

Review

# Consumer Acceptance of Alternative Proteins: A Systematic Review of Current Alternative Protein Sources and Interventions Adapted to Increase Their Acceptability

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**Abstract:** Conventional meat consumption has triggered an environmental burden along with effects on different disease spectrums according to existing research. The dietary patterns adopted by consumers significantly impact both planetary and individual health. Interventions are needed to support the protein transition. However, there is not yet an overview of interventions towards acceptance of novel proteins available. This systemic review highlights different varieties of alternative proteins and interventions adopted to increase the acceptance of alternative protein sources. Educational intervention, persuasion, training, and modeling approaches are summarized in this review. Furthermore, behavioral models triggering the consumer's response towards different alternative proteins are also discussed. The systemic review highlights that consumer acceptance varies among different alternative proteins. Food choice motives, familiarity, food neophobia, disgust, and cultural norms are among the various drivers of consumer acceptance. A comparison of these drivers indicates inconsistencies, presenting the need for future research.

**Keywords:** alternative proteins; dietary patterns; consumers; behavioral models; consumer response; consumer acceptance; neophobia; food choice motives; meat alternatives



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## 1. Introduction

It has been consistently shown that overconsumption of conventional meat is associated with disease spectrums and negative environmental effects [1–3]. Due to overconsumption of conventional meat, numbers of animals are reduced and, thus, the balance in the environment is disturbed and there is fear of the extinction of animals. Reducing meat consumption and replacing these proteins with more alternative proteins is necessary to address environmental and health concerns, as well as ensure food security, which is especially important due to the risk of overpopulation and limited protein raw materials.

According to estimates by the United Nations, the world population will grow to approximately 8.4–8.7 billion by 2030 and will reach 9–10 billion in 2050. Moreover, the life expectancy of individuals is expected to increase to up to 77 years by 2045–2050 [4]. Large-scale environmental problems and maintenance of food supplies are significant concerns in light of the estimated growth in population. More specifically, the increasing world population will lead to increased consumption of foods rich in protein. On the one hand, proteins have various advantages. For example, proteins are a fundamental requirement for individuals, necessary for muscle mass strength and maintenance, especially in aged individuals [5]. Proteins are also essential for healthy growth in children [6]. In addition, proteins maintain and protect the bones in all stages of life; good protein health also enhances the adaptive response during the training of athletes and sportspeople [7]. However, research consistently reveals that the consumption of animal-based proteins is too high, resulting in health hazards (cardiovascular diseases, diabetes type II, etc.) and environmental burdens associated with loss of biodiversity and the environmental impact of animal-based proteins in terms of their carbon footprint. A change in consumption trends from animal-based diets to plant-based diets has created potential benefits for individual health and the climate [8–11]. Possible interventions to enhance the acceptability of alternative proteins include educational persuasion, training, and modeling approaches [12].

There are various ways in which consumers can reduce meat consumption and replace protein intake: following a plant-based diet, which is also known as curtailment [13]; lowering meat consumption frequency, which is called flexitarianism [14]; or eliminating meat-based products entirely from the diet, referred to as vegetarianism or veganism. However, all of these meat-reduction strategies share low levels of consumer acceptance, which make it challenging for consumers to transition to consuming alternative and novel proteins. Alternative proteins include a variety of proteins that provide novel options that differ from traditional animal-based proteins. There is still no well-developed market for alternative proteins, which include algae (aquatic organisms that can be consumed), insects, plant-based meat alternatives, and cultured meat (clean meat produced in vitro). The demand for alternative protein sources needs to be increased by strengthening scientific support, both in research and development, regarding the various advantages over conventional meat and finding ways to increase consumer awareness of these alternative proteins [11].

An expanding body of research explores the factors that contribute to consumer acceptance of alternative proteins. These studies reveal that many factors drive the acceptance of alternative proteins. The most prominent factors of acceptance are motives behind food choices [15], perspectives on alternate protein sources [16], food neophobia, reluctance to consume novel foods [17], and familiarity with or exposure to the new products available in the market [18]. Different acceptance factors have been evaluated based on product-related factors, including food motivations (healthiness, taste, convenience, environmental benefits, and appearance). Upon consumption, it has been found that approximately 80% of participants believed insects to be a healthy source. Food familiarity is also a significant contributor to food motivation [19,20].

There is a need to translate this knowledge of consumer acceptance into behavior change interventions. There are far fewer studies on alternative proteins and interventions than on drivers of acceptance [11]. Additionally, to our knowledge, there are no systematic literature reviews on alternative proteins or interventions. This study, therefore, aimed to conduct a systematic literature review to determine which interventions are most effective in supporting behavior change in the context of alternative proteins. A food-related lifestyle framework is employed that utilizes local concepts. This framework helps identify food choices linked with personal decisions and food-related behaviors. Additionally, this review provides a detailed and comprehensive overview of the possibilities for increasing consumers' acceptance of alternative proteins. We start with a literature overview that highlights the need to increase consumer acceptance (Section 2) and provides a detailed

understanding of major alternative protein categories; namely, plant-based meat products, cultured meat, single-cell proteins, and insects (Sections 2.1–2.4).

## 2. The Need to Increase Acceptance of Alternative Proteins

Educational interventions are strategies that provide information. These educational interventions can significantly impact the psychological behavior of consumers by enhancing their level of knowledge, improving mood, and reducing the degree of uncertainty. It is considered that the foundation of behavioral change is knowledge, which drives consumers to adopt more self-care approaches [21]. However, information alone does not lead to behavioral change in consumers [22]. According to [23], it is necessary to specify the category of information for the targeted behavior. Framing information with persuasion, another intervention, can be an effective way to increase the efficiency of educational interventions. Persuasion refers to manipulating various forms of information [24]. In achieving consumer acceptance of alternative proteins, framing information practices have been proved to enhance consumer acceptance [25]; for instance, explaining how the final product of culture meat is obtained enhances its acceptance level compared to describing cultured meat itself [26]. Similarly to educational interventions, persuasion strategies alone are ineffective in reducing conventional meat consumption and increasing acceptance of alternative proteins [27]. These persuasion approaches can be effectively used in combination with other strategies that enhance their impact. For example, combining educational practices with interventions involving text messages [28] or self-care through the imagination of future goals [29] decreases conventional meat consumption, highlighting the relevance of combining different intervention studies.

Additionally, training refers to the development of skills that contribute to an individual's capability to perform targeted behavior [12]. The fourth type of intervention is benefit-based intervention, which refers to incentives and expectations. When consumers expect a reward, they will be attracted to the novel alternative product. For example, the use of price promotions attracts consumers towards meat alternatives. Several studies have utilized these approaches to change consumption trends towards lower consumption of red meat [11,25,27]. These expected rewards lead to environment-friendly purchase behavior [30]. Lastly, there are modeling approaches that aim to inspire consumers by encouraging famous individuals; e.g., celebrities [30,31]. Studies have proved that consumers mimic the behavior of models, such as movie stars and television stars [32]. As a significant proportion of the world population consumes conventional meat, changing people's social norms is quite challenging. However, studies on dynamic norms have observed that people are inspired by specific individuals and reduce meat consumption by following those individuals and adhering to a vegetarian diet [33]. To minimize environmental impact and to counteract growing protein requirements, food industries and the scientific community are exploring novel and alternative resources for protein. These alternative proteins can be obtained from plants, insects, or microorganism-based sources, such as single-cell proteins, making it possible to develop novel food products high in protein content [34,35]. Different motives and barriers may explain consumer acceptance of the various categories of alternative proteins. The most often cited classes of alternative proteins [36] are described below in detail. We define each category, describe the significant benefits and challenges, and summarize the compositions regarding specific relevant products (Table 1). Then, we explore which interventions are most appropriate for each category, thereby unraveling routes for each category and how consumer acceptance might be increased.

### 2.1. Plant-Based Meat Products

Plant-based meat products are based on protein obtained from plants following processing, such as silking, extrusion, and conditioning [37]. In the past, plant-based food materials, such as wheat, pea, rice, and peanut, have been used as meat alternatives in food products [38]. Most plant-based meat alternatives are currently developed from soybean due its higher protein content, nutritional properties, and low price.

The major problem that needs to be solved in developing meat alternatives using plant-based sources is the reconstruction of plant protein's globular structure into animal muscle protein's fibrous structure. Meat's color, taste, and flavor must also be reproduced. Plant-based meat substitutes are generally developed from soy and wheat proteins. Products made from soy proteins with 30% wheat protein substitution have attained the fibrous structure, chewiness, hardness, and texture closest to meat [37]. Pea proteins have also been used to produce plant-based meat alternatives as they have no beany smell, which leads to greater acceptability, and are not comprised of the allergens primarily associated with proteins from soybean [39]. Moreover, plant proteins obtained from legumes, such as lupins, chickpeas, and peanut, and grain proteins, such as proteins from corn, have been proven to be potential sources for plant-based meat alternatives [40].

### 2.2. Cultured Meat

One of the most promising meat alternatives is cultured meat, since animal-based proteins can be obtained directly from *ex vivo* cultivation of stem cells without raising and slaughtering animals [41,42]. Production of cultured meat products provides a more sustainable and environmentally friendly alternative to traditional meat production with similar flavor, taste, and nutritional profiles, so it is a potentially revolutionary meat production technology [43,44]. The production process for the development of cultured meat can be divided into three steps: (A) preparation of raw material (e.g., preparation of culture medium and isolation of animal stem cells); (B) formation of tissue cultures, such as the proliferation and growth of stem cells in large bioreactors, for the development of tissues and muscle fibers; (C) processing of end products—developed muscle cells are processed into required meat products.

Many types of stem cells can be used to develop cultured meat, such as endothelial cells, blood cells, and fibroblasts. However, obtaining highly purified muscle stem cells is the major challenge in stem cell acquisition. For this purpose, fluorescence-activated cell sorting technology has been widely used to purify the known population of stem cells [45]. To attain effective sorting of cells, expensive antibodies are required. In short, a culture system of various cell types is needed to selectively promote the growth of required stem cells and inhibit the growth of other cell types based on the metabolic characteristics of stem cells [46]. Using induced pluripotent stem cell (iPSC)-based technology, efficient derivation of animal muscle protein from porcine iPSCs in culture has been achieved by Genovese et al. and proved to be helpful for the development of meat substitutes [47] that have the potential for large-scale production in bioreactors [48]. The development of induced pluripotent stem cells from adult cells can be used to obtain cultured meat.

### 2.3. Single-Cell Proteins

Single-cell proteins, also known as microbial proteins, are also considered as meat substitutes. These proteins are primarily used in animal feed due to their high nutritional value [49]. This edible microbial protein industry uses wastewater from forestry, animal husbandry, and agriculture for the development of single-cell proteins; therefore, the production of these proteins is economical and cost-effective as it promotes the minimization of waste. Single proteins are currently consumed as meat alternatives after disruption of cell walls, extraction, and purification of proteins.

Single-cell proteins are comprised of eight essential amino acids that include lysine, which is usually absent in plant proteins [44]. In addition, single-cell proteins have been proved beneficial in terms of having a wide range of producing organisms, reduced growth time, and high production efficiency [50]. Single-cell proteins can be made suitable for human consumption by degrading the cell wall of microorganisms and removing nucleic acid [51]. These animal proteins exhibit various advantages, such as water retention, thermal gelation ability, fiber-forming properties, and ease of digestion [52].

In addition to single-cell proteins, edible fungi are also suitable meat substitutes due to their high nutritional value. They contain high levels of protein and dietary fiber, low levels

of fat, and high levels of sulfur-containing amino acids; furthermore, some kinds of edible fungi produce a meaty flavor. These edible proteins can be attained from various species of fungi, such as *Pleurotus eryngii*, *Lentinus edodes*, *Agaricus bisporus*, *Pleurotus ostreatus*, and *Flammulina velutipes*. Edible fungal protein is cost-effective and economical compared to plant/animal or bacterial proteins. Some edible fungi are easy to cultivate and harvest. Moreover, these proteins have healthy, beneficial biological activities; additionally, they are widely accepted by consumers in terms of their safety and health benefits [53]. Further studies of disputing the necessity of animal proteins are needed to increase consumer acceptance of these proteins.

#### 2.4. Insects

Insects are a significant source of protein and are used as animal feed to provide sustainable protein content. Insects are comprised of primary fat content (PUFA), protein, minerals, and vitamins. Moreover, they utilize low levels of land and water resources and produce fewer greenhouse gases [51,54]. Significantly, they feed on organic waste, garbage, and other waste streams. They can significantly reduce environmental pollution and production costs. Nearly 1900 species of insects have been found to be suitable for consumption as human food. Compared to chicken, cattle, and pigs, the feed conversion efficiency of insects is significantly higher, leading to a reduction in food wastage [55]. The insect species traditionally consumed are different for different regions of the world, but beetles are consumed commonly in various parts of the world. Crickets and mealworm larvae are the two most common insects used in food and feed industries [56].

However, various factors limit the use of insects as meat substitutes; most prominently, consumer acceptance and issues regarding food safety. Food safety issues include the aflatoxin content exceeding the limit of 10 microgram/kg in some edible dried insects [57]. Some insect proteins can contain allergens and pathogenic bacterial strains [55,58]. Insects have significant potential to be used as meat substitutes if they can achieve higher customer acceptance by being carefully treated, safely farmed, and carefully processed.

**Table 1.** Protein content and different functional properties of various alternative proteins.

Protein Type *	Protein Content (%)	Functions	References	
Plant-based proteins	Soybean	40	Gelation, fiber formation, emulsification, coil binding	[59]
	Pea	20–25	Fiber formation, gelation, emulsification	[60]
	Cowpea	40	Gel formation, emulsification, foaming, thickening	[61,62]
	Zein (corn)	45–50	Solubility, foaming, moisture adsorption	[63]
	Faba bean	29	Improve physical and oxidative stability of oil in water emulsions	[64]
	Wheat	14	Elasticity, extensibility, fibrous structure	[65]
Insect-based proteins	<i>Telegraphus emma</i> (cricket)	54–56	Water-holding capacity, oil-holding capacity	[66]
	<i>Protaetia brevitarsis</i> (larvae)	43–45	Gelation	[66]
	<i>Schistocerca gregaria</i> (locust)	76	Foaming properties	[67]
	<i>Zophobas morio</i> (larvae)	24–26	Gel formation, emulsification	[68]
Single-cell proteins	<i>Saccaromyces cerevisiae</i> (sugarbeet bagasse)	45–49	Foaming, emulsion, bulk density	[69]

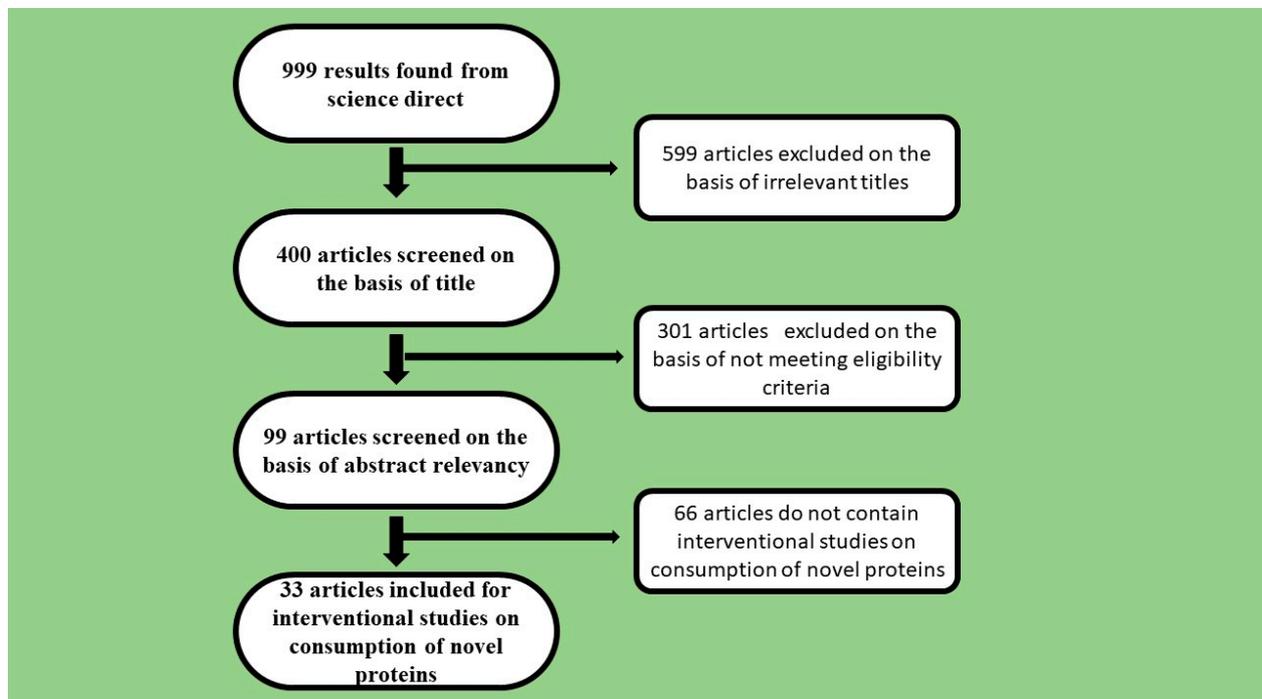
\* At the moment, information about cultured meat's protein content and functional properties is extremely limited.

### 3. Methodology

#### 3.1. Eligibility Criteria, Article Search Strategy, and Dataset Development

Employing a population, intervention, comparators, outcomes, and study (PICOS) design, we used the following inclusion criteria: (1) emphasis on reducing meat consumption; (2) pertains to intervention studies based on the use of novel proteins as alternative proteins; (3) focus on consumer behavior regarding consumption of novel proteins; (4) articles consistently written in English and published after being peer-reviewed. Accordingly, a raw dataset was constructed and extracted after careful evaluation of articles that reported alternative protein substitutes to decrease conventional meat consumption from animal sources. The articles were carefully chosen and selected by following Preferred Reporting Items for Systematic Reviews (PRISMA) guidelines [70]. The published articles were extracted into Mendeley references manager (<https://www.mendeley.com/> (30 January 2022)) with criteria as follows: (1) name of author; (2) publication year; (3) study; (4) type of alternative protein used; (5) and results. Initially, 999 results were obtained through a search of Science Direct (<https://www.sciencedirect.com/> (30 January 2022)).

Five hundred ninety-nine studies were excluded because they were not related to the behavior of consumers consuming alternative/novel proteins. Three hundred and one articles were excluded due to being studies related to conventional meat consumption. Sixty-six articles were excluded since they did not contain interventional studies on consumption of novel proteins. After this process, 33 articles finally remained for systematic review. The algorithm search key for published articles was set for 2016–2022 using the MESH terms (“interventions”) AND (“Protein”) AND (“plant-based protein” OR “animal-based protein” OR “cultured meat” OR “edible insects” OR “single-cell protein” OR “pulses” OR “legumes”). The articles that met the criteria were [11,15,16,26,71–100], (Figure 1; Table 2).



**Figure 1.** Diagram flow of article selection for interventional studies on consumption of alternative proteins using PRISMA method.

**Table 2.** Overview of 33 studies included in this systematic review.

Novel Proteins	Country	Outcomes	Type of Study	References
Plant-based meat	Finland	27% of participants willing to reduce consumption of beef 26% willing to increase consumption of plant-based protein 24% willing to increase insect-based protein	Online survey of 18–79 year old consumers in Finland ( $n = 1000$ ) from five consumer clusters	[90]
	Belgium	Significant increase in satisfaction for consumption of plant-based diets	Two waves of an online cross-sectional survey from a nationally representative sample in Belgium in 2019 ( $n = 1001$ ) and 2020 ( $n = 1000$ ).	[85]
	Canada	There can be a greater uptake of plant-based products if they are placed on the same shelves in supermarkets as meat products	7 supermarket audits, 24 consumer interviews, and 5 key informant interviews	[74]
	Germany	Value of environmental and health claims for new legume products is discussed	Online auction involving German consumers	[16]
Cultured meat	China	Assessment of effect of smooth muscle cells on the quality of cultured meat. Smooth muscle-secreted collagen affects internal structure of cultured meat during culture; however, it possesses good texture after 6 days culture	Lab-based study aimed at building a cultured meat model containing smooth muscle cells and further evaluating the effect of smooth muscle cells on the quality of cultured meat	[95]
	United States	Framing may be causing consumers to develop more negative attitudes toward cultured meat	Face to face interviews with 480 U.S. adults on cultured meat consumption	[75]
	United Kingdom	Counter-messaging led to change in acceptance of cultured meat and this change in acceptance was predicted by perceived consumer effectiveness	3 × 1 randomized experimental design with a sample of 302 British adults where participants were provided with one of two differently focused counter-messages (animal welfare or environmental impact) or a control text	[96]
	Italy	Claims such as animal welfare, human safety, and impact on environment significantly increase willingness to substitute cultured meat	Online survey of 603 participants (61% females, 15–80 years old) randomly assigned to four blocks, each corresponding to one type of information: human safety; animal welfare; environmental impact; no additional information (control)	[100]
	China	Cultured meat technology aimed at developing meat by ex vivo culture of animal cells, which is a transformative approach in meat production	Lab-based study and analysis of cutting-edge operational strategies and recently characterized regulatory mechanisms for muscle stem cells	[86]

Table 2. Cont.

Novel Proteins	Country	Outcomes	Type of Study	References
	Japan	Festivals increase acceptance of cultured meat as compared to other venues. Friends increase anticipated acceptance of eating insects, cultured meats, and 3D printed foods more than other companions	Comprehensive review on the influence of social companions (alone, friend, family, acquaintance, partner) and venue (home, cafe, bar, pub, food festival, restaurant), on the anticipated willingness to try a number of novel/unfamiliar foods (insect-based foods, cultured meats, plant-based meat alternatives, and 3D printed foods)	[98]
	Germany	Attitude found to be strongest driver for consuming cultured meat	Face to face filling out of questionnaire in a paper-and-pencil format for study Willingness of children and adolescents ( $n = 718$ , MAge = 13.67, $SD = 2.31$ ; female = 57.5%) from Germany to consume insects and cultured meat	[81]
	Switzerland	Cultured meat perceived as unnatural. Information regarding cultured meat increases acceptance of traditional meat	Online experiments that examined the impact of perceived naturalness and disgust on consumer acceptance of cultured meat	[26]
	Italy	Positive consumer perception towards extrinsic attributes of cultured meat	Online survey with submission of a questionnaire to 525 Italian consumers aimed at analyzing the willingness to try, buy, and pay for cultured meat	[78]
	Germany	Germany moderately prepared to accept cultured meat. Animal welfare and ecological wellbeing were the strongest positive drivers	Current attitude research summarizing objections perceived by consumers concerning cultured meat based on online survey of 713 German consumers	[84]
	Belgium	Females, vegetarians, and older people less like to consume cultured meat Framing as cultured or synthetic has less impact	Study of the impact of initial perceived barriers to and motives for consumers' willingness to eat cultured meat based on analysis of cross-sectional data from a representative consumer sample ( $n = 398$ ) from Flanders (Belgium)	[92]
	China, India, Columbia, and Switzerland	Cultured meat considered as a technology product rather than meat	Cross-cultural survey of participants from China (20), India (20), Colombia (20), and Switzerland (20) assessing the cultural concepts underlying consumer readiness toward cultured meat consumption	[87]

Table 2. Cont.

Novel Proteins	Country	Outcomes	Type of Study	References
Single-cell protein	Pakistan	Addition of up to 4% single-cell protein observed to be optimum, as indicated by organoleptic properties	Determination of optimum single-cell protein yield (g/100 g) during process optimization; combinations of various temperatures and nitrogen sources	[88]
	Zambia	Single-cell protein considered as alternative feed ingredient	Investigation of the effect of either partially or totally replacing fishmeal (up to 15% of the diet) with the inactivated dry yeast product DY-Pro in Nile tilapia <i>Oreochromis niloticus</i> diets	[94]
Insects	Italy	Positive information increases consumption of insects; however, food neophobia and specific beliefs affect consumers' willingness to pay for insects	Analysis of 200 Italian consumers' preferences for three insect-based products through a non-hypothetical willingness to pay elicitation mechanism (the Multiple Price List) in a mixed within/between-group experimental design	[77]
	Denmark and Italy	Communications among individuals and social benefits of insect consumption increase consumption of insects	Investigation of the possibility of fostering people's willingness to eat insect-based food through communication and comparison of messages based on individual vs. societal benefits of the eating of insects	[72]
	Italy	Most powerful driver of insect consumption is invisibility of insect shape	Literature review regarding barriers to and drivers of consumption of insects	[73]
	Germany	Consumer acceptance can be increased through novel food processing and reduced visibility of insects and their species	Self-administered personal survey of consumer acceptance of two different insect species with varying degrees of processing that led to different degrees of insect visibility	[80]
	Germany	Consumption of insects is sustainable valorization of food waste and valorization of valuable proteins	Literature review of existing strategies for the promotion of novel and/or waste-based food, as well as insect-based food	[82]
	Australia	Some participants reported safety concerns and some participants were positive about consumption of insects in future	Online survey of 601 (23.8% male, 76.2% female) Australian consumers' experiences with edible insects, identifying barriers to consumption and exploring possible factors that may motivate Australians to consume insects	[97]
	Italy	Males more willing to eat insects as compared to females. Insect eating was linked to daring, adventurous, and wild emotions	Online questionnaire of 400 Italian consumers aimed at analyzing attitudes towards specific insects, their gastronomic preparations, their relationships with human factors, and the characteristics of insects as a food source	[83]

Table 2. Cont.

Novel Proteins	Country	Outcomes	Type of Study	References
	Chile	Validation of entomophagy attitude questionnaire in Chile, which predicts consumption of food based on insects, whether visible or not	Entomophagy attitude questionnaire filled out online by 400 consumers	[89]
	Germany	Reduce visibility of insects and increase production of processed insects products	Online survey of the German population with a final sample of 393 participants aimed at examining prospects for edible whole-insect and processed insect-based food in Germany and investigate determining factors for acceptance	[79]
	Denmark and Sweden	Sustainability is major driver for acceptance of insects	Review of the literature aimed at identifying the key factors influencing consumer perception and acceptability of insect-based foods	[93]
	The Netherlands	Good sensorial characteristics and exposure of positive tasting experience are important drivers of insect consumption	Online survey of Dutch sample consisting of 2461 respondents (male: 58.9%) with a mean age of 46.0 years ( $SD = 15.8$ ) regarding consumption of insects as feed and food	[15]
	The Netherlands	Academic and commercial implications of consumer acceptance of insects are discussed	33 semi-structured interviews regarding acceptance of insects as food	[71]
	Switzerland	Managing expectations through social norms is a good driver highlighting the adoption of insects in Western markets	Face to face survey regarding acceptance of insects as foods: study 1: peer influence study 2: expert influence	[76]
	Europe	Consumption of insects is helpful to reduce carbon foot print of European consumers	Short and thematically focused literature review on the global warming potential values of broiler, insect, and soybean meal production from a variety of life cycle assessment studies	[91]
	The Netherlands	Taste, health, attitude, social norms, neophobia, and familiarity affect consumption of alternative proteins	Systematic review of 91 articles with a focus on the drivers of consumer acceptance of five alternative proteins: pulses, algae, insects, plant-based alternative proteins, and cultured meat	[11]

### 3.1.1. Consumer-Based Intervention Studies on Different Alternative Proteins Plant-Based Meat

Studies on plant-based meat seem to focus on health and sustainability motives or claims. Health and sustainability motives increased alternative protein consumption among females and young consumers [90]. Plant-based meat alternatives proved to be more common in women. Consumer attitude towards plant-based diets and concerns regarding food environmental impact were also studied [85]. Supermarkets can increase the availability of plant-based meat alternatives to limit consumers for more plant-based

options [74]. Acceptance of legume-based proteins conforming to health and sustainability claims can be increased [16].

### Cultured Meat

Cultured meat is prepared by using smooth muscle cells, and smooth muscles secrete extracellular matrix proteins; e.g., collagen [95].

Farming practices influence the acceptability of cultured meat, with studies showing that positive attitudes [75], perceived consumer effectiveness [96], informative claims that increased consumer acceptance of cultured meat [100], muscle stem cells and their implications [86] increased acceptance of cultured meat. Other relevant drivers mentioned were unfamiliar and novel foods [98] and greater acceptance of cultured meat than insects in meat substitutes [81].

The acceptability of cultured meat can be influenced by changing the perception of the naturalness of cultured meat among consumers. Acceptance of cultured meat depends on its promotion and methods that increases its acceptability [26]. Positive attitude is not a necessary marker for the prediction of willingness to purchase cultured meat, and consumers, except vegetarians, were willing to purchase cultured meat [78]. Consumers moderately accept cultured meat in Germany, and a reasonable price comparable to conventional meat is needed to increase the acceptance of cultured meat [84]. Perceived barriers are more important as compared to motives for the approval of cultured meat [92]. Another study investigated doubt among consumers regarding the consumption of cultured meat [87].

### Single-Cell Proteins

Production of single-cell proteins leads to food waste management and addresses food security by fulfilling protein requirements [88]. Single-cell proteins were used to replace fish meal and proved to be able to effectively replace feed ingredients for aquaculture [94].

### Insects

Food neophobia, ethical beliefs, and perceptions of insects have considerable negative impacts on edible insect consumption; however, positive information enhances consumer acceptability [77]. The results of communications and implicit associations have significant impacts on eating behavior regarding insects [72]; additionally, claims regarding health and sustainability enhance the acceptability of edible insects [73]. Type of insect species and familiarity with the species enhance willingness to pay [80]. Another study investigated food waste valorization by using edible insects [82]. It was found that more significant opportunities, better nutrition knowledge, and awareness about edible insects increase consumer acceptability [97]. Males are more willing to eat edible insects [83]. Another study investigated the nomological validity of eating processed insects [89].

Other topics included low willingness to try; the prevalence of barriers, such as neophobia and disgust, and the visibility of insects [79]; information barriers regarding alternative proteins [93]; enhancement of consumer acceptability regarding consumption of edible insects through effective emotional (instead of cognitive) messages [15]; initial consumption and repeat consumption factors [71]; the effect of peers and experts on consumer perceptions of insect protein-based food products [76]; and reductions in food-based carbon footprints in Germany through the use of insects [91].

Behavioral frameworks were used to describe the results obtained via surveys to fully comprehend consumers' perceptions of different marketed products. Additional drivers were employed to identify their relevant personal diversifications in understanding consumer acceptance. It is, therefore, essential to identify consumer groups that are receptive towards alternative proteins; for instance, consumers with low scores for food neophobia and disgust and exhibiting positivity towards different types of alternative proteins. Research is needed to produce direct comparisons among various drivers, but a simplified representation is given in Table 3 [11].

**Table 3.** Simplified overview of relevant consumer acceptance drivers for alternate proteins (source: Onwezen et al., 2021).

Pulses	Plant-Based Alternatives of Meat	Algae	Insect-Based Proteins	Cultured Meat
Social norms Attitudes Motives Taste Health	Attitude Social norms Taste and health Motives	Food neophobia Familiar food Attitudes Taste and health Motives	Social norms Food neophobia Disgust, fear Attitudes Appropriateness and familiarity Taste and health Motives Environment	Natural attribute Trust Food neophobia Disgust Attitudes Taste Environment Motives

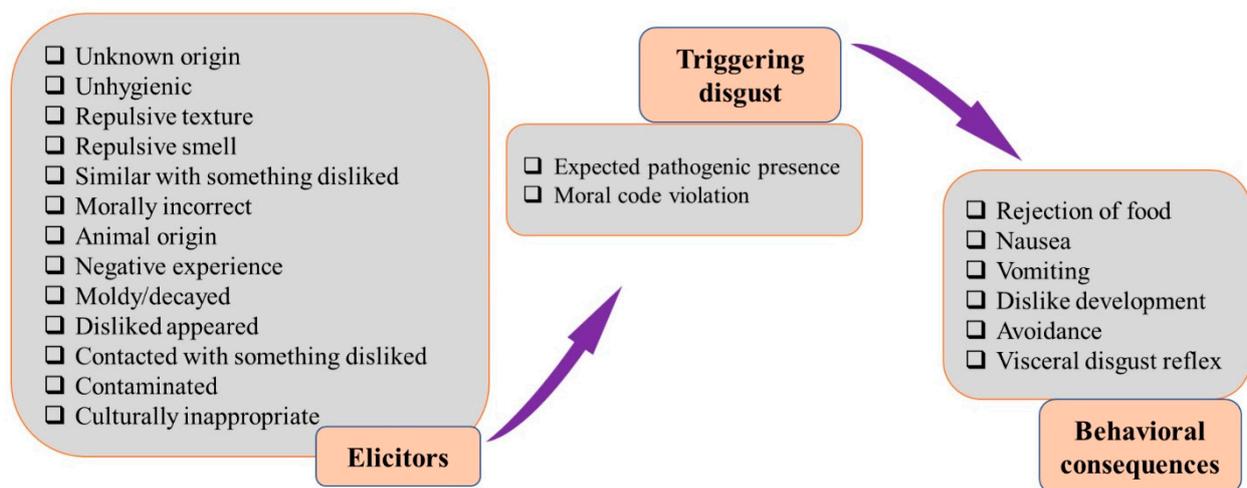
#### 4. Frameworks Employed and Consumer Categories

Table 3 highlights that different drivers impact the acceptance of alternate proteins among consumers. Therefore, future research needs to be conducted on targeted proteins to estimate approval by focusing on the barriers, attributes, environmental drivers, and motives relating to targeted proteins [11].

Another framework methodology, known as the food-related lifestyle (FRL) framework, was adopted to identify segregation among consumers' preferences and was mainly employed in relation to local concepts (perceptions, purchasing, venues, descriptive and injunctive norms, demographics, and communication-based variables). This FRL framework identifies food choices associated with personal decisions and food-related behaviors. It was significantly helpful in relating abstract values to specified food product choices based on the knowledge and behavior linked to that specific food. This framework was designed to highlight identical lifestyles in order to market the products in different European locations accordingly. Consumer behavior is associated with lifestyle, linking abstract cognitive categories, "lifestyle" impacts, and perceived specific commodities with solid, tangible thoughts [101].

Typical consumers in Europe are grouped as careless, adventurous, conservative, uninvolved, and rational. Consumers with adventurous attributes have a strong interest in cooking and shopping therapy. Rational category people are interested in these aspects too but have a higher interest in a product's information and the prices accompanying meal planning. In contrast to this is the careless group, who only undertake activities that are without any constraints and place greater value on convenient and novel products. Conservative consumers, the fourth group, are opposed to novel foods and seek suitable and sensitively priced products. They are also considered synonymous with the traditional group of customers. The only differences identified between conservative and traditional consumers are that the latter enjoy cooking food themselves. Lastly, the fifth group is named uninvolved because they lack interest in shopping or cooking and exhibit indifference towards different foods types [101]. Other than in European countries, researchers in Taiwan, Singapore, China, and Australia have also used this FRL model quite extensively [101]. In the U.S, it has been used to explain various food-purchasing local behaviors in analyses [102–104]. This research highlights that rational and adventurous customers show inquisitiveness towards local food; however, more clarification is needed to trace local food consumption patterns in terms of sustainable restaurants and farmers' market demand to understand local food purchasing behaviors more thoroughly. Another study conducted in Germany found higher consumer preference for local ingredients in food products [105]. Research indicates that the novelty of a product dramatically impacts consumption behaviors, overriding homeostatic and hedonic drives. In experiments conducted on rats, males became habituated to novel foods faster than females, which suppressed consumption [106]. Further research is recommended to comprehend the substrates in novel food processing mechanisms among both genders.

Regarding sensory profile, research showed that, for higher acceptance of novel products, health and environmental benefits were irrelevant compared to hedonic claims [107]. Many instruments have been utilized to operationalize mental construction to enhance the consumer acceptance of novel foods. These instruments employ statements set using a Likert scale confirming acceptance or rejection. An undisputed barrier to acceptance is food neophobia; therefore, the food neophobia scale (FNS) quantifies traits encouraging food neophobia. Similarly, the food technology neophobia scale (FTNS) has also been developed to address the fear of various new food technologies. The FTNS also effectively addresses the lower acceptance of novel foods [108]. Food-related disgust sensitivity, another mental disposition, can be validated through food neophobia. Different factors are responsible for initiating food disgust, with cultural and societal norms leading to deep-rooted disgust perception. Sensitivity to disgust is utilized to determine novel food acceptance or lack thereof, including novel animal-based food and novel food technologies. Positive experiences associated with novel foods enhanced parental support, and product visibility can lead to better and quicker adaptability. Some common elicitors and their behavioral consequences are grouped in Figure 2.



**Figure 2.** Potential food-related visceral disgust elicitors and the resulting behavioral response consequences.

Different elicitors initiate moral violations, triggering disgust and resulting in behavioral consequences, such as nausea, vomiting, and other forms of rejection. Research indicates that food neophobia is associated with food preferences, and a lower level is a marker for fruit and vegetable preference and sour and pungent foods [109]. Moreover, high food neophobia predicts food dislikes and other health-related biomarkers. More investigation is recommended to comprehend the impact of cognitive factors and affective influencing factors during ontogenesis [110].

## 5. Alternative Proteins and Food Laws

Alternative proteins are considered a challenge for food laws, requiring proper safety assessment before submission for various market permissions [111]. In Europe (EU), various companies have researched best practices for incorporating ranges of insects into the diet. Insects are readily available via online sales, food markets, festivals, restaurants, supermarkets, and private sale events. Sales have drastically escalated in the past few years as per consumer demand. The EU Legislation on Novel Food enabling edible insect consumption in Europe was the first step in guaranteeing both producers and consumers regarding safety. A lack of clear legislation deters companies from harvesting and selling insects as food, resulting in an expensive and lengthy process for stakeholders [112]. Therefore, more work is needed in terms of regulation, legislation, and policymaking to

impact consumers' consumption behaviors and attitudes [35]. As food products enter the European food chain, legislative constraints are becoming a significant barrier for insects. For marketing purposes, the International Platform for Insects as Food and Feed (IPIFF) suggested increased freedom through changes in EU laws. More systemic data are required to authenticate the nutrition-related attributes and safety aspects of insect foods and increase consumer confidence in the new, alternative protein sources [112,113]. The legislative framework is briefly explained in Table 4.

**Table 4.** Overview of legislative structure regarding novel foods around the world.

Country/Continent	Current Scenario	References
Canada	One hop kitchen employs and breeds crickets; however, a decision by the Bureau of Microbial Hazard in Food board of directors is still pending for insects	[114]
USA	The Food and Drug Administration (FDA) highlights insects in the Food Defect Action Levels (FDAL), setting an acceptable defect level permitted in products. Legal ambiguities remain even with a commercialized market for insects	[113]
Oceania	Australia and New Zealand collectively share an Office of Food Standards addressing food safety issues but no consumption limits have been set so far. Similarly, no legislation on imports has been imposed yet	[114,115]
Africa	Insects constitute a portion of the traditional diet. Four government departments oversee good practices in the domestication and transport of insects in South Africa. International frameworks (FAO, WHO) are being followed instead of developing national policies	[116,117]
European Union (EU)	The EU parliament developed the novel food class in 2015, leading to approval processes. France exhibited a tolerant attitude whereas in other areas it is close to nil. Germany started exhibiting insects in the supermarkets in 2018, while Belgium, the Netherlands, Denmark, and Finland have indicated some permissible limits in the consumption and promotion of such alternative proteins	[114]
Asia	Traditional usage of insects is normal practice for Southeast Asia, but no legislation exists for the production, selling, harvesting, and export of these insects. Thailand has an extensive breeding site for crickets and exhibited flexible farming regulations in 2017. China employs different insects in dietary routines without any food law encompassing them. In 2014, silkworm pupae were included within the food list published by the Health Ministry. The South Korean government allowed consumption of insects (larva, crickets) in 2011	[114]

## 6. Conclusions

This systemic review summarized different alternative proteins and the drivers responsible for their consumer acceptance. These alternative proteins, including pulses (lentils and beans), algae, insects, plant-based meat alternatives, and cultured meat, elicit different levels of different consumer acceptance. The major drivers include motives behind food choices, perspectives on alternate protein sources, neophobia or reluctance to consume, variations in protein choices, and familiarity with or exposure to the new products available in the market. An overview of multiple drivers for alternative proteins among various countries highlighted the need for future comparative research. Existing data indicate that intervention studies should be focused more on information and enhancing familiarity while stating benefits and motives. Legislation also lacks an extensive framework to facilitate existing production houses of alternative proteins. Comprehensive marketing is needed, with adequate information educating the consumer's mindset about ongoing alternative proteins. Some sustainable protein sources are more thoroughly researched; for instance, insects and pulses compared to algae. Different regulation procedures should be followed for other alternative protein sources to confirm their safety for human consumption. Legislative ambiguity needs to be strongly addressed to align demand with market supply. Future research should be conducted to increase comparisons across studies with standardized measures. Developing these standardized measurements with personal, so-

cial, and physical variables would also be interesting. This would enable the identification of relative importance across different drivers responsible for consumer acceptance.

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