mensching, A., & Mörlein, D.	2020	Alternative protein sources in Western diets: Food product development and consumer acceptance of spirulina-filled pasta.	Food Quality and Preference
25	Gullón, B., Gagaoua, M., Barba, F. J., Gullón, P., Zhang, W., & Lorenzo, J. M.	2020	Seaweeds as promising resource of bioactive compounds: Overview of novel extraction strategies and design of tailored meat products.	Trends in Food Science & Technology
26	Hartmann, C., Ruby, M. B., Schmidt, P., & Siegrist, M.	2018	Brave, health-conscious, and environmentally friendly: Positive impressions of insect food product consumers.	Food Quality and Preference
27	Hartmann, C., Shi, J., Giusto, A., & Siegrist, M.	2015	The psychology of eating insects: A cross-cultural comparison between Germany and China.	Food Quality and Preference
28	Hartmann, C., & Siegrist, M.	2016	Becoming an insectivore: Results of an experiment.	Food Quality and Preference
29	Hartmann, C., & Siegrist, M.	2017	Consumer perception and behaviour regarding sustainable protein consumption: A systematic review.	Trends in Food Science & Technology
30	Annet C. Hoek, Pieternel A. Luning, Pascale Weijzen, Wim Engels, Frans J.Kok, & Ceesde Graaf	2017	Shrinking the food-print: A qualitative study into consumer perceptions, experiences and attitudes towards healthy and environmentally friendly food behaviours	Appetite
31	Hoek, A. C., Pearson, D., James, S. W., Lawrence, M. A., & Friel, S.	2017	Shrinking the food-print: A qualitative study into consumer perceptions, experiences and attitudes towards healthy and environmentally friendly food behaviours.	Appetite
32	House, J.	2016	Consumer acceptance of insect-based foods in the Netherlands: Academic and commercial implications.	Appetite
33	Imm, B. Y., Heo, Y. W., & Imm, J.-Y.	2021	Effects of plant-based content, flavor and texture information on consumer satisfaction with non-fried ramen.	Food Quality and Preference

34	Jensen, N. H., & Lieberoth, A.	2019	We will eat disgusting foods together – Evidence of the normative basis of Western entomophagy-disgust from an insect tasting.	Food Quality and Preference
35	Kostecka, J., Konieczna, K., & Cunha, L. M.	2017	EVALUATION OF INSECT-BASED FOOD ACCEPTANCE BY REPRESENTATIVES OF POLISH CONSUMERS IN THE CONTEXT OF NATURAL RESOURCES PROCESSING RETARDATION.	Journal of Ecological Engineering
36	la Barbera, F., Verneau, F., Amato, M., & Grunert, K.	2018	Understanding Westerners' disgust for the eating of insects: The role of food neophobia and implicit associations.	Food Quality and Preference
37	Laureati, M., Proserpio, C., Jucker, C., & Savoldelli, S.	2016	New sustainable protein sources: Consumers' willingness to adopt insects as feed and food.	Italian Journal of Food Science
38	Lazzarini, G. A., Visschers, V. H. M., & Siegrist, M.	2017	Our own country is best: Factors influencing consumers' sustainability perceptions of plant-based foods.	Food Quality and Preference
39	le Goff, G., & Delarue, J.	2017	Non-verbal evaluation of acceptance of insect-based products using a simple and holistic analysis of facial expressions.	Food Quality and Preference,
40	Lemken, D., Knigge, M., Meyerding, S., & Spiller, A.	2017	The Value of Environmental and Health Claims on New Legume Products: A Non-Hypothetical Online Auction.	Sustainability
41	Lensvelt, E. J. S., & Steenbekkers, L. P. A.	2014	Exploring Consumer Acceptance of Entomophagy: A Survey and Experiment in Australia and the Netherlands.	Ecology of Food and Nutrition
42	Lombardi, A., Vecchio, R., Borrello, M., Caracciolo, F., & Cembalo, L.	2019	Willingness to pay for insect-based food: The role of information and carrier.	Food Quality and Preference,
43	Losada-Lopez, C., Dopico, D. C., & Faína-Medín, J. A.	2021	Neophobia and seaweed consumption: Effects on consumer attitude and willingness to consume seaweed.	International Journal of Gastronomy and Food Science
44	Losada-Lopez, C., Dopico, D. C., & Faína-Medín, J. A.	2021	Neophobia and seaweed consumption: Effects on consumer attitude and willingness to consume seaweed.	International Journal of Gastronomy and Food Science,
45	Mancini, S., Moruzzo, R., Riccioli, F., & Paci, G.	2019	European consumers' readiness to adopt insects as food. A review.	Food Research International

46	Marberg, A., van Kranenburg, H., & Korzilius, H.	2017	The big bug: The legitimization of the edible insect sector in the Netherlands.	Food Policy
47	McCarthy, K. S., Parker, M., Ameerally, A., Drake, S. L., & Drake, M. A.	2017	Drivers of choice for fluid milk versus plant-based alternatives: What are consumer perceptions of fluid milk?	Journal of Dairy Science
48	Menozzi, D., Sogari, G., Veneziani, M., Simoni, E., & Mora, C.	2017	Eating novel foods: An application of the Theory of Planned Behaviour to predict the consumption of an insect-based product.	Food Quality and Preference,
49	Michel, F., Hartmann, C., & Siegrist, M.	2021	Consumers' associations, perceptions and acceptance of meat and plant-based meat alternatives.	Food Quality and Preference
50	Milinovic, J., Mata, P., Diniz, M., & Noronha, J. P.	2021	Umami taste in edible seaweeds: The current comprehension and perception.	International Journal of Gastronomy and Food Science,
51	Niva, M., & Vainio, A.	2021	Towards more environmentally sustainable diets? Changes in the consumption of beef and plant- and insect-based protein products in consumer groups in Finland.	Meat Science
52	Pagliarini, E., Proserpio, C., Spinelli, S., Lavelli, V., Laureati, M., Arena, E., di Monaco, R., Menghi, L., Gallina Toschi, T., Braghieri, A., Torri, L., Monteleone, E., & Dinnella, C.	2021	The role of sour and bitter perception in liking, familiarity and choice for phenol-rich plant-based foods.	Food Quality and Preference
53	Palmieri, N., & Forleo, M. B.	2020	The potential of edible seaweed within the western diet. A segmentation of Italian consumers.	International Journal of Gastronomy and Food Science
54	Palmieri, N., & Forleo, M. B.	2020	The potential of edible seaweed within the western diet. A segmentation of Italian consumers.	International Journal of Gastronomy and Food Science
55	Pascucci, S., & de magistris, T.	2013	Information bias condemning radical food innovators? The case of insect-based products in the Netherlands.	International Food and Agribusiness Management Review
56	Peschel, A. O., Kazemi, S., Liebichová, M., Sarraf, S. C. M., & Aschemann-Witzel, J.	2021	Consumers' associative networks of plant-based food product communications.	Food Quality and Preference
57	Piha, S., Pohjanheimo, T., Lähteenmäki-Uutela, A., Křečková, Z., & Otterbring, T.	2018	The effects of consumer knowledge on the willingness to buy insect food: An exploratory	Food Quality and Preference

			cross-regional study in Northern and Central Europe.	
58	Possidónio, C., Prada, M., Graça, J., & Piazza, J.	2021	Consumer perceptions of conventional and alternative protein sources: A mixed-methods approach with meal and product framing.	Appetite
59	Possidónio, C., Prada, M., Graça, J., & Piazza, J.	2021	Consumer perceptions of conventional and alternative protein sources: A mixed-methods approach with meal and product framing.	Appetite
60	Qi, X., & Ploeger, A.	2021	An integrated framework to explain consumers' purchase intentions toward green food in the Chinese context.	Food Quality and Preference
61	Renner, B., Sproesser, G., Strohbach, S., & Schupp, H. T.	2012	Why we eat what we eat. The Eating Motivation Survey (TEMS).	Appetite
62	Saint-Eve, A., Irlinger, F., Pénicaud, C., Souchon, I., & Marette, S.	2021	Consumer preferences for new fermented food products that mix animal and plant protein sources.	Food Quality and Preference
63	Schiano, A. N., Harwood, W. S., Gerard, P. D., & Drake, M. A.	2020	Consumer perception of the sustainability of dairy products and plant-based dairy alternatives.	Journal of Dairy Science,
64	Schlup, Y., & Brunner, T.	2018	Prospects for insects as food in Switzerland: A tobit regression.	Food Quality and Preference
65	Schösler, H., Boer, J. de, & Boersema, J. J.	2012	Can we cut out the meat of the dish? Constructing consumer-oriented pathways towards meat substitution	Appetite
66	Schouteten, J. J., de Steur, H., de Pelsmaecker, S., Lagast, S., Juvinal, J. G., de Bourdeaudhuij, I., Verbeke, W., & Gellynck, X.	2016	Emotional and sensory profiling of insect-, plant- and meat-based burgers under blind, expected and informed conditions.	Food Quality and Preference
67	Sheppard, B., & Frazer, P.	2015	Comparing Social and Intellectual Appeals to Reduce Disgust of Eating Crickets.	Studies in Arts and Humanities
68	Siegrist, M., & Hartmann, C.	2019	Impact of sustainability perception on consumption of organic meat and meat substitutes.	Appetite
69	Slade, P.	2018	If you build it, will they eat it? Consumer preferences for plant-based and cultured meat burgers.	Appetite
70	Sogari, G.	2015	Entomophagy and Italian consumers: An exploratory analysis.	Progress in Nutrition

71	Sogari, G., Menozzi, D., & Mora, C.	2017	Exploring young foodies' knowledge and attitude regarding entomophagy: A qualitative study in Italy.	International Journal of Gastronomy and Food Science,
72	Sogari, G., Menozzi, D., & Mora, C.	2018	Sensory-liking expectations and perceptions of processed and unprocessed insect products.	International Journal on Food System Dynamics,
73	Spencer, M., Cienfuegos, C., & Guinard, J. X.	2018	The Flexitarian Flip™ in university dining venues: Student and adult consumer acceptance of mixed dishes in which animal protein has been partially replaced with plant protein.	Food Quality and Preference
74	Tan, H. S. G., Fischer, A. R. H., van Trijp, H. C. M., & Stieger, M.	2016	Tasty but nasty? Exploring the role of sensory-liking and food appropriateness in the willingness to eat unusual novel foods like insects.	Food Quality and Preference
75	Tan, H. S. G., van den Berg, E., & Stieger, M.	2016	The influence of product preparation, familiarity and individual traits on the consumer acceptance of insects as food.	Food Quality and Preference
76	Vainio, A.	2019	How consumers of meat-based and plant-based diets attend to scientific and commercial information sources: Eating motives, the need for cognition and ability to evaluate information.	Appetite
77	van Loo, E. J., Caputo, V., & Lusk, J. L.	2020	Consumer preferences for farm-raised meat, lab-grown meat, and plant-based meat alternatives: Does information or brand matter?	Food Policy
78	Vanhonacker, F., van Loo, E. J., Gellynck, X., & Verbeke, W.	2013	Flemish consumer attitudes towards more sustainable food choices.	Appetite
79	Verbeke, W.	2015	Profiling consumers who are ready to adopt insects as a meat substitute in a Western society.	Food Quality and Preference
80	Verneau, F., la Barbera, F., Kolle, S., Amato, M., del Giudice, T., & Grunert, K.	2016	The effect of communication and implicit associations on consuming insects: An experiment in Denmark and Italy.	Appetite
81	Wang, O., & Scrimgeour, F.	2021	Willingness to adopt a more plant-based diet in China and New Zealand: Applying the theories of planned behaviour, meat attachment and food choice motives.	Food Quality and Preference
82	Wang, O., & Scrimgeour, F.	2021	Willingness to adopt a more plant-based diet in China and New Zealand: Applying the theories of	Food Quality and Preference

			planned behaviour, meat attachment and food choice motives.	
83	Wendin, K., & Undeland, I.	2020	Seaweed as food – Attitudes and preferences among Swedish consumers. A pilot study.	International Journal of Gastronomy and Food Science
84	Wier, M., O'Doherty Jensen, K., Andersen, L. M., & Millock, K.	2008	The character of demand in mature organic food markets: Great Britain and Denmark compared.	Food Policy
85	Ye, T., & Mattila, A. S.	2021	The effect of ad appeals and message framing on consumer responses to plant-based menu items.	International Journal of Hospitality Management

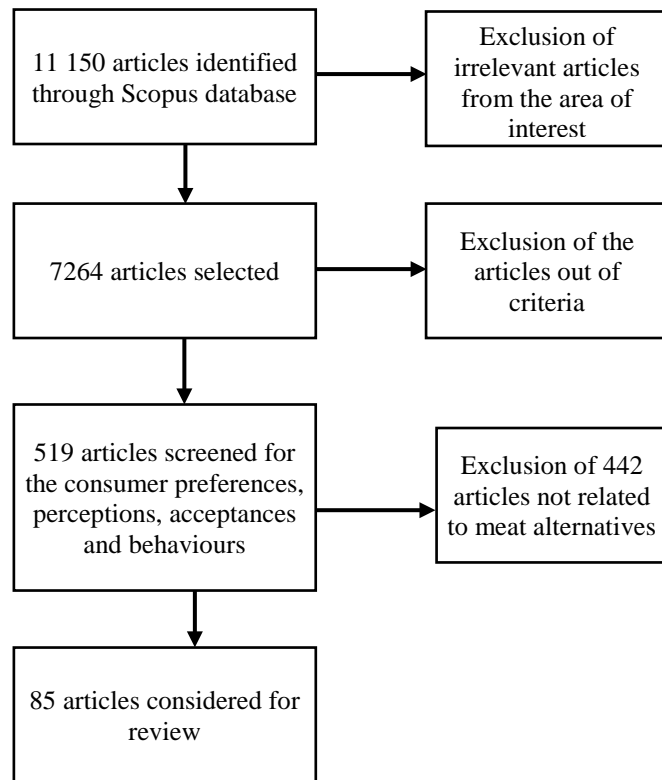


Figure S1. Flowchart highlighting the screening strategy used to identify the eligible papers.

Table S2. Inclusion and exclusion criteria for the selection process of the peer-reviewed articles

Inclusion criteria	Exclusion criteria
<ul style="list-style-type: none">• Contains data collection by a quantitative and qualitative approach• Written in English and published during last 10 years (2021-2021)• Categorized as research articles• Clearly mentions the country for data collection and the products investigated• Concerns on plant-, seaweed-, and insect-products as meat alternatives• Focuses on consumer preferences, perceptions, acceptance and behavior	<ul style="list-style-type: none">• Reviews, opinions, conference papers that are not related to meat alternatives• Concerns in policy of meat alternatives