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CONSUMER ACCEPTANCE, ATTITUDE AND KNOWLEDGE STUDIES ON ALTERNATIVE PROTEIN SOURCES: INSIGHT REVIEW

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ABSTRACT
As the world's population grows and climatic conditions worsen, the world's current resources are rapidly depleting. Human behavior exacerbates this adverse situation. One of these behaviors is traditional eating habits. A traditional diet that consists of animal-based proteins consumes more resources and pollutes the environment to a greater extent. The traditional diet, which consists of mostly animal-based proteins, may turn towards plant-based proteins. In addition to plant-based proteins, in recent years scientists have focused on exploring alternative protein sources that do not pollute the environment and require fewer resources. Plant-based proteins, algae, insect-based proteins, and cultured meat have all been identified in the literature as alternative protein sources that may be consumed alone (in dry or concentrated form) or added to foods. While alternative protein sources are still being developed, the consumer's opinion on these sources is being assessed. So, in this review, consumers' knowledge, acceptance, and attitude to alternative protein sources are discussed. Data shows that plant-based protein sources, including algae, are now widely claimed to be more accepted than traditional protein sources. It has also been established that most individuals are prejudiced toward insect-based protein and cultured meat due to lack of sufficient information.
Keywords: Alternative protein sources, consumer acceptance, consumer attitude, sustainability

ALTERNATİF PROTEİN KAYNAKLARI ÜZERİNE TÜKETİCİ KABULÜ, TUTUMU VE BİLGİ ÇALIŞMALARI: DERLEME MAKALESİ

ÖZ
Dünya nüfusu arttıkça ve iklim koşulları kötüleştikçe, mevcut kaynaklar hızla tükenmektedir. İnsan davranışları bu olumsuz durumu daha da kötüleştirmektedir. Bu davranışlardan biri de geleneksel beslenme alışkanlıklarıdır. Hayvansal proteinlere dayalı bir geleneksel diyet, daha fazla kaynağı tüketir ve çevreyi daha fazla kirletir. Çoğunlukla hayvansal protein içeren geleneksel diyet, bitki temelli proteinlere doğru yönelebilir. Son yıllarda bilim adamları, çevreyi kirletmeyen ve daha az kaynak gerektiren alternatif protein kaynaklarını keşfetmeye odaklanmıştır. Bitki temelli proteinler, algler, böcek temelli proteinler ve kültürlenmiş et, literatürde belirtildiği gibi tek başına tüketilebilen (kuru veya konsantre formda) veya yiyeceklere eklenen alternatif protein kaynakları olarak tanımlanmıştır. Alternatif protein kaynakları hala geliştirilmekte olup tüketicilerin bu kaynaklara yönelik görüşleri

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değerlendirilmektedir. Bu derlemede, tüketicilerin alternatif protein kaynaklarına yönelik bilgi, kabul ve tutumları tartışılmaktadır. Veriler, bitki temelli protein kaynaklarının, alglerin de içinde bulunduğu, geleneksel protein kaynaklarından daha fazla kabul edildiğini göstermektedir. Ayrıca, çoğu bireyin yeterli bilgiye sahip olmadığı için böcek temelli protein ve yapay et konusunda önyargılı olduğu belirlenmiştir.
Anahtar kelimeler: Alternatif protein kaynakları, tüketici kabulü, tüketici tutumu, sürdürülebilirlik

INTRODUCTION

The global population is projected to rapidly increase, reaching 9.7 billion by 2050 and 11 billion by 2100, according to the United Nations (United Nations, 2019). Alongside this development, the number of individuals who are malnourished is increasing daily. Undernourishment prevalence jumped from 8.0% in 2019 to around 9.3% in 2020 and continued to rise in 2021 to around 9.8%, with an estimated 828 million people facing hunger in 2021 (Food and Agriculture Organization, 2022). In contrast, 650 million individuals are considered obese, and 1.9 billion people are overweight (World Health Organization, 2020). This disparity between those who lack access to adequate and healthy food and those who are obese has been exacerbated by the COVID-19 pandemic (Workie et al., 2020).

The COVID-19 outbreak disrupted inter-country trade, causing interruptions in transportation networks, workforce shortages in food supply chains, and limitations on product movement. Each country had to rely on the resources at hand, leading many companies to go out of business and employees in various sectors to be laid off or experience financial losses (Özdin and Bayrak Özdin, 2020). This led to a realization that the world's current resources were unsustainable, and the concept of sustainability resurfaced.

Sustainability is defined as the ability to maintain a system in the long term and meet the needs of the present without compromising the needs of future generations (United Nations, 2022). To ensure the sustainability of community nutrition, decreasing underground and surface resources should be taken into account as well as increasing environmental pollution. Scientists have been working on producing alternative protein sources to ensure the long-term sustainability of public nutrition. These alternative protein sources should be easily accessible, clean, consistent, and provide sufficient nutrients to sustain life (World Economic Forum, 2019). Plant-based proteins (de Koning et al., 2020), algae (Enzing et al., 2014), insect-based protein (La Barbera et al., 2020), and cultured meat (World Economic Forum, 2019) have all been identified as protein sources that can potentially meet these sustainability parameters.

Despite the difficulties of altering a person's traditional diet, various efforts must be taken to achieve this change for the health of both the individual and the environment. The first step is to alter the type of protein in the diet. However, most consumers are uninformed about the environmental impact and are reluctant to change (Siegrist and Hartmann, 2019; Onwezen et al., 2021). Therefore, it is essential to understand why consumers may be unwilling to consume alternative protein sources and to develop interventions to promote consumer acceptability of various protein sources (Onwezen et al., 2021).

Most consumer acceptability and knowledge research has focused on plant-based proteins, algae (Onwezen et al., 2021), insect-based proteins (de Carvalho, 2020; La Barbera et al., 2020), and cultured meat (Thavamani et al., 2020). The results of this review are important for guiding society toward more sustainable protein consumption, industry development of alternative proteins, and identifying knowledge gaps in the consumption of alternative protein sources for sustainability reasons. Therefore, this review aims to summarize consumer awareness, attitude, knowledge, and acceptability research as well as provide information on alternative protein sources in the literature.

ALTERNATIVE PROTEIN SOURCES

In January 2016, the United Nations (UN) published the Sustainable Development Goals.

All member states have signed the goals, which include 17 titles that draw attention to concerns like poverty and hunger reduction, economic injustice, and climate change (United Nations, 2022). The second title included in the UN's goals is "Zero Hunger". According to the World Food Program, 135 million people are suffering from acute hunger, primarily as a result of human-induced conflicts, economic retrogression, and climate change. With billions of people on the brink of famine, actions are needed to deliver food and humanitarian aid to the areas most at risk. Simultaneously, a major shift in the global food and agricultural systems is required to secure enough nourishment for the more than 690 million people who are hungry now, as well as the projected 2 billion people who will be on the planet by 2050 (United Nations, 2022). Among the things that may be done to effect this radical change is the proliferation of alternative protein sources, which can avert potential hunger while creating less environmental harm than traditional protein sources. In recent years, scientists have concentrated their efforts on creating alternative protein sources in a variety of research and biotechnological studies (Can et al., 2021).

Plant-based Proteins

The demand for plant-based proteins has increased in recent years due to the rise in obesity, animal-based illnesses, and antibiotic-fed animals, as well as rising meat prices, which have limited people's consumption (Mongi and Gomezulu, 2022).

Plant-based proteins refer to products mostly composed of proteins derived from vegetables, legumes, grain protein (Clark and Bogdan, 2019). They are known as storage proteins and determine the nutritional values and functional properties of plant-based protein-derived foods (Saldamlı and Temiz, 2017). Most plant-based protein alternatives are currently developed from soybean due to their higher protein content, nutritional properties, and low price (Siddiqui et al., 2022).

Legumes can deliver greater quantities of protein (20-30%) without the high-fat content associated with protein-rich foods, whereas carbohydrates constitute approximately 75% of cereals, and their protein content ranges from 6 to 15% (Can et al., 2021). For example, chickpeas provide 18.56 g of protein, green lentils have 23.00 g, and peas have 19.82 g per 100 g with pulses getting 20-30% of their energy from protein and just about 3% from lipids (Ahnen et al., 2019; Can et al., 2021). This demonstrates that the protein content and quality of legumes are quite high and healthier than high-fat animal-based protein sources (Clark and Bogdan, 2019). When cereals and legumes were examined in terms of protein quality, it was observed that the protein digestibility-corrected amino acid scores (PDCAAS) of cereals ranged between 63 and 95, while dry legumes ranged between 68 and 100 (Can et al., 2021). Accordingly, it can be said that plant-based proteins are a healthy alternative that can compete with animal-based proteins.

Plant-based proteins also pollute less and consume fewer resources than animal-based proteins. For example, 1 kilogram of beans requires 3.8 m^2 of land, 2.5 m^3 of water, 39 g of fertilizer, and 2.2 g of pesticides; the same amount of beef requires 52 m^2 of land, 20.2 m^3 of water, 360 g of fertilizer, and 17.2 g of pesticides (Can et al., 2021) (Figure 1). Given the significant difference, it would be more prudent to manufacture plant-based proteins rather than animal-based proteins for the sake of global health and sustainability.

Protein isolates (≥ 90% protein content) and concentrates (48-70% protein content) derived from legumes, particularly grains, and oilseeds, are used in the industry (Can et al., 2021; Mongi and Gomezulu, 2022). However, the utilization of plant-based proteins in food compositions is currently limited. Plant-based protein sources contain non-nutritive components such as tannin, phytic acid, trypsin inhibitor, oligosaccharide, and have lower amino acid variety than animal-based proteins, in addition to being less digestible (Mongi and Gomezulu, 2022). Various studies have determined that plant-based proteins are the

most commonly preferred alternative protein source; however, there is still a need for extensive research in this area (Onwezen 2022; Takeda et al., 2023; Waehrens et al., 2023).

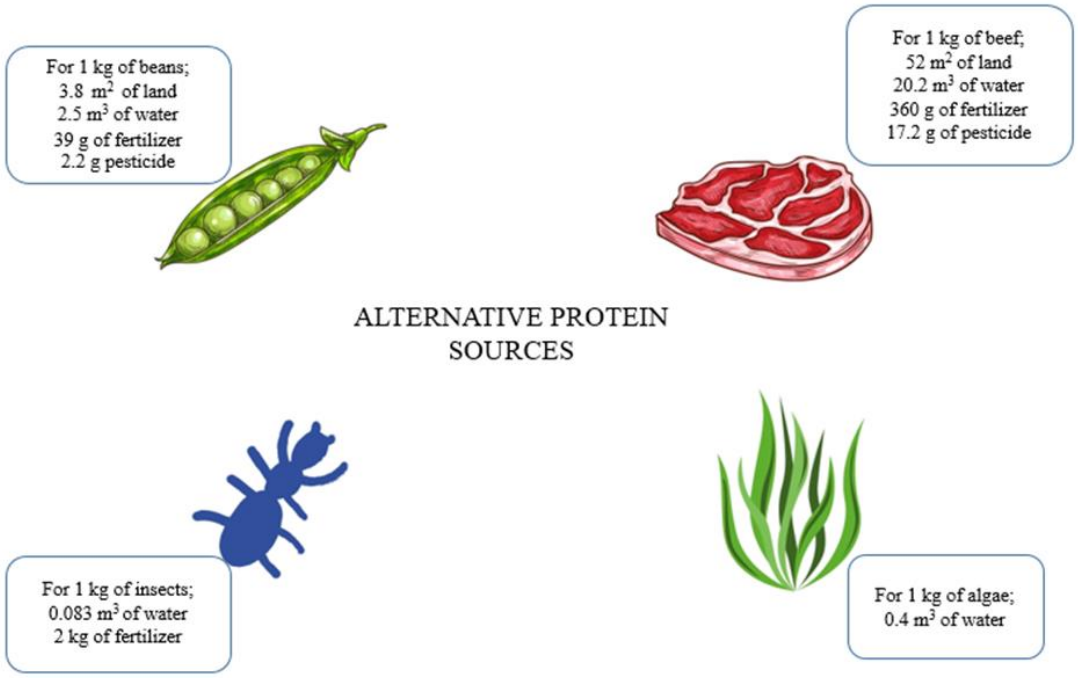

Figure 1. Current sources consumption amount of various alternative protein sources (Uribe-Wandurraga et al., 2013; Can et al., 2021)

Plant-based proteins are utilized in the production of plant-based meat analogs (PBMA) through various structuring processes (He et al., 2020). Replacing meat with plant-based proteins by 50% can reduce greenhouse gas emissions (GHGE) by 32% (Xue et al., 2019). However, traditional meat consumers often find PBMA unappealing in terms of taste and appearance (Wild et al., 2014). Improvements in the sensory and structural properties of PBMA are necessary for its widespread acceptance, and this is expected to increase as the food industry strives to enhance the quality of plant-based alternatives (Wild et al., 2014; Al-Thawadi, 2018). Consumer behavior must also be addressed to encourage the consumption of alternative protein sources with minimal environmental impact.

Algae

Algae are small, single-celled organisms that can thrive in both marine and freshwater environments. According to the World Health Organization, microalgae is now considered one of the world's largest superfoods, and NASA has deemed microalgae to be the best source of nourishment for astronauts in space (Stunda-Zujeva and Ruģele 2018). For centuries, Asians have regarded algae as a miraculous source of food and medicine and have consumed them as traditional cuisine. As a result of immigration from China, Japan, and the Republic of Korea, the consumption of algae has spread around the world, and it is now consumed in many countries (Al-Thawadi, 2018).

Algae are considered to be a good source of natural and renewable bioactive compounds such as polysaccharides, peptides, vitamins, minerals, phlorotannins, fatty acids, and terpenes (Øverland et al., 2019). They are particularly rich in proteins, making them a suitable choice for filling the "protein gap" (Tiasto et al., 2018).

Research has also identified algae as one of the alternative protein sources that can be consumed in the future, with protein quality comparable to that of animal-based protein sources. *Chaetoceros* sp. (protein percentage 33%, protein quality 60%), *Dunaliella* sp. (25.7-35.7%), and *Synechococcus* sp. (63-88%) were the algae species with the highest protein percentage and quality. Additionally, their amino acid composition is similar to protein sources such as eggs or soybeans, with brown seaweeds having a high proportion of aspartic and glutamic acids (22-44% of total amino acids in some species of brown algae) (Can et al., 2021; Rawiwan et al., 2022) . It is nutritious enough to fulfill growth requirements and could be used to combat hunger and malnutrition, making it one of the alternative protein sources that can be consumed in the future.

Over 28,000 new algae chemicals have been discovered since its identification (El Zokm et al., 2021). Two popular species of algae, *Spirulina* and *Chlorella*, are commercially available and generally recognized as safe (GRAS) (Can et al., 2021). *Spirulina* is commonly harvested from lakes and oceans, but due to increased demand, it is also grown in specialized ponds using photosynthetic activity at optimal temperatures of 35-38 °C (Rawiwan et al., 2022). *Spirulina* is consumed as a tea or added to different foods to substitute existing food additives. *Chlorella* and *Arthrospira platensis* are also used as ingredients in various forms like powder, paste, pellets, and flakes to produce vegetarian meat analogs, animal feeds, pasta, and beverages (Moura et al., 2023). Seaweed farming is more prominent in Asia (China, Indonesia, Philippines, Korea, and Japan) and Africa (Zanzibar and Madagascar) and serves as a socio-economic opportunity for coastal communities (Food and Agriculture Organization, 2021).

Despite the increasing popularity of algae-based products, especially *Spirulina*, it still lacks recognition and popularity among many people (Henchion et al., 2017). However, algae are considered marine vegetables in some countries like France and Italy, where they are widely consumed (Sampels, 2014; Palmieri and Forleo, 2020). To increase acceptability, various products with added *Spirulina* have been developed, and studies have determined the appropriate amount and product type for consumer acceptance (Batista et al., 2017; Niccolai et al., 2019; Grahl et al., 2020; Letras et al., 2022). Adding microalgae to ketchup could increase its nutritional value and acceptability (Martínez-Monzó, 2021), and *Spirulina* added to pasta and cereal bars was better liked by consumers (Lucas et al., 2023).

As the research on the nutritional value of algae grows, studies should also be conducted to dispel people's misconceptions about algae consumption. Furthermore, national research on the acceptance of algae consumption and opinions that may lead to consumer bias in different countries should be conducted.

Cultured Meat

Meat demand is dominated by beef, pork, sheep, and poultry globally. The demand is expected to increase by 14% by 2030, driven mainly by population and income growth (OECD/FAO, 2023). Cultured meat, also known as cell-based, clean, or lab-grown meat, has recently gained popularity as a solution to the challenging environmental issues related to livestock farming (Heinrich-Böll-Stiftung, 2021; Pakseresht et al., 2022). Cultured meat is produced from the in-vitro cultivation of animal cells, eliminating the need for large-scale farming practices (Post, 2014). However, the cost of production remains high due to developing technology (Enzing et al., 2014).

Compared to a $1 beef hamburger that can be made in no time, the first in vitro hamburger in 2013 cost over $300,000 and took 2 years to develop (Mateti et al., 2022). Humbird estimates the market price for premium quality in vitro meat to be a minimum of $50/kg, whereas large-scale batch processes using low-cost media could provide meat under $25/kg (Humbird, 2021).

However, animal agriculture and meat production are under scrutiny for their impact on the environment, public health, and animal welfare

(Bryant and Sanctorum, 2021). They generate 14.5% of greenhouse gas emissions and cause deforestation worldwide by requiring a considerable amount of land resources (Enzing et al., 2014; Garcia et al., 2017). The sector also uses the most pesticides, contaminating groundwater, and harming biodiversity. The use of antibiotics in livestock can lead to increased microbial resistance in humans, affecting human health (Enzing et al., 2014). The harmful effects of excessive meat intake on human health have also become alarming (Marinova and Bogueva, 2019; Thavamani et al., 2020) Therefore, the food industry is exploring non-animal-based proteins as meat alternatives that have similar sensory qualities to traditional meat and are appealing to consumers (He et al., 2020). The research community is investigating three forms of meat analogs: cultured meats, PBMA, and mycoprotein-based meat (Kristensen et al., 2016; World Economic Forum, 2019). Plant-based meat alternatives are derived from plant-based ingredients such as beans, legumes, lentils, and grains. They offer a sustainable protein source that closely mimics animal meat in texture, flavor, color, and nutritional profile (Zor et al., 2024). However, PBMA doesn't quite match the sensory qualities of traditional meat, and scientists are still working on producing cultured meat in laboratory settings (Clark and Bogdan, 2019; Thavamani et al., 2020; Gousset et al., 2022).

Cultured meat is produced by taking cells from a living animal, which are then grown in a cultivator to create muscle and adipose tissue that can be processed into meat products without the need for animal slaughter. Cultured meat has several advantages over PBMA, including comparable nutritional value, flavor, aroma, texture, and taste to traditionally produced meat, lower resource requirements, and reduced greenhouse gas emissions (Weinrich et al., 2020; Bryant and Sanctorum, 2021). Cultured meat production is also expected to reduce the use of pesticides and chemicals (Mancini and Antonioli, 2022a). However, cultured meat is currently the most expensive alternative protein source to produce, followed by insect-based protein sources, while protein derived from grains and beans have the lowest costs (World Economic Forum, 2019). Despite this, meat alternatives are becoming increasingly popular in various markets worldwide (de Koning et al., 2020).

The legal status and labeling requirements for cultured meat are still being debated (Can et al., 2021; Mancini and Antonioli, 2022a). In some studies, individuals were found to be ambivalent about consuming cultured meat (Tso et al., 2020; Gousset et al., 2022) while a few studies found a high willingness to consume it (Wilks and Phillips, 2017; Weinrich et al., 2020; Mancini and Antonioli, 2022b).
If the necessary infrastructure is built, it is expected that consumers will readily accept this alternative protein source if the taste and smell of cultured meat are identical to or extremely similar to beef.

Insects-based Proteins
Insects are gaining popularity as a protein source, with potential benefits for sustainability (Wendin and Nyberg, 2021). Although insects have been a part of diets in many parts of the world, European consumers are just starting to consider this food (Piha et al., 2018). Consumer beliefs and behaviors play a key role in this trend (Grasso et al., 2019).

Insects are considered a valuable resource for long-term sustainability, with the potential to directly contribute to eight of the 17 UN Sustainable Development Goals and indirectly to nine (Uribe-Wandurraga et al., 2013). With their high nutritional value, insects are particularly suited to meeting the goal of "Zero Hunger."

Insects have a high protein content, ranging from 13 to 77%, and their protein digestibility is lower than animal-based proteins but higher than most plant-based proteins, ranging from 76-98%. Additionally, insects have a varying essential amino acid profile ranging from 50-80%, making them a potential source of protein to alleviate hunger (Can et al., 2021). The fat content of edible insects ranges between 10% and 50%. As a result, even small quantities will provide high calories. For example, 100 grams of *Coleoptera* (adult,

larvae) insects supply 490 kcal to an individual; 484 kcal of *Hymenoptera* (ants, bees); 508 kcal of *Lepidoptera* (butterflies, moths); and 650 kcal of *Galleria mellonella* (waxworms) (Can et al., 2021). Insects also have a high concentration of lipids, high-quality and easily digested proteins, vitamins, minerals, and other bioactive compounds (de Carvalho et al., 2020). Due to their high content of vitamins such as B_{12}, minerals like iron and zinc, fiber, essential amino acids, omega-3, omega-6, and antioxidants, they have positive effects on health (Özdal and Nakilcioğlu, 2024). Micronutrients such as calcium, iron, magnesium, manganese, phosphorus, selenium, and zinc are examples, as are vitamins such as riboflavin, pantothenic acid, biotin, and, in some cases, folic acid (Akande et al., 2020). With a diverse nutritional profile, insects can play an essential role in avoiding hunger and malnutrition.

When it comes to the development of insect-based protein sources, edible insects have a greater feed-to-conversion rate than typical animal-based protein sources. It also produces less GHGE and consumes fewer resources. As a result, insects are considered a sustainable and viable source of food and feed (Figure 1) (Uribe-Wandurraga et al., 2013).

Approximately 1900 insect species are consumed globally, of which 524 are consumed in developing countries (Awobusuyi et al., 2020). Socio-demographic factors like age, gender, and nationality also influence insect consumption. For example, young people are more willing to eat insect-based cuisine than older ones (Naranjo-Guevara et al., 2021), and men are more open to consuming insects than women (Sogari et al., 2019). Social norms also play a role in people's reluctance to consume insects (Jensen and Lieberoth, 2019; Lammers et al., 2019; Dagevos and Taufik, 2023). In Australia, factors such as taste, appearance, safety, and quality are crucial in increasing consumer willingness to eat insects (Wilkinson et al., 2018). As people become more aware of climate change and environmental health, insect-based protein meal consumption is projected to increase.

Consumer Acceptance and Knowledge Studies on Alternative Protein Sources

Given the climate crisis and a rapidly increasing world population, equitable access to clean and sufficient food will be challenging (Øverland et al., 2019). As a result, demand for alternative protein sources is rising. Research on people's knowledge, attitudes, and preferences toward alternative protein sources has gained momentum in the literature over the past five years, with studies encompassing various age groups and nationalities.

For example, in a study of elderly individuals in the EU, plant-based proteins were most accepted (58%), while cultured meat and insect-based proteins had the lowest acceptability (Grasso et al., 2019). However, Mancini and Antonioli found that novel plant-based foods and edible insects were the most viable future alternatives for Italian consumers (Mancini and Antonioli, 2022b). Cultured meat was difficult to accept for most people, according to the study. Gender did not affect the likelihood of choosing protein sources in the future, but younger participants were more willing to try new protein alternatives (Clark and Bogdan, 2019). Portuguese men are more knowledgeable about sustainability and accept insect-based protein meat at a higher rate than women (Florença et al., 2021).

The COVID-19 and African Swine flu pandemics, food safety concerns, and the risk of disease from animal-sourced food have increased the demand for PBMAs (Tso et al., 2020). Plant-based protein sources are the most preferred alternative protein sources (58%) (Grasso et al., 2019). It is hoped that this shift in the pandemic will change traditional dietary components. PBMA products are perceived as modern, artificial, and expensive compared to pulses (Spendrup and Hovmalm, 2022). Consumers of PBMA are generally younger, mostly female, well-educated, and concerned about health and the environment. Educating others about this issue is critical (Siegrist and Hartmann, 2019). A joint study in the UK, Germany, and France found that burgers made with seaweed and peas were less acceptable than beef burgers due to high

adherence to beef, negative attitudes towards vegetarian and vegan lifestyles, and food neophobia. Despite negative sentiments, peas, and algae emerged as viable protein alternatives due to favorable health and environmental friendliness expectations (Michel et al., 2021).

Consumer acceptance of algae as a food source is currently uncertain. Gender and country differences have been observed in attitudes toward microalgae consumption. Social events positively impact the attitudes of Dutch female consumers towards microalgae while negatively impacting Dutch and German males. Higher-income decreases French male consumers' positive attitudes toward microalgae while increasing it for Dutch male consumers (Weinrich and Elshiewy, 2023). Additionally, the type of product in which algae is consumed influences demand. Young men prefer seaweed in snack products and fast food more than women (Wendin and Undeland, 2020).

Grahl et al. studied consumer willingness to try three *Spirulina*-containing meals and found *Spirulina*-filled pasta to be the preferred product (Grahl et al., 2020). In the UK, individuals are open to accepting microalgae, but beliefs about cost, health, and sustainability have a weak influence on acceptance (Embling et al., 2022). Increasing knowledge levels may help boost the effect of these factors, but many people in Spain are still hesitant to consume microalgae due to food neophobia, despite believing it is sustainable, nutritious, and safe (Lafarga et al., 2021; Losada-Lopez et al., 2021). Familiarity with the Spirulina flavor has been shown to increase acceptance in some participants (Al-Thawadi, 2018; Grahl et al., 2020; Lafarga et al., 2021).

Consumer opinions on insect-based proteins vary widely. Bread made from insect flour has been found to cause "disgust and anxiety" in some individuals (Castro Delgado et al., 2020; García-Segovia et al., 2020), while 64% of Americans are reportedly willing to try insect-based meals (Ruby, et al., 2015). In Germany, 41.9% of participants were willing to consume insect burgers, but "disgust" was cited as the main reason for avoiding insect-based foods in Turkey (Yüksel and Canhilal, 2018). Hungarian participants were found to be unaware of the health benefits of insect-based protein sources, and food neophobia hindered their willingness to consume insects (Gere et al., 2017; Naranjo-Guevara et al., 2021). Differences in consumer acceptance may be related to dietary patterns, as individuals in countries where insects are not traditionally consumed may have difficulty accepting insect-based proteins. Knowledge of the protein source is a key factor in determining consumer willingness to consume insect-based foods (Naranjo-Guevara et al., 2021), and as people become more educated about alternative protein sources and environmental health, it is expected that consumer acceptability will increase.

Table 1 summarizes various studies on consumer knowledge and acceptance of alternative protein sources in numerous countries revealing diverse results. Although there are country-specific studies in the research, given each country's traditions, religious regulations, and habits, these facts cannot be applied to all of humanity. As a result, the findings of the investigations cannot be generalized.

Table 1. Consumer acceptance and knowledge studies on alternative protein sources in various countries

Country	Method	Results	Publication
Japan	The research was completed by an online questionnaire with participants from all over Japan (N=5,000).	It was determined that the highest accepted alternative protein source was PBM. More than 40.0% of respondents requested the government to regulate labeling for all alternative proteins.	(Takeda et al., 2023)

China	In the study, consumers were presented with different labels, different countries of origin, and various options to purchase hamburgers made from PBM or animal meat.	Respondents hold overall positive attitudes toward PBM food; 85 and 82% of respondents reported experience in eating and purchasing PBM food, respectively. Females and those with at least a bachelor's degree, higher income, religious beliefs, and dietary restrictions are more likely to buy PBM burgers than their counterparts.	(Ge et al., 2023)
	The research was completed by an online questionnaire (men:772 (50.39%); women:760 (49.61%)	Around 44% of the participants indicated that they would be willing to try CM, and 32% would be likely to purchase it.	(Li et al., 2023)
Austria, German, Belgium, Netherlands, Denmark, Sweden	Sensory analysis of PB alternatives to chicken, beef, semi-hard cheese, cream cheese, yogurt, and milk was studied via (part 1) a sensory vocabulary development and, subsequently, (part 2) an online survey (n = 416–1829) in some countries using the quick sensory descriptive method Rate-All-That-Apply.	While PB milk and yogurt alternatives received high liking scores (7.1-7.0/9), lower liking scores (5.3/9) were reported for semi-hard cheese alternatives.	(Waehrens et al., 2023)
United Kingdom	Participants were grouped as meat-eaters and non-meat-eaters. Products such as beef burgers, cheese sandwiches, and blueberry muffins were presented to the participants with three different labels (e.g., 'traditional', 'plant-based', and 'cultured' for the beef burger). Each product was evaluated for elements such as fullness, satisfaction, disgust, and WTP.	Both groups were more accepting of traditional meat products. The meat-eaters perceived PBMA as less satisfying but healthier. The meat-eater group found cultured meat healthier but more disgusting.	(Vural et al., 2023)
	Half of the participants were given an informative briefing on IBFs. The effect of various psychological factors on WTP for IBFs was then examined by all participants.	After being treated with the briefing, participants rated higher against IBFs. In addition, individuals with food neophobia and low eco-consciousness have lower attitudes toward IBFs.	(Michel and Begho, 2023)
Turkey	In the study, in vitro meat perspective was assessed through an online questionnaire (n=417).	Although participants saw IVM as a viable alternative to traditional meat, they did not find it natural, healthy, ethical, safe, or tasty. They also reported that they do not intend to consume IVM regularly.	(Baybars et al., 2023)

Ghana	Ghanaian consumers' knowledge of PBB, sensory attributes driving preferences and selection, and willingness to purchase were investigated.	Most of the consumers reported that they have sufficient awareness of PBB. Taste, cost, availability, and culture were the main barriers to consumption.	(Acquah et al., 2023)
Australia, India, Singapore, United States	The WTC of various food technologies has been tested in multiple countries.	Indians are more positive about all new food technologies than consumers, especially in the US and Australia. About one-fifth of consumers demonstrated high acceptance.	(Giacalone and Jaeger, 2023)
Colombia, France	Their perceptions and preferences for various packaging versions and insect-based bread and chips were investigated.	The perception of health/sweetness and WTP have changed significantly in terms of both product style and visual design, as well as suitability and taste.	(Marquis et al., 2023)
Australia	The research consisted of 1012 Australian food customers as a mixed-methods exploration study.	52% of consumers reported never purchasing alternative protein products, mainly due to lack of interest, sensory characteristics, lack of familiarity, and price. Three segments (30%) are willing to increase their consumption of alternative proteins. 6% of participants are against consuming all alternative protein sources.	(Malek and Umberger, 2023)
United States	Untrained participants were asked open-ended questions with 4 burger patties alternatives (beef, meat-mushroom hybrid protein, pea protein, and animal-like protein). One group was given blind tasting without being informed, while the other group tasted after being informed.	Beef and animal-like protein patties had the most meat-like attributes. In the blind condition, the hybrid burger ranked as the least favorite option. Both the texture and taste of the pea protein burger were not liked.	(Sogari et al., 2023)
	The participants, who were randomly divided into two groups, were asked to watch a hamburger advertisement for 10 s, made of 100% beef/0% PB and 80% beef/20% PB in the first group. The second group featured a hamburger ad made from 80% beef/20% PB and 80% PB/20% beef protein.	For consumers with a restrained mindset, perceptions of environmental sustainability increase with higher levels of PB protein content in hybrid meat analogs, which in turn leads to higher purchase intentions these effects are not observed for consumers with an indulgence mindset.	(Smart and Pontes, 2023)

Netherlands	This research is the first exploratory study of consumers' sympathy for circularity as a distinctive feature of insects as food and feeds to their acceptance of eating insects (i.e., entomophagy)	This study finds that consumer sympathy for the entomophagy of the participants in this study increases modestly, albeit statistically significant and in a robust way, as a result of providing information about the environmental, circular benefits of entomophagy.	(Dagevos and Taufik, 2023)
Belgium, China, Italy, Mexico, United States	The motivations of the participants in the study from different countries to accept or reject whole and processed mealworms were evaluated with an online questionnaire consisting of two open-ended questions.	"Healthiness" was the most frequent driver to accept whole and processed mealworms, except in Italy. "Aversion" and "dislike" were the most important barriers that led to rejecting these products across all five countries.	(Tzompa-Sosa et al., 2023)
Italy	In this study, attitudes towards seaweed, insects, and jellyfish were compared, the role of individual variables was investigated, and a new approach focusing on their potential gastronomic uses was proposed.	The results showed a significant effect of the product on the perceived positive impact of consumption on health (seaweed > insects > jellyfish) and the environment (jellyfish > seaweed and insects) and on WTT and WTD (seaweed > jellyfish > insects).	(Palmieri et al., 2023)
United Kingdom	In the study, the participants were divided into 6 focus groups. All groups were asked a series of questions about "algae" and "algae-based foods" using the "Zoom" application. First, the participants were asked to discuss their initial ideas about the term "algae". Secondly, a presentation about "algae" and "algae-based foods" was shown to the participants. Finally, participants were asked to discuss their willingness to purchase "algae" and "algae-based foods."	It was determined that although the participants had limited knowledge about algae, they were willing to consume algae. Under the algae consumption acceptance, various characteristics are included, including innovation, edibility, health, sustainability, and affordability.	(Mellor et al., 2022)
Italy	The effects of considerations such as human safety, animal welfare, and environmental impact on the willingness to try, purchase and analogs cultured meat were investigated through the online questionnaire.	While environmental impact united respondents, human safety and animal welfare claims differed significantly between gender and age groups. However, the weak relationship between WTT and WTS may indicate that being curious may not necessarily mean changing actual behavior	(Piochi et al., 2022)

United Kingdom	In an online study (N = 476), participants were presented with a general description of edible seaweeds, and descriptions of seaweed-based food products (e.g., 'seaweed burger').	Perceiving foods to be tasty and familiar mediated the negative effect of food neophobia on consumer acceptance ($p < .05$).	(Embling et al., 2022)
Germany	Information on the environmental benefits or resource savings of the technology and consumer assessment was questioned in a four-part questionnaire.	The study reveals that consumers accept new foods more easily when they have a clearer idea of a food production process and its products.	(Weickert et al., 2021)
	This study analyses consumer knowledge on protein sources in animal feeding and the likelihood of consumers being willing to try pork and poultry that has been produced using insects or micro algae in the feeding regime through univariate analyses as well as structural equation modeling.	Structural equation models reveal that consumers depend on the desire to purchase insect-based meat as an alternative protein source.	(Weinrich and Busch, 2021)
Spain	Participants in the young cooking workshop were asked questions measuring their views and attitudes before/after the seaweed tasting.	Food neophobia has affected algae consumption desire.	(Losada-Lopez et al., 2021)
	A 5-point hedonic scale was used on 3084 Spanish consumers over the age of 18.	Spanish consumers of micro algae; think that it is sustainable and environmentally friendly, nutritious and healthy, and safe to add to food products. It has been reported that the main reasons why its consumption is not widespread are the lack of information about the products and the lack of consumption habits.	(Lafarga et al., 2021)
Belgium	A survey was directed to the participants in 2019 and 2020. Participants answered online questions about their diet, their attitudes towards PBMA, and their attitudes towards cultured meat (grown from animal cells).	The proportion of Belgian consumers who say that existing PBMA meet their needs has increased significantly, from 44% to 51% in 2020.	(Bryant and Sanctorum, 2021)
	In this study, only a portion (eg, 20% to 50%) of the meat product was replaced with PBP. The opinions of consumers about the modified meat product were investigated.	The results show that more than 50% of consumers substitute meat at least occasionally.	(Profeta et al., 2021)
Germany, France, UK	The online survey was conducted with meat-eating participants from Germany (N = 567), France (N = 605), and the United Kingdom (N = 562). The questionnaire was evaluated with pictures of burgers made from peas, algae, and beef.	Participants in all three countries expected pea and algae burgers to be less tasty, but healthier and more environmentally friendly compared to the beef burger.	(Michel et al., 2021)

China	In the questionnaire used in the study, food purchasing criteria, personal perceptions of cultured meat compared to traditional meat or PBMA, and participants' desire for cultured meat consumption.	In the study, it was determined that 87.2% of the participants were not WTC cultured meat compared to traditional meat. It is reported that one of the reasons behind this reluctance is the "perception of nonsense or disgusting".	(Liu et al., 2021)
USA, Mexico, Spain	100% whole wheat flour; chocolate chip cookies with 15% and 30% cricket powder added was presented to the individuals participating in the study.	It was determined that Mexican and Spanish consumers liked the 15% sample more than the 30% sample. Spanish consumers were also reported to like the control product more than the 30% sample. Accordingly, by adding 15% cricket powder, both the negative impact on the taste of the product can be prevented and the protein content can be improved.	(Castro Delgado et al., 2020)
Germany	Researchers focused on comparing children's and adolescents' attitudes towards foods made from insect-based protein and cultured meats and analyzing the effect of some nutritional-psychological factors on these attitudes.	The study participants showed a significantly higher WTC the cultured meat burger than the insect burger, although no difference could be shown in their attitudes toward the alternatives as food (i.e., irrespective of their form of preparation).	(Dupont and Fiebelkorn, 2020)
China, USA, France, UK, New Zealand, Netherlands, Brazil, Spain, and the Dominican Republic	Meat products derived from PB and insect-based protein were offered to 3091 participants, and behaviors such as trying, buying, and paying for these two analogs were evaluated, as well as their desire for meat.	Food neophobia was found to have a negative impact on the acceptance of two types of analogs.	(de Koning et al., 2020)
European Union countries	While using the frequency of food consumption to measure the dietary habits of elderly individuals, a questionnaire was created to investigate the consumption of various protein sources. A total of 1825 elderly individuals from 5 countries participated in the study.	The most preferred alternative protein sources are respectively; PB (58%), algae (20%), and insects (9%).	(Grasso et al., 2019)
Canada	A 24-question survey was administered to 410 adults, including various questions about the motivations behind their food choices.	It has been determined that they prefer pulses and soy products, paying attention to the fact that they are not processed in PBP sources. Perceptions of price, too much processed, and too much sodium content are seen as barriers to trying new plant-based proteins.	(Clark and Bogdan, 2019)

Germany	An online questionnaire was administered to 49,480 participants asking about their eating habits, sustainability awareness scale, food neophobia scale, familiarity with insects, insect-based food consumption, WTC to insect-based burgers and worms, and sociodemographic characteristics.	Although the sustainability awareness of the individuals participating in the study was strong, it did not have any effect on their desire to consume insect-based hamburger patties.	(Lammers et al., 2019)
Finland, Sweden, Germany, and the Czech Republic	Consumer survey data collected from 887 participants were analyzed with structural equation modeling and multi-group models.	Different types of knowledge and food neophobia cause general attitudes about insect-based foods. These effects differed significantly between Northern and Central Europe. Consumers in Northern Europe are more positive towards insect-based foods than consumers in Central Europe.	(Piha et al., 2018)
Germany, Netherlands, Italy	In the first of the stages arranged for the study, the participants were asked whether they had consumed any meat analogs before. In Stage 2, the reasons for consuming or not consuming meat analogs in their meals were investigated. In the next step, the interviewees were asked to indicate why they would not use analog meat in meals.	German participants were found to be more open-minded to trying new meat analogs than French participants. However, participants in all three countries had health concerns about meat analogs.	(Weinrich, 2018)
United Arab Emirates	A pilot study with 30 participants was conducted for the research. In this study, participants were asked to consume 7 types of algae, mango juice containing algae, and orange juice.	It was determined that 71% of the participants knew that algae were sold in the market and 73% preferred to consume algae.	(Al-Thawadi, 2018)

CONCLUSION

Future challenges include the growing global population, depletion of natural resources, and protein resource scarcity. Alternative protein sources with high protein and energy content are being explored as sustainable food alternatives, such as plant-based protein sources, algae, insect-based proteins, and cultured meat. Despite this, there is still prejudice against these alternative protein sources.

Plant-based protein sources and algae are the most popular alternative protein sources that people can consume. The major reason individuals consume these alternative protein sources is that they are familiar with their flavor.

Insect-based proteins and cultured meat have low consumer acceptability due to a lack of awareness about their nutritional makeup and a feeling of disgust among consumers. Additionally, the lack of a cultural habit of consuming insects is a major obstacle to their consumption.

Misinformation and lack of knowledge also exist among people regarding cultured meat. Additionally, the sensory differences, such as color, odor, texture, and taste, between cultured

meat and traditional meat can lead to prejudice and hesitation in consuming it. However, research on improving these sensory aspects could potentially increase consumer acceptance.

Educating consumers is crucial to increase their acceptance and knowledge of alternative protein sources. With proper education, individuals can understand the need for sustainable food alternatives and take individual measures for resource continuity and environmental health.

Country-specific studies on alternative protein sources cannot be generalized due to the influence of traditions, religious regulations, and habits.

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