

Review of factors affecting consumer acceptance of cultured meat

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ABSTRACT

Concerns about animal welfare and sustainable meat production are growing among consumers. The awareness of carbon emissions linked to livestock and ethical concerns have triggered interest in more sustainable meat alternatives, among which cultured meat (also known as laboratory grown meat) is a recent entry. Like any new food, the ultimate success of cultured meat depends on consumer acceptance. This study analyses the peer-reviewed literature on consumer attitudes towards cultured meat to synthesize the existing evidence and identify priorities for future research. A systematic literature review was undertaken using the Web of Science, Science Direct and Scopus databases over 2008–2020, resulting in a final number of 43 articles meeting our selection criteria. The most important factors influencing consumer acceptance/rejection of cultured meat include public awareness, perceived naturalness, and food-related risk perception. Ethical and environmental concerns prompted consumers to be willing to pay a premium price for purchasing meat substitutes, but not necessarily cultured meat. Also, food neophobia and uncertainties about safety and health seem to be important barriers to uptake of this technology. Availability of other alternatives such as plant-based meat substitutes and product features, such as price and sensory appeal, are considered determinants of consumer reception of this technology. The effect of demographic factors is mixed. More research on the interrelationships between livestock production, food security, and alternative meat products is recommended.

1. Introduction

A new era of sustainability is emerging, which has challenged different sectors of the food value chain, including meat production. On a global scale, the livestock sector has come under greater scrutiny in the past few years owing to its climatic, ethical, and human health impacts (Scollan et al., 2011; Stephens et al., 2018).

Such concerns, combined with the projections of rising demand for protein products in the coming decades, necessitate developing alternative proteins produced more sustainably (Gerber et al., 2013). Cultured meat (also known as "cell-based", "cultivated", "clean", "slaughter-free", "in-vitro", "lab-grown", and "nano-pastured" meat), which promises to help solve some of the livestock-related, challenging environmental problems (for details refer to Stephens et al., 2018), has gained popularity over the past few years. Cultured meat does not require large-scale farming practices but is produced from the in-vitro cultivation of animal cells without growing the whole animals (Datar

& Betti, 2010; Post, 2014a). In contrast to the plant-based meat trying to replicate the taste and texture of traditional meat, cultured meat is derived from animal muscle tissue (Newburger, 2019). Nevertheless, cultured meat technology is still being researched, examining different production methods (e.g., cyanobacteria-based versus plant-based growth media for tissue culturing) to improve the benefits and sensory characteristics (Tuomisto, Ellis, & Hastrup, 2014).

This emerging technology, which was first brought to the public when a cultured beef hamburger was publicly tested on August 5, 2013, in London, is claimed to be a high-quality protein substitute that promotes a more sustainable environment (likely) at a lower cost (Bekker, Fischer, Tobi, & van Trijp, 2017). Proponents argue that cultured meat will be produced with fewer or almost no farm animals and helps alleviate the environmental problems behind the livestock high carbon footprint and water footprint (Hocquette, 2016; Hopkins, 2015; Tuomisto et al., 2014; Tuomisto & Teixeira de Mattos, 2011).

Industrial-scale production of cultured meat is still at an embryonic

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stage. Companies are seeking ways to increase their efficiency and cut costs to launch their products on the competitive market. Thus, various technological production issues still need to be resolved (Mancini & Antonioli, 2019). Also, if companies developing cultured meat desire to sell it as an environmentally friendly substitute, they need to employ renewable energy resources in their process (Lynch & Pierrehumbert, 2019; Newburger, 2019). However, the most important barrier in commercializing cultured meat is consumer acceptance (Hocquette, 2016). Researchers have already established that consumer attitudes play a key role in accepting novel food technologies (Armitage & Conner, 2001; Bekker, Fischer, Tobi, & van Trijp, 2017; Frewer et al., 2014; Mancini & Antonioli, 2019). Findings show that consumers are ambivalent regarding accepting cultured meat (Bekker, Fischer, et al., 2017; Verbeke, Marcu, et al., 2015; Verbeke, Sans, & Van Loo, 2015; Wilks & Phillips, 2017). A few studies highlighted a high willingness to consume cultured meat (Mancini & Antonioli, 2019; Weinrich, Strack, & Neugebauer, 2020; Wilks & Phillips, 2017) or at least to try it (Verbeke et al., 2015a, 2015b), while others have found that many respondents would eat cultured meat, but the majority would still lean towards conventional meat (Hocquette et al., 2015a; Slade, 2018; Verbeke, Sans, & Van Loo, 2015).

This paper contributes to a growing body of reviews concerning cultured meat (Alexander et al., 2017; Arshad et al., 2017; Datar & Betti, 2010; Kadim, Mahgoub, Baqir, Faye, & Purchas, 2015; Post, 2012; Stephens et al., 2018). Previous reviews provided an overview of the technology developments (for a summary of reviews on challenges and prospects refer to Kadim et al., 2015), environmental effects (e.g. Alexander et al., 2017; Mattick, Landis, & Allenby, 2015), and market potential (Bhat, Kumar, & Fayaz, 2015; Hamdan, Post, Ramli, & Mustafa, 2018; Hocquette, 2016; Hocquette et al., 2018; Hopkins, 2015). Extant systematic reviews of the empirical findings on consumer behaviour towards cultured meat are scarce and based on limited literature (see e.g. Bryant & Barnett, 2018) or on diverse stimuli (e.g. Hartmann & Siegrist, 2017; Onwezen, Bouwman, Reinders, & Dagevos, 2021). To fill this gap, in this systematic review, we aim to identify, critically review, and synthesize the empirical findings of extant studies, thus providing an extensive overview of recent empirical evidence on consumer acceptance of cultured meat. We focus on consumer acceptance because of its paramount relevance and the already large body of research that deals with this issue, justifying a specific analysis. While we acknowledge the importance of other socio-political aspects like policy and regulatory issues, such analysis is beyond the scope of this paper (for detailed policy discussions refer to Stephens et al., 2018). Furthermore, this paper does not seek to compare technological characteristics between cultured meat and other meat analogues (for detailed technological discussions refer to Alexander et al., 2017; Bonny, Gardner, Pethick, & Hocquette, 2015).

2. Methodology

2.1. Selection of relevant studies

Reviews aim ultimately to bring about new integrated insights based on available findings of scientific quality (Higgins & Green, 2011; Lesnikowski et al., 2011). A systematic literature review entails four main features: (a) collecting the literature; (b) thoroughly evaluating the quality of the included results; (c) setting a protocol to collate scientific evidence; and (d) ensuring a rigorous, evidence-focused selection process, transparency, and replicability (Briner & Denyer, 2012; Mallett, Hagen-Zanker, Slater, & Duvendack, 2012; Petticrew & Roberts, 2008; Waddington et al., 2012).

This review identifies and analyzes empirical studies entailing consumer acceptability of cultured meat based on a protocol for identifying, screening, and evaluating the eligibility of articles, as illustrated in Fig. 1 following the PRISMA reporting approach (Moher et al., 2015; Xhakollari, Canavari, & Osman, 2019). Science Direct, Web of Science, and

Scopus, three of the largest databases for peer-reviewed literature (Burnham, 2006; Fernandes et al., 2019),² were used to search, select, and examine papers published up to May 31, 2020, involving consumer acceptability of cultured meat (see Table 1 for inclusion/exclusion criteria). These databases were particularly appropriate to the scope of the current systematic review owing to their extensive coverage and content quality (Clark, Stewart, Panzone, Kyriazakis, & Frewer, 2017; Frewer et al., 2013; Siva et al., 2016). Boolean searches were performed on the title, abstract and keywords through each database, using the following query:

(consumer* OR customer*) AND ("cultured meat" OR "clean meat" OR "vitro meat" OR "cell-based meat" OR "cultivated meat") AND (accept* OR assess* OR evaluat* OR willing*)

Overall, the literature search of the three databases found 202 articles from Science Direct (133 research and 69 review articles), 78 articles from Web of Science (including one review paper), and 161 articles from Scopus (121 research and 40 review articles) (Fig. 1). The articles were imported into the EndNote library, 72 duplicates were removed, and 308 articles were included in the initial list. After screening based on title and abstract, 243 included articles were assessed against eligibility criteria (Table 1), and 189 were discarded. Eligibility evaluation of the retrieved articles was performed independently by two of the authors. Overall, inter-rater agreement was high, and disagreement between the evaluators was settled by consensus (e.g., assessing the study design or results). Finally, after excluding non-peer-reviewed papers, 35 articles were considered eligible for full-text review. Reference lists of included literature were considered for possible supplementary articles, which yielded eight additional papers and 43 articles in total (see Table A1 in Appendix I).

2.2. Data collection process

Information from each article, including study design, sample size and country, main findings, outcome variables and factors influencing consumer acceptance, was extracted (see Tables A1-3 in Appendix I).

The key data from these 43 articles were extracted and tabulated to synthesize existing knowledge on factors affecting consumers' acceptance of cultured meat technology.

3. Results

3.1. Bibliographic analysis

Interest in cultured meat technology and its potential advantages has increased among scholars; hence literature on this technology has grown significantly during the last decade (Fig. 2). Results from three databases show that published articles regarding cultured meat increased nearly two-fold between 2015 and 2020 (May). Most of the articles published thus far fall into the realm of natural sciences, with a technological focus. The growing literature on cultured meat in recent years suggests that cultured meat technology is spreading rapidly in the agri-food biotechnology industry and is getting close to market access, as recent news about the first approved use of this product in restaurants suggests (BBC, 2020). Fig. 2 shows that, despite a growing trend, studies examining consumer responses to this technology are still rather scarce (Verbeke, Sans, & Van Loo, 2015).

In total, 43 (17.7%) of the 243 screened literature pieces were related to consumers' evaluation of cultured meat (with empirical data), mostly focused on the United States (14 articles), followed by the United Kingdom, the Netherlands, Australia, China and Germany (4 articles each). Across journals published peer-reviewed articles, *Appetite* and *Meat Science* had the prevalence.

² According to AMSTAR (A Measurement Tool to Assess systematic Reviews) guidelines, at least two databases have to be considered for a reliable systematic review (Tawfik et al., 2019).

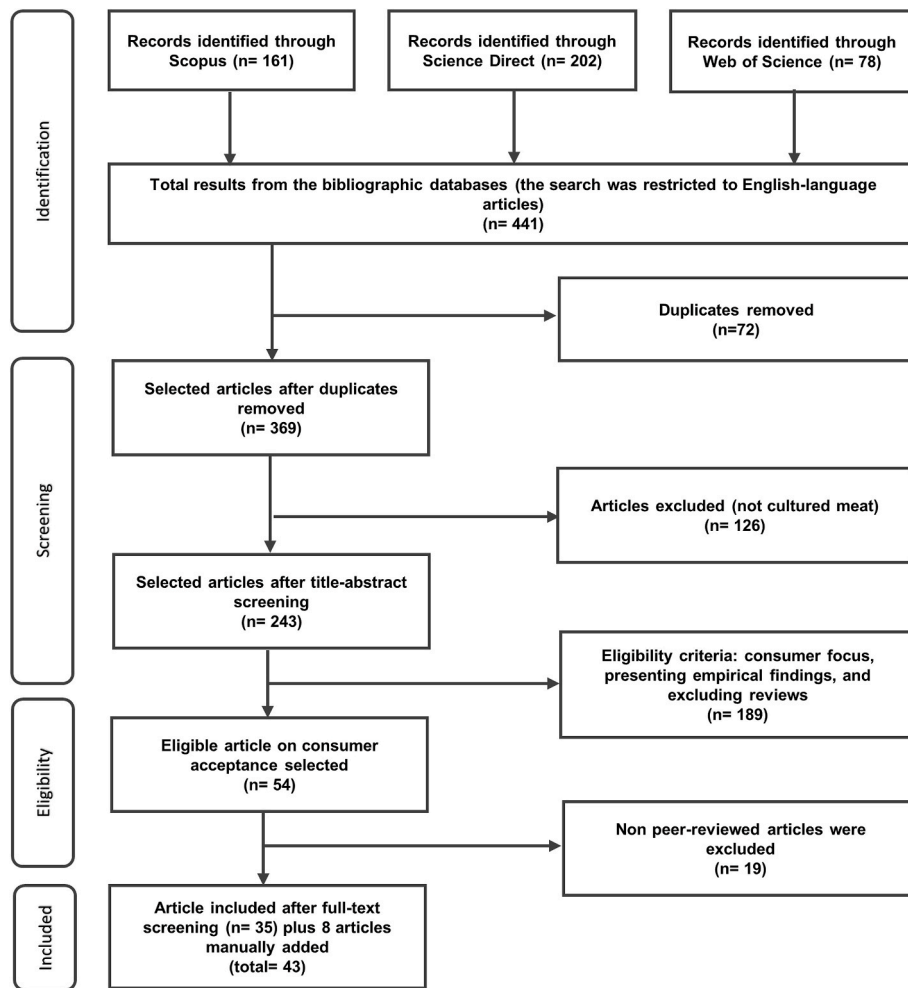


Fig. 1. Flow diagram of included and excluded studies in the review.

Table 1
Inclusion and exclusion criteria.

Inclusion criteria
<ul style="list-style-type: none"> • Focus on consumer behaviour or acceptance of cultured meat • Papers presenting original results of primary empirical studies (e.g., focus groups, surveys, experiments) • Full-text papers published in a peer-reviewed journal • Published since 2008 (inclusive) up to May 2020 • Full-text papers written in English
Exclusion criteria
<ul style="list-style-type: none"> • Sources that do not discuss consumer perceptions of cultured meat • Papers that do not include original empirical data (such as review articles, opinion papers, discussion papers) • Conference proceedings, book chapters, unpublished theses and white papers • Papers focusing on other aspects of cultured meat (such as production processes, regulation, media coverage) and no consumer behaviour focus. • Trends in food and meat consumption patterns • Physiological aspects of meat consumption

3.2. Determinants of cultured meat acceptance

Altogether, consumer studies that were considered, indicated at least seven factors affecting consumer acceptance of cultured meat (Table A2, Appendix I), and the themes identified in our review include public awareness, risk-benefit perception, ethical and environmental concerns, emotions, personal factors, product properties, and availability of meat alternatives (see Fig. 3). In Fig. 3, the length of the bars represents the frequency of the factors examined in the reviewed articles. The width of bars depicts the average sample size of included studies (\bar{N}). The frequencies and sample sizes are adjusted to account for variations (e.g., studies with multiple sub-samples) reported in the reviewed articles. For instance, Bekker, Fischer, Tobi, and van Trijp (2017) reported results from three experiments on consumer awareness in each subsample, while Siegrist and Sütterlin (2017) also had three experiments but only Experiments 2 and 3 reported results for factor awareness. Hence, Experiment 1 of this paper was not included in the frequency and sample size calculation (for details, refer to Table A2, Appendix I).

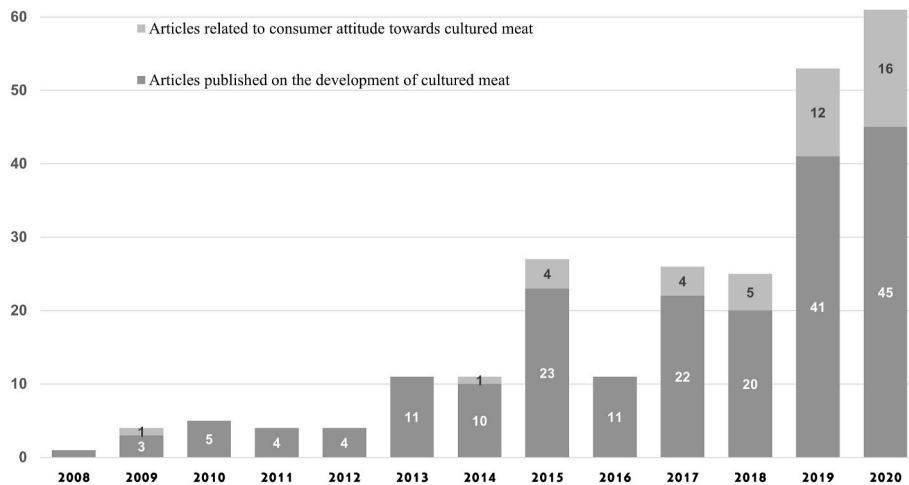


Fig. 2. Frequency of articles on the development of cultured meat and consumer attitudes toward this technology, by publication year. Note: Total articles retrieved after duplicates removed = 243 publications (including review papers). Source: Authors' elaboration on Science Direct, Scopus, and Web of Science data, retrieved on May 31, 2020.

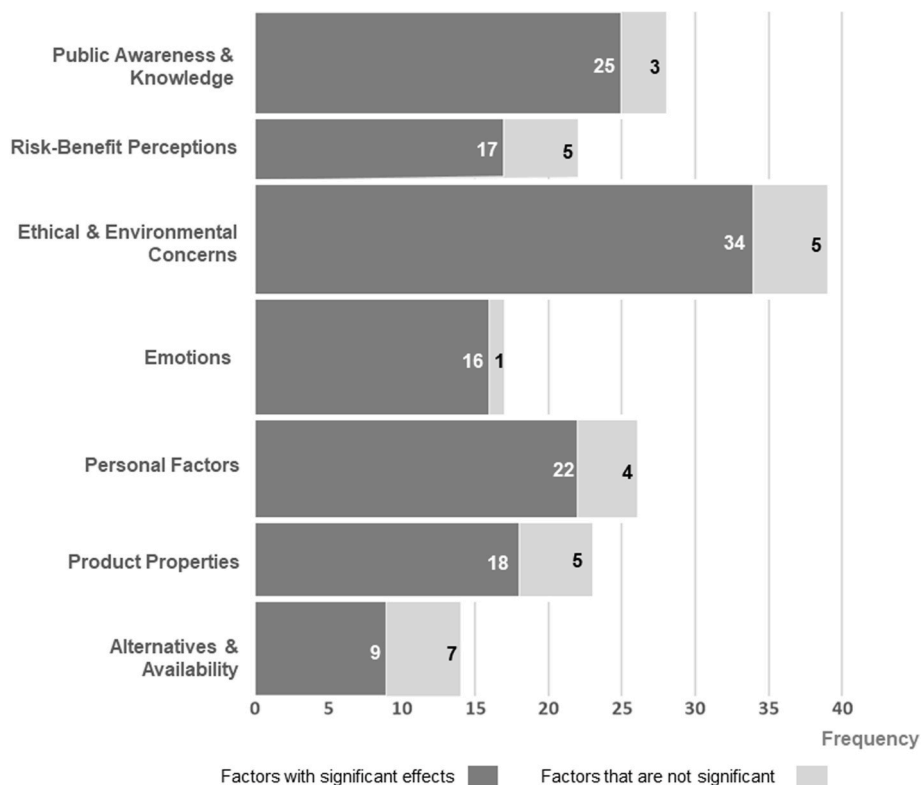


Fig. 3. Frequency of major factors influencing the acceptance of cultured meat derived from the retrieved articles (number of articles = 43). The length of bars represents the frequency of articles that considered the factors (see Table A2 Appendix I). The width of bars represents the average sample size (\bar{N}) of respective studies. Note: Factors marked with (*) are adjusted for sub-samples.

3.2.1. Public awareness & knowledge

Consumers' attitudes can play an essential role in accepting meat alternatives (Verbeke, Sans, & Van Loo, 2015), and factors like awareness and knowledge of the technology involved affect attitude (Wu, 2010). Past research has shown a link between knowledge and attitude

towards agro-food technologies (Armitage & Conner, 2001; Rollin, Kennedy, & Wills, 2011). Consumers' scepticism for new technologies in food production is often ascribed to the lack of awareness of the technology and its advantages (Bhat & Bhat, 2011; Lusk, Roosen, & Bieberstein, 2014; McCluskey & Swinnen, 2011). However, one can

distinguish between awareness and knowledge about innovation (Rogers, 2003; Trevethan, 2017), although these terms have been used interchangeably in many reviewed articles, and such distinction is less prevailing. Awareness (and familiarity) is often the first stage to acceptance of a novel technology (Agarwal & Prasad, 1998; Rogers, 2003). Awareness does not necessarily lead to an attitude towards novel technology but rather induces curiosity and propensity (Brennan, Canning, & McDowell, 2020). The next step is acquiring knowledge, which intends to learn more about the innovation process and its advantages (Rogers, 2003).

Several recent pieces of evidence on controversial food innovations, like nanotechnology, biotechnology, and irradiated foods, suggest that poor prior familiarity contributes to general consumer reticence to accept novel foods (Bieberstein, Roosen, Marette, Blanchemanche, & Vandermoere, 2012; Gunes & Deniz Tekin, 2006; Hocquette, 2016). For instance, Bieberstein et al. (2012) examined the effect of familiarity on the acceptance of food derived from nanotechnology. Bieberstein et al. (2012) reported that while most consumers are reluctant to accept nanotechnology in food applications, those with prior knowledge (awareness) of the technology are more inclined to accept nano-fortified food. Results from House et al. (2004) and Huffman, Shogren, Rousu, and Tegene (2003) have likewise affirmed the role of prior knowledge on the acceptance of biotechnology in food applications.

As depicted in Table 2, the literature on cultured meat has also pointed to consumers' lack of knowledge of this technology (Grasso, Hung, Olthof, Verbeke, & Brouwer, 2019; Valente, Fiedler, Sucha Heidemann, & Molento, 2019; Verbeke, Sans, & Van Loo, 2015). Prior studies have reported that the provision of information can improve willingness to accept cultured meat (Bekker, Fischer, et al., 2017; Gasteratos & Sherman, 2018; Rolland, Markus, & Post, 2020; Verbeke et al., 2015a, 2015b). For instance, in a survey conducted by Verbeke, Sans,

and Van Loo (2015), only 13% (out of a total sample of 180) of respondents had prior knowledge of cultured meat. Nearly two-thirds supported this technology after providing information on its characteristics and potential advantages (relative to the issues associated with traditional livestock production). More than half of the participants expressed willingness to try cultured meat (Verbeke, Sans, & Van Loo, 2015). Rolland et al. (2020) found a significant difference in the responses of interviewees who did not yet know about cultured meat and those who were familiar with this technology. They concluded that knowing exactly what cultured meat was, led to higher acceptance than not having any information about it. Lupton and Turner (2018) revealed that familiarity with food and processing methods could help resolve people's lack of understanding of new meats. However, consumers express concerns about the impact of cultured meat on farming and traditional agriculture (Verbeke et al., 2015a, 2015b).

Vinnari and Tapio (2009) identified a diversity of views towards changing consumers' meat consumption. They found that new knowledge of the effect of meat consumption on human health and well-being has reduced consumption of conventional meat products. However, it seems that this shift in consumption would not tilt towards cultured meat but rather plant-based protein alternatives. Bryant, van Nek, and Rolland (2020) found that providing pro-cultured meat information on food safety is considerably more effective than those with an animal or environmental friendliness focus. Goodwin and Shoulders (2013) studied the provision of information covering cultured meat in print media. They found that the media discussion of this technology and its process is informative, but it is overly technical and may confuse consumers. Goodwin and Shoulders (2013) pointed out that the support of this technology demonstrated in print media outweighs the objection and scepticism. However, European consumers are still reluctant to support cultured meat, and scepticism continues to progress with the

Table 2
Factors affecting consumer acceptance of cultured meat-consumer awareness and knowledge.

Topics	Papers	Country (sample)	Key Findings
Product awareness and familiarity	Rolland et al. (2020)	Netherlands (193)	There was a difference in acceptance for respondents who did not yet know about cultured meat. Familiarity with the technology can positively influence consumer perception.
	Mancini and Antonioli (2019)	Italy (525)	
	Lupton and Turner (2018)	Australia (30)	Familiarity with food and processing methods can help resolve people's ambiguities about meat analogues.
Knowledge of the production process	Valente et al. (2019)	Brazil (626)	Most consumers (87%) had little or no knowledge of cultured meat. Though, after receiving information, 39.3% of respondents indicated a willingness to eat cultured meat (21.7% of respondents answered "I don't know", 24.3% "it depends", and 14.7% "Not willing to eat").
	Van Loo, Caputo, and Lusk (2020)	U.S. (1800)	Provision of information about technology and environmental advantages had minor effects on the acceptance of cultured meat.
	Zhang, Li, and Bai (2020)	China (1004)	An overwhelming majority of respondents were unacquainted with cultured meat, and half of the respondents were neutral. After providing information about cultured meat, the percentage of opposition dropped from 22% to 12%.
	Siegrist, Sütterlin, and Hartmann (2018)	Switzerland (363)	Providing additional information about the process of developing cultured meat reduced concerns about the naturalness of the production process and led to increased support for it.
	Lupton and Turner (2018)	Australia (30)	Provision of information about technology and environmental advantages had minor effects on the acceptance of cultured meat.
Knowledge of the technology advantages	Mancini and Antonioli (2020)	Italy (525)	Positive information improves perceptions of nutritional, safety, and sustainability aspects of cultured meat.
	Wilks, Phillips, Fielding, and Hornsey (2019)	United States (1193)	Results show that a substantial group of respondents strictly opposes cultured meat, suggesting that providing information on the benefits of cultured meat will not necessarily improve attitudes.
	Gasteratos and Sherman (2018)	US and Australia (5,071)	Provision of potential benefits of cultured meat increased willingness to pay.
	Lupton and Turner (2018)	Australia (30)	Since the environmental and animal welfare advantages of cultured meat have lower priority in food decisions for most consumers, improving consumers' knowledge on these advantages does not motivate its acceptance.
	Verbeke, Sans, and Van Loo (2015)	Belgium (180)	The likelihood of consumer acceptance of cultured meat will increase with the provision of univocal information on the advantages of technology compared to the environmental risks associated with conventional meat production ("surely willing to try" increased from 23.9% to 42.5% after additional information).
Vinnari and Tapio (2009)	Finland (215)	The provision of new knowledge about the effects of meat consumption on human health and wellbeing has led to reducing conventional meat products, but cultured meat is considered the least preferable meat substitute.	

development of the technology (Goodwin & Shoulders, 2013).

How information is communicated (for example, specific focus and wordings) would impact consumer behaviour towards novel food technologies (Frewer et al., 2011; Siegrist & Hartmann, 2020a). Asioli, Bazzani, and Nayga (2021) conducted a choice experiment in the U.S. and reported an inverse relationship between prior familiarity with cultured meat technology and consumer acceptance. Asioli et al. (2021) found a significantly lower willingness to pay for 'cultured chicken' among those who had heard about the technology before the study. Their results revealed that consumers' responses would differ depending on how they have been informed (e.g. wordings and terms used). According to Asioli et al. (2021), consumers form only the slightest negative perception if they have heard about the technology when it is referred to as "cultured meat" in comparison with more controversial labels such as "lab-grown" and "artificial" meat. Bryant and Barnett (2019) also found that "cultured meat" and "clean meat" have created more positive attitudes than "lab-grown" and "artificial" meat.

McFadden (2016) reported that the impact of knowledge on consumers' attitudes is non-uniform and depends, to a great extent, on the type of knowledge (i.e., perceived vs actual knowledge). Food choice literature has made a distinction between the effect of subjective knowledge (what consumers perceive they know) and objective knowledge (what consumers truly know) on the purchasing behaviour (Ellen, 1994; House et al., 2004; Pieniak, Aertsens, & Verbeke, 2010). Consumers with high subjective knowledge are less likely to take information about the impact of novel food technology before making their choice. In other words, the provision of information to these overconfident consumers may reduce their reliance on new information (House et al., 2004). In this case, additional information would raise concerns about the technology or product, and decision making becomes more complex (House et al., 2004). McCluskey and Swinnen (2011) maintain that new information supporting a more positive view of the technology may not be able to influence consumers' opinion due to both confirmatory bias (the tendency in accepting the piece of information that confirms prior personal belief) and negativity bias (negative information have a stronger effect on one's perception than positive information). The confirmatory bias on the acceptance of genetically modified food, for instance, has been substantiated by Poortinga and Pidgeon (2006). Lusk et al. (2014) pointed out that empirical results show that familiarity with technology affects the novel food choice. Once a technology is appraised as risky or advantageous, consumers use new information to confirm their opinion rather than adjust it. Hitherto, consumer studies do not lend adequate support for the effect of additional information on acceptance of cultured meat; rather, prior subjective knowledge seems to play a more significant role.

3.2.2. Risk-benefit perceptions

Extant literature highlights the role of the risk-benefit trade-off on consumer attitude towards novel food technologies (for reviews refer to Finucane & Holup, 2005; Frewer et al., 2013), though some studies (e.g. Gaskell et al., 2004) place more emphasis on the role of benefits than risks. A large body of research has been focused on how individuals perceive food risk (e.g. Magnusson & Hursti, 2002; Marette, Roosen, Blanchemanche, & Feinblatt-Mélèze, 2010; Redmond & Griffith, 2004; Siegrist, Stampfli, & Kastenholz, 2009; Webster, Jardine, Cash, & McMullen, 2010; Williams & Hammitt, 2001) and how they assess the risk against other food characteristics (e.g. Loureiro & Umberger, 2007; Van Wezemael, Verbeke, Kügler, & Scholderer, 2011). Verbeke, Marcu, et al. (2015) found that most consumers consider cultured meat to have no desirable attributes. Instead, they perceived it as risky for human

consumption and associated it with unnaturalness and uncertainty (Verbeke, Marcu, et al., 2015). Gómez-Luciano, de Aguiar, Vriesekoop, and Urbano (2019) suggest that the development of this technology requires a deeper understanding of consumer perception of the characteristics of health, naturalness, and sustainability (see Table 3).

Novel food reception largely depends on the trade-offs people make on what they gain in exchange for accepting specific risks (Torgersen, 2004). Goodwin and Shoulders (2013) found that the benefits of cultured meat (including environmental advantages, food security, human health advantages, and animal welfare) were widely discussed in the EU and US media (benefits of cultured meat are fully articulated in Datar & Betti, 2010; Kadim et al., 2015; Post, 2012; Stephens et al., 2018). Bryant and Dillard (2019) showed that benefits associated with cultured meat increase consumer support of the technology. Rolland et al. (2020) showed that the perceived benefits of consuming cultured meat led to an increase in the acceptance of this product. Gómez-Luciano et al. (2019) pointed out that if consumers are being ensured about the healthiness of cultured meat, the probability of cultured meat consumption will be increased. However, most of the benefits associated with cultured meat are viewed as credence goods (Isaac & Phillips, 1999; Siegrist et al., 2018), in which consumers cannot easily recognize their relative value. Hocquette et al. (2015a) found that people trust researchers and support the development of novel technologies like cultured meat that may be useful soon. Still, they were not convinced that meat produced with this technology would be safe and healthy. Verbeke, Marcu, et al. (2015) found that consumers acknowledge the societal benefits of cultured meat (e.g., environmental advantages) while envisaging limited direct personal benefits. The perception of a lack of clear personal benefits also has been reported in a survey conducted by Henchion et al. (2013). In addition, experiment results from Siegrist and Sütterlin (2017) suggest that the health risks associated with meat consumption were much more acceptable for conventional meat compared with cultured meat.

The literature on consumer behaviour has indicated that framing of information affects overall perception and choice (Kahneman & Tversky, 1979; Rothman & Salovey, 1997; Tversky, 1972; Tversky & Kahneman, 1989). The effect of negative and positive statements (framing effect) has been confirmed as important for accepting genetically modified food (Heiman & Zilberman, 2011). Results of the experiment conducted by Heiman and Zilberman (2011) showed that negative framing affects the perception of biotechnology but, more importantly, increases the weight assigned to health benefits versus taste. Regarding cultured meat, Bryant and Dillard (2019) found that positive framing (e.g. it is healthier and beneficial for the environment) had positively affected consumer attitude.

In a series of experiments, Bekker, Fischer, et al. (2017) investigated the effect of information provision on explicit and implicit attitudes towards cultured meat. Explicit attitudes are conscious attitudes and predictive for deliberate behaviour, whereas implicit attitudes are mental associations between a phenomenon and related unconscious positive or negative evaluation (Glasman & Albarracín, 2006; Perugini, 2005; Rydell, McConnell, Mackie, & Strain, 2006). Bekker, Fischer, et al. (2017) found that positive (or negative) valence of the information alters explicit attitude in favour (or disfavour) of cultured meat (as an unfamiliar object). This effect was less sizeable for consumers with prior familiarity with cultured meat, showing congruence with other studies on attitude change (Gregg, Seibt, & Banaji, 2006; Ratliff, Swinkels, Klerx, & Nosek, 2012). However, Bekker, Fischer, et al. (2017) failed to detect any significant effect on implicit attitude from the information or affect stimuli.

Table 3
Factors affecting consumer acceptance of cultured meat- Risk-Benefit perception.

Topics	Papers	Country (sample)	Key Findings
Risk-benefit trade-offs	Gómez-Luciano et al. (2019)	UK, Spain, Brazil, and the Dominican Republic (729)	The development of this technology requires a deeper understanding of consumer perception of the characteristics of health, naturalness, and sustainability. Ensuring the healthiness of cultured meat increases its consumption probability.
	Verbeke, Marcu, et al. (2015)	Belgium, Portugal and the UK (179)	Participants perceived cultured meat as risky for human consumption due to fears of nutritional deficiencies and unknown adverse long-term consequences.
Perception of healthiness	Dupont and Fiebelkorn (2020)	Germany (718)	In terms of health and naturalness, the cultured meat hamburger was evaluated more negatively, compared with the insect hamburger.
	Wilks, Hornsey, and Bloom (2020)	USA (904)	Results showed that perception of unnaturalness flowed more from affective factors such as disgust and fear than from information processing and rational decision-making.
	Wilks et al. (2019)	USA (1193)	Naturalness bias was identified as the least significant predictor for consumer attitudes towards cultured meat.
	Bryant, Szejda, Parekh, Deshpande, and Tse (2019)	China, India, and the US (total sample = 3030 of which 987 US, 1024 India, and 1019 China)	Perceived naturalness of cultured meat affects consumer acceptance.
	Siegrist et al. (2018)	Switzerland (363)	Consumers perceive cultured meat differently from conventional meat because of the production process and inherent negative connotations. Resistance to cultured meat has been linked to concerns about its perceived unnaturalness.
	Siegrist and Sütterlin (2017)	Switzerland (497)	The lack of perceived naturalness raises concerns in the acceptance of the risks associated with the consumption of cultured meat.
	Verbeke, Sans, and Van Loo (2015)	Belgium (180)	Traditional meat consumers would reject cultured meat if it is considered to be heavily processed, unnatural, and with a lack of sensory characteristics.
	Verbeke, Marcu, et al. (2015)	Belgium, Portugal and the United Kingdom (179)	Participants expressed a sense of disgust not towards cultured meat but rather to the process by which it is created. The participants' revulsion is attributed to the perceived transgression of natural (conventional) meat production.
Framing effects	Laestadius and Caldwell (2015)	Across seven US-based online news sources	Analysis of the comments on online news articles revealed that concerns about naturalness and risks appear to be a substantial barrier to public acceptance of this technology.
	Hallman and Hallman (2020)	USA (3,186)	Assessment of common names to label cell-based seafood products indicated that the 'cell-based seafood' term outperforms the other names examined.
	Bryant and Dillard (2019)	USA (480)	Positive framing had a positive effect on consumer attitudes towards cultured meat. Using terms such as "cultured meat" and "clean meat" have created more positive attitudes than "lab-grown" and "artificial meat".
	Siegrist et al. (2018)	Switzerland (363)	How the technological and product advantages are described affects the consumers' perception.
	Asioli et al. (2018)	US (625)	Consumers are less averse to the term "cultured meat" than "artificial" and "lab-grown" meat.
	Bekker, Fischer, et al. (2017)	Netherlands (576)	The positive valence of information alters explicit positive attitudes towards cultured meat.

3.2.3. Ethical and environmental concerns

Demand for meat is still on the rise globally, leading to increased societal concerns about intensified livestock production and, consequently, animal welfare issues (Bryant & Barnett, 2018; Henchion, De Backer, & Hudders, 2017; Post & Hocquette, 2017). Valente et al. (2019) found that animal welfare plays a role in consumers' reduced meat diet and acceptance of cultured meat. Table 4 summarises number of consumers' environmental and ethical concerns regarding development of cultured meat. Weinrich et al. (2020) revealed that animal welfare and ecological concerns were the most influential positive drivers of consumers' attitudes towards cultured meat. Mancini and Antonioli (2019) showed that ethical concerns increase consumers' willingness to adopt meat substitutes and pay a premium price. The results showed that 26% of respondents tend to reduce meat consumption due to animal welfare issues. A recent study by Dupont and Fiebelkorn (2020) revealed that consumers considered cultured meat ethically acceptable.

Nevertheless, Elaine (2019) showed that, in comparison with rural consumers, urban consumers are more likely to consider cultured meat as an ethical substitute. However, Tucker (2014) conducted a focus group that found that while ethical or animal welfare of cultured meat was considered relevant by most, the adoption of novel meat substitutes (including cultured meat) merely due to these motives is far less likely.

Instead, likely health advantages appear as a stronger motivator to change meat-centric consumption to a plant-based diet (Tucker, 2014). Conversely, consumer surveys identified a group of individuals who consider developing novel food technology as 'tampering with nature' and thus view it as morally questionable (Miles & Frewer, 2001; Verbeke, Sans, & Van Loo, 2015). Moreover, the development of food-specific technologies (e.g., biotechnology) might raise conflicts with consumers' religious values (Mayer & Stirling, 1999; Straughan, 1999). In the same vein, the way cultured meat is produced or the origin of the stem cell may raise some religious questions (Hamdan et al., 2018).

Attitudes towards the environment appear to be one of the most important determinants of consumers' consumption behaviour and new food acceptance (Slade, 2018). Slade (2018) found that consumers with environmental concerns were more willing to purchase meat alternatives, such as plant-based and cultured meat. These results are consistent with recent ecological food consumption patterns in which consumers are motivated to renounce meat products due to environmental, health, and animal welfare considerations (Hocquette et al., 2018; Izmirlı & Phillips, 2011; Jabs, Devine, & Sobal, 1998; Tobler, Visschers, & Siegrist, 2011). For example, Izmirlı and Phillips (2011) examined students' animal-based food consumption and reported that the majority of vegetarian students refused meat products due to health concerns, but

Table 4
Factors affecting consumer acceptance of cultured meat- Ethical and environmental concerns.

Topics	Papers	Country (Sample)	Key Findings
Animal welfare	Bryant et al. (2020)	Germany and France (2000)	Pro-cultured meat information focusing on food safety and antibiotic resistance is considerably more convincing than those centred on animals or the environment.
	Dupont and Fiebelkorn (2020)	Germany (718)	While respondents considered cultured meat "guilt-free" meat consumption, 3D-printed cultured meat was presumed to be not fresh, unnatural, and overly processed.
	Weinrich et al. (2020)	Germany (713)	Animal welfare and ecological concerns were the strongest positive drivers of consumer attitudes.
	Mancini and Antonioli (2019)	Italy (525)	Animal welfare and sustainability concerns increase consumers' willingness to adopt cultured meat and their willingness to pay a premium price.
	Dupont and Fiebelkorn (2020)	Germany (718)	Consumers with ethical concerns view cultured meat more positively.
	Valente et al. (2019)	Brazil (626)	Animal welfare plays a role in consumers' reduced meat diet and acceptance of cultured meat
Unnatural production process (tampering with nature)	Elaine (2019)	Ireland (312)	Urban consumers are more likely than rural consumers to consider cultured meat as an ethical substitute.
	Slade (2018)	Canada (533)	Concerns for animal welfare did not induce a greater preference for cultured meat.
	Dupont and Fiebelkorn (2020)	Germany (718)	In terms of naturalness, the cultured meat hamburger was evaluated more negatively than the insect hamburger.
	Wilks et al. (2020)	USA (n = 904)	Results showed that perception of unnaturalness flowed more from affective factors such as disgust and fear than from information processing and rational decision-making.
	Bryant, Szejda, et al. (2019)	China, India, and the US (total sample = 3030)	Perceived naturalness of cultured meat affects consumer acceptance.
	Wilks et al. (2019)	USA (1193)	Naturalness bias was identified as the least significant predictor for consumer attitudes towards cultured meat.
	Siegrist et al. (2018)	Switzerland (363)	Consumers perceive cultured meat differently from conventional meat because of the production process and inherent negative connotations. Resistance to cultured meat has been linked to concerns about its perceived unnaturalness.
	Siegrist and Sütterlin (2017)	Switzerland (497)	The lack of perceived naturalness raises concerns in accepting the risks associated with the consumption of cultured meat.
Environmental concerns	Laestadius and Caldwell (2015)	Across seven US-based online news sources	Analysis of the comments on online news articles revealed that concerns about naturalness and risks appear to be a substantial barrier to public acceptance of this technology.
	Verbeke, Marcu, et al. (2015)	Belgium, Portugal and the United Kingdom (179)	Participants expressed a sense of disgust not towards cultured meat but rather to the process by which it is created. The participants' revulsion is attributed to the perceived transgression of natural (conventional) meat production.
	Verbeke, Sans, and Van Loo (2015)	Belgium (180)	Traditional meat consumers would reject cultured meat if it is heavily processed, unnatural, and lacks sensory characteristics.
	Dupont and Fiebelkorn (2020)	Germany (718)	Only a few participants prioritized environmentally sustainable and ethical production concerns in their evaluation of cultured meat technology.
	Circus and Robison (2019)	UK (139)	The results suggest that consumers accept cultured meat as an effective technology in addressing global environmental issues but were reluctant to consume it personally.
	Slade (2018)	Canada (533)	However, authors further show that individual and global perceptions of cultured meat tend to be congruent, where if they chose to consume cultured meat (or other protein alternatives) personally, they support it globally. They would not support it globally if they did not intend to consume it personally.
	Tucker (2014)	New Zealand (69)	For environmentally-conscious consumers, environmental risks of food systems correlate with preferences for meat alternatives, including cultured meat, significance at the one per cent levels). Adopting novel meat substitutes (including cultured meat) seems far less promising merely based on environmental or animal welfare motives.

others were motivated by both ecological and health reasons. Nevertheless, findings from Bryant et al. (2020), Dupont and Fiebelkorn (2020) and Tobler et al. (2011) suggest that environmental concerns alone might not be the strongest motivation to renounce conventional meat. Van Loo et al. (2020) found that farm-raised beef was the preferred choice even with a substantial price reduction (e.g., 50%) of plant-based and cultured meat alternatives.

Past research also shows that perceived naturalness, among other factors, has a decisive role in the consumer acceptance of novel food (Hemmerling, Canavari, & Spiller, 2016; Laestadius, 2015; Laestadius & Caldwell, 2015; Siegrist, 2008). Rozin, Fischler, and Shields (2012) surveyed respondents from the US, UK, France, Germany, and Switzerland and found that people in these countries were very receptive to the notion of 'natural' food. Their results indicated that naturalness is linked to a lack of human intervention in food development or processing in any form.

Siegrist et al. (2018) pointed out that consumers perceived cultured meat differently from conventional meat because of the production process and inherent negative connotations. The literature considered indicates that the majority of consumers perceive cultured meat as unnatural and see it as "abnormal", "fake", and "artificial" (Bryant, Anderson, Asher, Green, & Gasteratos, 2019; Bryant & Barnett, 2018, 2019; Bryant & Dillard, 2019; Elaine, 2019; Henchion et al., 2013; Laestadius, 2015; Lupton & Turner, 2018; Wilks et al., 2020). A study by Siegrist and Sütterlin (2017) indicated that perceived naturalness affects the acceptance of cancer risks associated with meat consumption. They found that a lack of perceived naturalness diminishes the acceptance of health risks in the case of cultured meat, a novel production technology that is more environmentally friendly and less harmful to the animal. Verbeke, Sans, and Van Loo (2015) found that consumers' initial responses were a sense of unnaturalness and disgust when they learned about cultured meat. The lack of naturalness invoked technology

Table 5
Factors affecting consumer acceptance of cultured meat- Emotions.

Topics	Papers	Country (sample)	Key Findings
Fear of unfamiliar technology	Dupont and Fiebelkorn (2020)	Germany (718)	Food neophobia affects willingness to consume cultured meat burgers.
	Gómez-Luciano et al. (2019)	United Kingdom, Spain, Brazil, and the Dominican Republic (729)	Food technology neophobia was most prominent in willingness to pay for meat substitutes.
	Lupton and Turner (2018)	Australia (30)	In panel discussions, respondents expressed that they were unfamiliar with the novel food production, and hence, they were unsure about the safety of the process.
Fear of unknown effects	Bryant, Anderson, Asher, Green, and Gasteratos (2019)	United States (1185)	Food neophobia is inversely linked with consumers' stated willingness to eat cultured meat.
	Elaine (2019)	Ireland (312)	Most respondents fear this new technology because of the unknown long-term health effects.
	Wilks et al. (2019)	United States (1193)	The neophobia and suspicion towards food sciences influence consumers' negative attitudes towards this technology.
Disgust sensitivity	Siegrist and Hartmann (2020b)	Australia, China, England, France, Germany, Mexico, South Africa, Spain, Sweden, and the US (6128)	The idea of cultured meat evokes more feelings of disgust among people with higher levels of food neophobia.
	Egolf et al. (2019)	Switzerland (330)	Consumers who described cultured meat as disgusting perceived it as more risky than beneficial and showed lower willingness to try it than those for whom cultured meat was not disgusting.
	Siegrist et al. (2018)	Switzerland (363)	Part of consumers reluctance towards cultured meat is attributed to the disgust factor.
	Verbeke, Sans, and Van Loo (2015)	Belgium (180)	When they learned about cultured meat, consumers' initial responses were a sense of unnaturalness and disgust).
	Verbeke, Marcu, et al. (2015)	Belgium, Portugal, and the United Kingdom (179)	Lack of appeal and feelings of disgust are identified as a barrier to trying cultured meat.

rejection and increased doubts about its purported health benefits (Palmieri, Perito, & Lupi, 2020; Verbeke, Sans, & Van Loo, 2015). Verbeke, Sans, and Van Loo (2015) concluded that traditional meat consumers would reject cultured meat as long as it was considered to be heavily processed, unnatural, and with a lack of sensory characteristics. Dupont and Fiebelkorn (2020) revealed that in terms of health and naturalness, a cultured meat hamburger was evaluated more negatively than an insect-based hamburger.

3.2.4. Emotions

One aspect of developing technological expertise includes dealing with the perception of adverse effects and consumers' phobia (Henchion et al., 2013). Food neophobia accounts for an individual's reluctance to consume novel food, rooted in one's culture and risk perception (Nezlek & Forestell, 2019; Rozin, 1997; Tuorila, Lähteenmäki, Pohjalainen, & Lotti, 2001). Food neophobia is seen as a barrier to consumer acceptance of meat substitutes (Hoefkens, Verbeke, & Van Camp, 2011; Hwang, You, Moon, & Jeong, 2020). Gómez-Luciano et al. (2019) also suggest that food technology neophobia played the most prominent role in willingness to pay for meat substitutes.

Dupont and Fiebelkorn (2020) indicated that food neophobia negatively affects the willingness to consume cultured meat burgers (see Table 5). In the case of cultured meat, food neophobia includes the fear of unfamiliar technology and the fear of unknown risks of novel food (Verbeke, Sans, & Van Loo, 2015). Elaine (2019) found that most respondents fear this new technology because of the unknown long-term health effects. Wilks et al. (2019) showed that the suspicion of food sciences influences consumers' negative attitude towards this technology (though this effect was less significant compared to other factors such as neophobia and political conservatism). Hence, food neophobia can be partly shaped by the trust in social actors (for an overview see Frewer, 2003; McComas & Trumbo, 2001; Siegrist, Cousin, Kastenholz, & Wiek, 2007). Green, Draper, and Dowler (2003) stated that consumers trust actors within the food system (e.g., retailers, regulatory, and research institutions) as a heuristic proxy to assess food safety. In effect, individuals compensate for their inability to realize food safety (a

credence attribute) by conferring trust in the food system actors (Berg, 2004; Frewer & Van Trijp, 2006; Siegrist & Cvetkovich, 2000).

Moreover, cultured meat evokes sense of disgust which is important factors in accepting this novel food technology (Egolf, Hartmann, & Siegrist, 2019; Siegrist et al., 2018; Siegrist & Hartmann, 2020b).

3.2.5. Personal factors

European consumers appear to be more unwilling than American consumers to reduce meat consumption and shift to simulated meats, especially those considered high-frequency meat-eaters (Tobler et al., 2011). As depicted in Table 6, demographic factors such as age, gender, and education level were associated with cultured meat acceptance (Bogueva & Marinova, 2020; Bryant & Dillard, 2019; Zhang et al., 2020). Grasso et al. (2019) and Rolland et al. (2020) demonstrated that higher education is related to the intention of adopting a diet with alternative proteins produced from sustainable sources. Mancini and Antonioli (2019), Wilks et al. (2019) and Slade (2018) found that young, male, educated consumers were more likely to consume meat alternatives. Wilks et al. (2019) reported that age and gender affect acceptance tendencies more than educational levels. Previous studies reported that women were more willing to adopt ecological food diets (Tobler et al., 2011). Mancini and Antonioli (2020) likewise found that a large proportion of those who desired to reduce meat were women. Nevertheless, this does not necessarily mean they would choose cultured meat. Instead, Slade (2018) showed that women were less likely to purchase hamburgers made from cultured meat. Furthermore, Dupont and Fiebelkorn (2020) reported that age was an important predictor for consuming cultured meat burgers. They showed that attitudes toward cultured meat as food were more accepting from children and adolescents due to lower levels of food disgust. In addition to the demographic factors, acceptance of cultured meat was also found to be linked to personality traits, diet preferences, and worldviews (Heidemann, Taconeli, Reis, Parisi, & Molento, 2020; Wilks et al., 2019; Wilks & Phillips, 2017).

The acceptance of cultured meat varies across countries, indicating the mediating role of culture (Bryant, Szejda, et al., 2019; Siegrist &

Table 6
Factors affecting consumer acceptance of cultured meat- Personal factors.

Topics	Papers	Country (sample)	Key Findings
Gender	Mancini and Antonioli (2020)	Italy (525)	Females that are not familiar with cultured meat and non-meat consumers showed the greatest change after receiving additional information related to the safety aspects of cultured meat.
	Slade (2018)	Canada (533)	Women are less likely to purchase hamburgers made from cultured meat, preferring plant-based burgers.
	Wilks and Phillips (2017) Tucker (2014)	United States (673) New Zealand (69)	Men were more receptive to cultured meat than women.
Age	Dupont and Fiebelkorn (2020)	Germany (718)	Women are more likely to hold an overall negative attitude towards cultured meat (69% of those with a positive view of cultured meat were male).
	Bogueva and Marinova (2020)	Australia (n = 227)	Attitudes toward cultured meat as food and hamburgers were more accepted in children and adolescents due to lower levels of food.
	Zhang et al. (2020)	China (1004)	Most respondents did not support cultured meat technology; however, young people were more prepared to try it.
	Wilks et al. (2019)	United States (1193)	Younger participants with a higher education degree had a more receptive attitude towards cultured meat.
	Tucker (2014)	New Zealand (69)	The effect of age and gender are more important for acceptance than educational level.
Education	Van Loo et al. (2020)	U.S. (1800)	In focus groups, younger participants were more positive towards cultured meat.
	Grasso et al. (2019) and Rolland et al. (2020)	The United Kingdom, the Netherlands, Poland, Spain, and Finland (1825) Netherlands (193)	Overall, more people opposed than supported cultured meat. However, young males and more educated individuals tend to show a relatively stronger preference for this product.
	Wilks et al. (2019) Slade (2018)	United States (1193) Canada (533)	Higher education affects the acceptance of alternative proteins produced from sustainable sources.
	Siegrist and Hartmann (2020b)	Australia, China, England, France, Germany, Mexico, South Africa, Spain, Sweden, and the US (6128)	Before providing information on cultured meat technology, consumers acceptance was examined based on cultural and sociodemographic variables (such as age, gender, beef consumption behaviour), and only education and frequency of meat consumption were relevant.
Intercultural differences	Wilks et al. (2019) Slade (2018)	United States (1193) Canada (533)	Educated consumers are more likely to consume cultured meat Younger and more educated consumers have stronger preferences for cultured meat.
	Siegrist and Hartmann (2020b)	Australia, China, England, France, Germany, Mexico, South Africa, Spain, Sweden, and the US (6128)	Substantial differences in approval of cultured meat were identified across countries (Australia, China, England, France, Germany, Mexico, South Africa, Spain, Sweden and the US), suggesting it might be problematic to generalize findings connected to this technology.
	Bryant et al. (2020)	Germany and France (2000)	The study found considerable markets for cultured meat in Germany and France, although German consumers are substantially more receptive to the concept than the French.
	Bryant, Szejda, et al. (2019) Gómez-Luciano et al. (2019)	China, India, and the US (total sample = 3030 of which 987 US, 1024 India, and 1019 China) United Kingdom, Spain, Brazil, and the Dominican Republic (729)	Results suggest that the acceptance of cultured meat varies considerably across cultures, with a higher acceptance rate in India and China than in the USA. Respondents from economically developed countries (e.g., the United Kingdom and Spain) tended to show more readiness to shift from a conventional meat diet to non-meat proteins
	Gasteratos and Sherman (2018) Bekker, Tobi, and Fischer (2017)	US and Australia (5,071) China, Ethiopia, and the Netherlands (30)	While 43% of U.S. consumers stated willingness to consume cultured meat, only 25% of Australians would consume it. Participants from China showed more support for cultured meat, associating it with animal welfare and environmental advantages, whereas both Dutch and Ethiopian participants linked it to unnaturalness.
Personality traits and worldviews	Wilks et al. (2019)	United States (1193)	Political conservatism was a strong predictor of attitude but not reliable determinants of opposition towards cultured meat. Moreover, a strong belief in conspiracies (tendency to resist scientific advancements) predicts absolute opposition towards cultured meat.
	Heidemann et al. (2020)	Brazil (272)	A study on the opinion of professionals involved in animal production indicated that specialists who were women, veterinarians, vegetarians, or vegans were more supportive of cultured meat.
	Siegrist and Hartmann (2020b)	Australia, China, England, France, Germany, Mexico, South Africa, Spain, Sweden, and the US (6128)	Personality traits such as food neophobia and food disgust sensitivity evoke a sense of disgust and have a negative effect on cultured meat acceptance.
	Valente et al. (2019) Wilks and Phillips (2017)	Brazil (626) USA (673)	Vegetarians were less likely to consider the consumption of cultured meat. There is a link between worldview and interpretation of innovation.
	Verbeke, Sans, and Van Loo (2015)	Belgium (180)	Conservatives tend to hold less receptive attitudes to cultured meat. Moreover, despite vegetarians being more likely to acknowledge advantages, they were less interested in trying cultured meat. Vegetarians were unconvinced about the healthiness of cultured meat, suggesting that this group may not be the main target group for cultured meat.

Hartmann, 2020b). This finding has also been reported regarding the application of various beef processing technologies (e.g. Van Wezemael et al., 2012). Overall, among EU countries, consumers in Belgium, the UK, Spain, and Italy appear more receptive to cultured meat; while German, French, and Finnish citizens were found to be less enthusiastic concerning cultured meat (Bryant et al., 2020; Gómez-Luciano et al., 2019; Mancini & Antonioli, 2019; Siegrist & Hartmann, 2020b; Verbeke,

Sans, & Van Loo, 2015; Vinnari & Tapio, 2009). The results of Wilks (2018) and Wilks and Phillips (2017) show a higher rate of US respondents intending to try cultured meat. Bekker, Tobi, and Fischer (2017) found that consumers expressed greater willingness to consume cultured meat in countries where a meat substitutes market (e.g., plant-based alternatives) already existed, like China.

In a recent study, Gómez-Luciano et al. (2019) examined consumers'

Table 7
Factors affecting consumer acceptance of cultured meat-Product properties.

Topics	Papers	Country (sample)	Key Findings
Price	Arora, Brent, and Jaenicke (2020)	India (394)	Four classes of Indian consumers were identified with different WTP estimates for cultured meat.
	Zhang et al. (2020)	China (1004)	Findings suggest that the price of cultured meat can be an obstacle in upscaling the technology. However, providing information about the technology advantages increased consumers' WTP to slightly more than conventional meat.
	Grasso et al. (2019)	The United Kingdom, the Netherlands, Poland, Spain, and Finland (1825)	A lower price would increase price-conscious consumers' motivation to choose cultured meat.
	Verbeke, Sans, and Van Loo (2015)	Belgium (180)	Sensory quality and an affordable price are the main determinants shaping future consumer acceptance or rejection of these novel meat substitutes.
Sensory expectations	Tucker (2014)	New Zealand (69)	Price can influence the reduction in conventional meat consumption and the shift to other meat alternatives.
	Gere, Harizi, Bellissimo, Roberts, and Moskowitz (2020)	USA (100)	Consumers would choose meat alternatives (including cultured meat) having similar sensory aspects as traditional meat.
	Ruzgys and Pickering (2020)	Canada (214)	Taste was found to be an important factor in the acceptance of cultured meat, especially for younger respondents (Responses to cultured meat would not taste the same as farmed meat were relatively evenly distributed between moderate or strong agreement (38%), moderate or strong disagreement (30%), and neither agreement nor disagreement (32%).)
	Gómez-Luciano et al. (2019)	The United Kingdom, Spain, Brazil, and the Dominican Republic (729)	Rather than environmental and health concerns, product attributes (e.g., taste and appearance) are more important determinants of willingness to purchase meat alternatives (plant, cultured meat and insect-based meats).
	Wilks and Phillips (2017)	United States (673)	Respondents found cultured meat less natural, less appealing, and less tasty than conventional meat, though more environmentally friendly.
	Verbeke, Marcu, et al. (2015)	Belgium, Portugal and the United Kingdom (179)	Lack of appeal and disgust feeling is identified as a barrier to trying cultured meat.
	Tucker (2014)	New Zealand (69)	Sensory properties, 'disgust' factor, healthiness, and unnaturalness are important drivers underpinning willingness to try novel food.
Effect of product type/technology type	Bryant, Anderson, et al. (2019)	USA (1185)	Higher consumer support for fish sticks and chicken nuggets compared to beef burgers.
	Lupton and Turner (2018)	Australia (30)	Consumers showed low interest in 3D-printed cultured meat.
	Slade (2018)	Canada (533)	Consumers preferred burgers made from cultured meat to chicken or steak analogues, possibly due to the ubiquity of vegan burgers.

willingness to purchase three alternative protein sources in the UK, Spain, Brazil, and the Dominican Republic. The results revealed that, overall, plant-based proteins were deemed the most preferred alternative. Consumers in Spain and Brazil were more inclined towards cultured meat than insect-based proteins (Gómez-Luciano et al., 2019).

Vinnari and Tapio (2009) examined Finish consumers and experts' opinions on probable and preferred development of different future meat scenarios, including cultured meat. They found neither consumers nor experts desired cultured meat technology; however, it was considered very likely to take the place of conventional meat in the near future. Weinrich et al. (2020) found that consumers in Germany were moderately prepared to accept cultured meat. Gasteratos and Sherman (2018) found that U.S. citizens were more receptive to cultured meat than Australians after providing information.

3.2.6. Product properties

Past research indicated that product properties such as price, sensory appeal, healthiness, and convenience are the most important factors that influence food choice (Malek, Umberger, & Goddard, 2019; Scheibehenne, Miesler, & Todd, 2007; Van Birgelen, Semeijn, & Keicher, 2009). In the case of novel foods, in addition to cognitive and motivation factors, product properties such as price and taste are also important in consumer acceptance or rejection (Barrena & Sánchez, 2013; Knight, Mather, & Holdsworth, 2005; Siegrist, 2008; Spence & Townsend, 2006). Gómez-Luciano et al. (2019) found that consumers attach more value to meat properties such as healthiness, safety, nutritional content,

and taste. They carefully consider price when comparing traditional meat to alternative proteins (See Table 7). A study by Grasso et al. (2019) suggests that convenience and sustainability motives were not strong determinants of cultured meat acceptance. Van Loo et al. (2020) also reported that even a substantial price reduction (e.g., 50%) did not motivate respondents to choose cultured meat among protein alternatives.

Several previous studies suggested that the availability of novel foods at a lower price would lead to more acceptance and increase market share (Bekker, Tobi, & Fischer, 2017; Gębski & Kosicka-Gębska, 2009; Knight et al., 2005; Siegrist, 2008; Spence & Townsend, 2006; Verbeke, Sans, & Van Loo, 2015; Zhang et al., 2020). For instance, Wilks and Phillips (2017) and Slade (2018) reported that consumers were less likely to pay a price premium for cultured meat. Tucker (2014) found that price could influence the reduction in meat consumption and shift to meat alternatives. The results of a recent study by Zhang et al. (2020) also confirmed the role of price. They concluded that information increases consumer willingness to try cultured meat (more than 70%) and found that WTP for cultured meat is just about 2.2% above the price of conventional meat. Grasso et al. (2019) study showed that lower prices would increase their motivation to choose cultured meat for price-sensitive consumers. However, the current production technology of cultured meat is rather expensive, hindering consumers' willingness to buy (Verbeke, Sans, & Van Loo, 2015).

Risk perception can also be influenced by the product type (De Steur et al., 2013; Frewer et al., 2013) or the level of processing (Hallman,

Table 8
Factors affecting consumer acceptance of cultured meat- Alternatives and availability.

Topics	Papers	Country (sample)	Key Findings
Plant-based alternatives	Van Loo et al. (2020)	USA (1800)	Farm-raised beef was the preferred choice even with a substantial price reduction (e.g., 50%) of plant-based and lab-grown alternatives.
	Arora et al. (2020)	India (394)	Respondents showed more support for plant-based meat compared with cultured meat.
	Circus and Robison (2019)	UK (139)	Plant-based meat substitutes were favoured the most, mainly due to ethical reasons, and insect-based proteins were favoured the least.
	Grasso et al. (2019)	USA (100)	Plant-based protein was the most accepted, and cultured meat was the least accepted alternative source
	Mancini and Antonioli (2019)	Italy (525)	Acceptance of cultured meat depends on the presence of other meat substitutes.
	Gómez-Luciano et al. (2019)	United Kingdom, Spain, Brazil, and the Dominican Republic (729)	Plant-based proteins were deemed the most preferred meat alternative compared to cultured meat and insect-based proteins since they are more well-established and widely available in the market.
	Lupton and Turner (2018)	Australia (30)	Respondents did not favour either 3D printed food made from insects or cultured meat but considered the latter more natural and nutritious.
	Slade (2018)	Canada (533)	Consumers tend to favour plant-based hamburgers over cultured meat hamburgers. Also, results indicated that individuals with local food preferences are more reluctant to accept cultured meat (and even plant-based meat).
	Bryant, Anderson, et al. (2019)	USA (1185)	People who were not interested in plant-based burgers tended to consider eating cultured meat burgers.
	Bryant and Dillard (2019)	USA (480)	Half of those who preferred plant-based meat tended to eat cultured meat too.
Insect-based protein	Dupont and Fiebelkorn (2020)	Germany (718)	In comparison with the burgers from cultured meat, insect burgers were considered more positive in terms of health and the environment

2000; Moses, 1999). Lupton and Turner (2018) examined consumer acceptance of 3D-printed food made from cultured meat or insects. Despite recognizing potential benefits, consumers showed low interest in these simulated technologies (Lupton & Turner, 2018). The study results by Bryant, Anderson, et al. (2019) found higher consumer support for fish sticks and chicken nuggets than beef burgers. The result of a study by Bryant, Anderson, et al. (2019) showed that among respondents who supported cultured meat, 42.8% were willing to pay for chicken, 42.6% for fish, and 39% for beef. In contrast, Slade (2018) found that consumers are more inclined to cultured meat burgers than simulated chicken or steak due to vegan burgers ubiquity. Thus, further research is needed to gain deeper insights into consumer acceptance of different types of simulated meat substitutes (Slade, 2018).

3.2.7. Alternatives and availability

In developed countries, there is a growing tendency to substitute meat with alternative protein sources (Malek et al., 2019). The adoption of alternative proteins depends on the availability of the product in the market (Bonny et al., 2015; Gómez-Luciano et al., 2019; Goodwin & Shoulders, 2013; Mancini & Antonioli, 2019; Schösler, De Boer, & Boersema, 2012). Despite its importance, there is a dearth of research in this area (Knight, Mather, Holdsworth, & Ermen, 2007; Malek et al., 2019; Powell, Blaine, Morris, & Wilson, 2003). The results of a few studies on controversial food technologies, like biotechnology, have shown that the availability of the GM product in the market would improve consumer acceptance (Aerni, 2011, 2013; Aerni, Scholderer, & Ermen, 2011; Knight et al., 2007; Mather et al., 2012).

The commercialization of cultured meat may be influenced by the availability of other alternative protein sources, including plant, insect, and single-cell based proteins (Bonny et al., 2015; Grasso et al., 2019; Mancini & Antonioli, 2019; Schösler et al., 2012; Sexton, 2018). As shown in Table 8, among meat substitutes, it is evident that plant-based meat is more widely preferred as it looks more natural and has fewer negative consequences for the consumers (Gómez-Luciano et al., 2019; Román, Sánchez-Siles, & Siegrist, 2017). Grasso et al. (2019) examined

consumers' willingness to accept alternative and sustainable protein sources in the European Union. Their results indicated that plant-based protein was the most accepted alternative source (58%), followed by single-cell (20%), insect-based (9%), and cultured meat protein (6%). Comparing consumption tendencies between cultured meat and insect burgers in Dupont and Fiebelkorn (2020) study indicated that respondents leaned more towards consuming cultured meat burgers. In individual cases, insect burgers were considered more favourably in terms of health and the environment. Slade (2018) examined consumer preferences for cultured meat and plant-based meat hamburgers. Respondents mostly opted for the beef burger, but 27% were interested in plant-based hamburgers, and only 13% were interested in cultured meat hamburgers (Slade, 2018).

Frequent meat-eaters were less likely to shift to simulated meat but may consider cultured meat a closer substitute for beef than plant-based beef (Slade, 2018). Bryant, Anderson, et al. (2019) research showed that about 57% of people who eat plant-based meat showed a willingness to eat cultured meat, and about 63% of those who do not eat plant-based meat were willing to eat cultured meat. Bryant and Dillard (2019) also found that about 50% of vegetarians and respondents currently consuming plant-based meat may consider eating cultured meat.

4. Discussion

Understanding drivers of consumer acceptance is essential to commercializing cultured meat technology (Harguess, Crespo, & Hong, 2020; Hartmann & Siegrist, 2017; Onwezen, Bouwman, Reinders, & Dagevos, 2021; Siegrist & Hartmann, 2020a). The present review provides an extensive overview of relevant factors of cultured meat acceptance (measured, for instance, in terms of preference, willingness to try/eat/pay). Our review identified three major themes across retrieved articles: a) a general reluctance in acceptance of cultured meat, b) knowledge and heuristic cues (such as perceived healthiness, naturalness, and disgust evoked by the unfamiliar technology) are the main drivers of acceptance, c) environmental and ethical concerns seem

to have minor effects. We elaborate on these outcomes in more detail below, followed by suggestions on future research and limitations.

4.1. Acceptance of cultured meat

In accordance with previous reviews (e.g., [Onwezen et al., 2021](#)), our findings indicate that the acceptance level of cultured meat is relatively low, especially for consumers with heavy meat consumption (e.g., [Onwezen, Van den Puttelaar, Verain, & Veldkamp, 2019](#); [Slade, 2018](#)). Our reviews showed cross-cultural differences in consumer responses towards cultured meat, which corroborates the findings of [Bryant and Barnett \(2018\)](#) and [Onwezen et al. \(2021\)](#). Environmental and animal welfare advantages of novel meat alternatives (both plant-based and cultured meat) do not seem to be a strong enough motivation for consumers with a diet heavily based on meat to reduce their meat consumption and include these new food sources into their diet ([Hopkins & Dacey, 2008](#)).

The results also indicate that, compared to vegetarians, individuals with high levels of meat consumption are more open to considering trying cultured meat. This new product is viewed as a suitable alternative by those responsible consumers that consider more sustainable food consumption patterns but are not willing to change their current meat-based diet ([Post, 2012](#); [Shapiro, 2018](#)).

Moreover, the development of affordable plant-based and cultured meat would have a counter effect on the acceptance of each other. Currently, plant-based proteins are the preferred alternative source of protein compared to cultured meat and other novel technologies such as protein from insects ([Circus & Robison, 2019](#); [de Boer, Schöslner, & Boersema, 2013b](#); [Onwezen et al., 2019](#); [Onwezen et al., 2021](#)). The unappetizing sensory properties of meat substitutes triggers repulsive responses ([Tucker, 2014](#)). Scientists are seeking to improve the taste and texture properties of these products, which could facilitate an upscale in producing different types of cultured meat products ([Ben-Arye et al., 2020](#)). Despite the technological challenges and general public reluctance, the cultured meat industry has seen rapid growth over the last few years, paving the way for alternative protein sources like chicken, fish and beef ([Corbyn, 2020](#)). These products will be produced in different forms, such as hamburgers, sausages and nuggets ([Goodwin & Shoulters, 2013](#)). Among these options, chicken is somewhat easier to produce because the vaccine industry has been using avian stem cells for many years, and the knowledge for producing in-vitro chicken meat is well established ([Corbyn, 2020](#)).

4.2. Role of knowledge, heuristics, and personal characteristics

Regarding the acceptance drivers, our analysis shows that knowledge about technology characteristics plays an important role in cultured meat acceptance (e.g., [Mancini & Antonioli, 2020](#); [Van Loo et al., 2020](#)). The importance of consumers prior knowledge on technology characteristics has been acknowledged in the previous reviews ([Bryant & Barnett, 2020](#); [Gunes & Deniz Tekin, 2006](#); [Hocquette, 2016](#); [Lusk et al., 2014](#)). Nevertheless, as [Siegrist and Hartmann \(2020a\)](#) indicated, the acceptance of novel foods depends on the perceived aspects of technology and the consumers' characteristics.

Studies examining attitudes towards cultured meat indicate a generally poor knowledge about the technology among average consumers. However, providing information triggers mixed reactions (see for example [Valente et al., 2019](#)). While in some studies, supply of information induced a more supportive attitude towards this technology (e.g., [Mancini & Antonioli, 2019](#); [Siegrist et al., 2018](#)), in other studies, it raised more concerns (e.g., [Wilks et al., 2019](#)). [Siegrist et al. \(2018\)](#)

argued that providing information on the benefits of cultured meat has the paradoxical effect of higher acceptance of traditional meat. [Lusk et al. \(2014\)](#) state that providing objective information deeming food technology beneficial and harmless does not necessarily lead to a favourable attitude. Indeed, providing information does not provoke instant attitude change. Instead, how the information is perceived is more relevant and can stimulate greater cognitive impression ([House et al., 2004](#); [Jacoby, 1974](#)). According to the transtheoretical model of decision making, attitudinal shifts occur over time and unfold through a string of distinct phases ([Prochaska, Redding, & Evers, 2008](#); [Prochaska & Velicer, 1997](#)). By providing information, individuals employ cognitive, affective, and evaluative processes, which may lead them to progress through different cognitive states or even relapse to their earlier predisposition ([Tobler et al., 2011](#)).

Providing information on the convincing benefits vis-à-vis technology would rectify consumers' unfavourable predispositions, which may lead them to ignore incongruent information. Earlier literature has suggested that incongruity arises amongst individuals who are holding strong unfavourable prior knowledge after the provision of new (positive) information, which may lead consumers to adopt a reflective process ([Cohen, Pham, & Andrade, 2008](#); [Lynch & Srull, 1982](#); [Schwarz, 1990](#)). In such cases, consumers rely on the available heuristic (implicit association) and use this as a base for judgment and decision making ([Thaler & Sunstein, 2008](#)). When consumers are uncertain about novel food technology (such as cultured meat) and its environmental and human health implications, perception of risk will be augmented and lead to a sense of low control over potential risks ([Lerner & Keltner, 2000](#)), which in turn affects preferences ([Loewenstein, 1996](#); [Schwarz & Clore, 1983](#); [Zajonc, 1980](#)).

Consumers often use heuristics to evaluate the risks associated with food technologies due to a lack of knowledge or ambiguity about the cultured meat production processes (as credence attribute). [Siegrist and Hartmann \(2020a\)](#) reviewed the literature on consumer perceptions of novel food technologies and suggested that affection and heuristics affect the acceptance of food technologies.

Moreover, several personal characteristics, such as food technology neophobia and food disgust sensitivity, are relevant in shaping individuals' attitudes toward novel food technologies (e.g., Genetic modification ([Siegrist, 2008](#)), novel foods ([Onwezen et al., 2021](#); [Siegrist & Hartmann, 2020a](#); [Tuorila & Hartmann, 2020](#))).

The studies focused on consumer views suggest that those consumers who perceived cultured meat as unnatural also considered the associated risks as less acceptable ([Kaptan, Fischer, & Frewer, 2018](#)), and this is coupled with a feeling of disgust ([Siegrist et al., 2018](#); [Siegrist & Sütterlin, 2017](#)). Disgust feeling has accounted for consumers disfavor predisposition towards novel food ([Egolf et al., 2019](#)) and, in particular, for novel animal-based food ([Mancini, Moruzzo, Riccioli, & Paci, 2019](#); [Siegrist et al., 2018](#)). [Powell, Jones, and Considine \(2019\)](#) examined the role of the disgust factor propensity on consumers' willingness to pay for food. They found that the willingness to pay for novel food is mediated by the disgust (yuck) factor induced by cognitive appraisals of perceived taste, naturalness, and visual appeal. A Disgust heuristic can be provoked from the perception of cell culturing and the associated production process. The perception of disgust is deeply rooted in cultural and societal convictions and hinders the approval of novel foods, even if they are possibly beneficial ([Tybur, Çınar, Karinen, & Perone, 2018](#)).

A related cognitive disposition to disgust is the fear of new food technology (food neophobia), which is a barrier to adopting novel foods ([Tuorila et al., 2001](#)). Such findings are consistent with other research, which has pinpointed the factors of 'disgust', unnaturalness, and healthiness as significant in individuals' willingness to try novel foods

(Bäckström, Pirttilä-Backman, & Tuorila, 2003; Lea & Worsley, 2001; Martins & Pliner, 2006; Prescott, Young, O'neill, Yau, & Stevens, 2002; Ruby & Heine, 2012; Tobler et al., 2011).

Another important and related mental disposition identified in our review is the perception of naturalness (refer also to the systematic reviews by Bryant & Barnett, 2018; Román et al., 2017). It seems that naturalness is tied with the healthiness of novel food and affects the willingness to consume it (Gómez-Luciano et al., 2019). According to Bruhn (2007), direct consumer benefits related to health and food safety are the most crucial factor in accepting the technology, but this issue has not been addressed thoroughly. Advocates of cultured meat posit that it would benefit human health by reducing the slaughtering of livestock and hence cutting down food-borne illnesses, such as *E. coli*, and decreasing the spread of infectious diseases, such as swine flu, from animals to humans. However, critics contend that the process of cell culture can never be entirely controlled and that some unexpected biological mechanisms may occur, which might have unknown adverse consequences for human health (Chriki & Hocquette, 2020; Hocquette, 2016). It is also argued that uptake of micronutrients and other biological compounds in the process of cell culturing need to be better understood (Chriki & Hocquette, 2020).

4.3. Trivial effects of environmental and ethical concerns

Environmental risk concerns stimulate a desire to preserve the environment and encourage consumers to accept more sustainable food production systems. The environmental advantages of developing cultured meat often focus on greenhouse gases, land, and water preservation (Goodwin & Shoulders, 2013). Nevertheless, the environmental advantages alone do not seem to be a strong motivation to compensate for perceived risks (or disgust impulse) of cultured meat (Henchion et al., 2013; Tobler et al., 2011; Tucker, 2014; Van Loo et al., 2020; Verbeke, Marcu, et al., 2015). The discrepancy between environmental risk perception and pro-environmental behaviours has been raised in previous research (Lacroix & Gifford, 2018; Zeng, Jiang, & Yuan, 2020). Despite consumers being convinced about the ecological advantages of adopting reduced meat diets, they are less willing to consider changing consumption behaviour (De Boer, Schöler, & Boersema, 2013a; Tobler et al., 2011). Nevertheless, evidence suggests that environmental concerns would instead result in a willingness to include more ecological food (e.g. vegetables and fruits) and not necessarily a willingness to reduce meat consumption (Tobler et al., 2011).

Moreover, Kaptan et al. (2018) conducted an intensive literature review to analyse how hazard characteristics (i.e., technological or naturally occurring) affect consumer risk-benefit perceptions. They concluded that for some technologies (e.g., use of GM animals in food production), ethical concerns were a more important factor in shaping consumer behaviour than risk-benefit perception. Ethically, cultured meat has the advantage of fewer animal welfare issues compared to conventional meat. Still, it does not seem to be a strong motivation for inducing imminent diet change among individuals with high levels of meat consumption. Indeed, from an animal welfare standpoint, this would be more appealing for vegetarians and those who desire to reduce their meat consumption for ethical reasons (Hopkins & Dacey, 2008).

4.4. Future research

This study provides an extensive overview of consumer research literature related to cultured meat technology, which allows us to identify research gaps and suggest an agenda for future consumer research.

First, our understanding of consumer behaviour concerning different methods of cultured meat technology is still limited. Previous food studies have shown relative differences in the individual's perception of risk associated with various methods in producing a specific novel food (Delwaide et al., 2015; Frewer, Howard, & Aaron, 1998; Onyango, Govindasamy, Hallman, Jang, & Puduri, 2006; Onyango & Nayga, 2004). For instance, consumers are more receptive to plant-based GM food than animal-related applications (Burton, Rigby, Young, & James, 2001; Canavari & Nayga, 2009; Chen & Raffan, 1999; Finucane & Holup, 2005; Frewer et al., 2013; Frewer, Howard, & Shepherd, 1997; James & Burton, 2003; Onyango & Nayga, 2004), and intragenic versus transgenic gene modifications (e.g. Lusk & Sullivan, 2002; Myskja, 2006). As for cultured meat, although the principle of the cultured cell is the same, various production methods are being used (Post, 2014b). These methods include bio-engineering or bioreactors for tissue culture (by growing prokaryotic and eukaryotic cells), electrical stimulation (creating muscle structures by using an electric field), and mechanical stimulation (providing cellular mechanical stimuli by using complex mechanism) (Arshad et al., 2017; Hopkins & Dacey, 2008; Moritz, Verbruggen, & Post, 2015). Alternatively, cultured meat is based on a 'fermentation-based cellular' technology in which the organic tissue is produced using bacteria, algae or yeast that are typically modified using recombinant DNA (Stephens et al., 2018). However, current literature does not support consumers' preference or risk perception of these production methods.

Secondly, this review's convincing body of evidence demonstrates that the presence and development of a range of alternative novel protein sources can affect the acceptance of cultured meat technology (e.g., Slade, 2018). Nevertheless, the literature appears scarce on how and what type of alternatives would affect consumers' novel food choices (Knight et al., 2007; Malek et al., 2019; Powell et al., 2003; Sexton, 2018). Moreover, those extant research that included (or compared) other alternatives mostly focused on plant-based alternatives (e.g., Arora et al., 2020; Grasso et al., 2019; Slade, 2018; Van Loo et al., 2020) and other novel sources, such as insect, and single-cell based proteins, are overlooked (e.g., Circus & Robison, 2019; Dupont & Fiebelkorn, 2020). Our findings suggest that plant-based proteins are deemed more acceptable than cultured meat and insect-based alternatives, in line with the previous reviews (e.g., Hartmann & Siegrist, 2017; Onwezen et al., 2021). Recently, Onwezen et al. (2021) conducted a systematic review on consumer acceptance of alternative proteins (including pulses, algae, insects, plant-based meat alternatives, and cultured meat) and concluded that compared with meat, in general, acceptance of all the alternative proteins is relatively low. They also showed that plant-based and pulses have the highest approval level among protein alternatives, whereas insects and cultured meat have the lowest acceptance rates. More research is still needed to corroborate these findings, especially considering the effect of different protein sources and technologies.

Another important avenue for consumer research will be open when cultured meat is available in mainstream retail channels. So far, research has been based on hypothetical consumption situations. However, recent news from the popular press suggests that this product is already available in Singapore (Lucas, 2020). Major food companies are also investing in new product development and acquisition. The actual availability of this product (as a prototype or on the market) will allow performing real-choice studies and obtaining more reliable insights on consumer acceptance and value perception.

4.5. Limitations

This study consists of a systematic literature review based on three

major databases (Web of Science, Science Direct and Scopus) covering the period 2008–2020. In our search, we did not consider other literature sources, such as FSTA – Food Science and Technology Abstracts, CAB Abstracts, Google Scholar, AgEconSearch and other numerous catalogues of grey literature, technical magazines and non-peer-reviewed papers that could be useful to provide a comprehensive picture of such a recent topic. However, it can be stated that the literature databases we used are the ones that include the highest quality, peer-reviewed articles, and this choice allowed us to focus on the content rather than on the scientific soundness of the studies analysed. Two recent reviews based on a Google Scholar search and authored by Bryant and Barnett (2018, 2020) can complement this study.

5. Conclusions

Global meat production increased by 1% in 2018, while overall production in the EU remained stable. The meat outlook may be affected by uncertainties linked to expected price declines, future trade agreements (e.g. Brexit), restricted policies related to animal disease outbreaks and environmental impacts combined with consumer preferences (OECD, 2019).

Many previous studies have highlighted a shift in the direction of lower meat consumption, [or plant-based diets] due to animal welfare concerns or reduced environmental and health risks (Audsley et al., 2010; MacMillan & Middleton, 2010). Nevertheless, consumers would consider a slight cut in meat intake to be potentially tolerable but are reluctant to support an intensive reduction, with concerns about retaining a varied diet (Bows et al., 2012). Among meat substitutes, cultured meat is well-positioned to fulfil this need, even with serious

technical hurdles to overcome, including the reprocessing of culture media and costly production systems (Alexander et al., 2017; Weinrich et al., 2020). The main barrier to developing this technology is consumer acceptance (Laestadius, 2015; Onwezen et al., 2021; Verbeke, Marcu, et al., 2015). Our review indicated eight major interconnected themes across peer-reviewed papers as determinants of consumer acceptance of cultured meat. These factors include awareness, risk-benefit perception, ethical and environmental concerns, emotions, personal factors, product properties, and availability of other substitutes. The role of knowledge, perceptions and personal traits seems to be more salient than environmental and ethical concerns alone. The extent that cultured meat is perceived as unhealthy food (Dupont & Fiebelkorn, 2020; Hocquette et al., 2015b; Siegrist et al., 2018; Tucker, 2014), unnatural (Bryant & Barnett, 2019; Laestadius, 2015; Laestadius & Caldwell, 2015; Siegrist et al., 2018; Tucker, 2014; Wilks & Phillips, 2017), not “real” meat (Bekker, Fischer, et al., 2017), or disgusting (Siegrist & Hartmann, 2020b), increases consumers reluctance towards this technology.

Currently, cell culture technology needs resource efficiency in energy and water usage (Moritz et al., 2015). Additionally, further investment is required to scale up its manufacturing and lower the price, especially in comparison with plant-based alternatives (Mattick & Allenby, 2012). Once scaled up, the impact of the cultured meat industry on the livestock farming system needs to be taken into account, in addition to GHG emissions, carbon storage, and biodiversity effects (Dumont, Jouven, Bonaudo, Botreau, & Sabatier, 2017; Onwezen et al., 2021; Ryschawy et al., 2019; van der Weele, Feindt, van der Goot, van Mierlo, & van Boekel, 2019). Siegrist et al. (2018) suggested that future consumer research should focus on understanding the healthiness, safety, naturalness, and sustainability characteristics of cultured meat.

Appendix I

Table A1

A list of the reviewed literature and a summary of the findings

Author (year)	Paper title	Method (Stimuli)	Country (Sample size)	Main finding
Arora et al. (2020)	Is India ready for alt-meat? Preferences and willingness to pay for meat alternatives	Survey	India (394)	Respondents were more willing to pay for plant-based meat than cultured meat.
Asioli et al. (2018) [#]	Consumers' valuation for lab-produced meat: an investigation of naming effects	Experimental (in-vitro chicken)	US (625)	Willingness to pay valuation showed that the term 'cultured' was perceived less negatively than other terms like 'artificial' and 'lab-grown'.
Bekker, Fischer, Tobi, and van Trijp (2017)	Explicit and implicit attitude toward an emerging food technology: The case of cultured meat	Experimental	Netherlands (576)	Positive information about sustainability affects explicit attitude (cognitive) towards cultured meat.
Bekker, Tobi, and Fischer (2017)	Meet meat: An explorative study on meat and cultured meat as seen by Chinese, Ethiopians, and Dutch	Interview	China, Ethiopia, and the Netherlands (30)	Participants perceived cultured meat as having some of the characteristics of meat. However, it was considered to be fake meat.
Bryant and Barnett (2019)	What's in a name? Consumer perceptions of in vitro meat under different names	Experimental	United States (185)	'Clean meat' provoked positive behavioural intentions in comparison with the 'lab grown meat' condition.
Bryant and Dillard (2019)	The impact of framing on acceptance of cultured meat	Experimental	United States (480)	High tech framing causes negative attitudes toward cultured meat.
Bryant, Szejda, et al. (2019) [#]	A survey of consumer perceptions of plant-based and clean meat in the USA, India, and China	Online questionnaire	China, India, and the US (total sample = 3030 of which 987 US, 1024 India, and 1019 China)	Results showed significantly higher acceptance of meat substitutes, including cultured meat in India and China, compared to the USA.
Bryant, Anderson, et al. (2019)	Strategies for overcoming aversion to unnaturalness: The case of clean meat	Experimental	United States (1185)	The unnaturalness of cultured meat had the greatest impact on its acceptance.
Bryant et al. (2020)	European markets for cultured meat: A comparison of Germany and France	Survey	Germany and France (2000)	Acceptance of cultured meat is higher among farmers and those who are closest to meat production.
Bogueva and Marinova (2020) [#]	Cultured Meat and Australia's Generation Z	Survey	Australia (n = 227)	Despite general agreement with technological advancements for a more sustainable food system, most (72%) participants rejected the concept of cultured meat.
Circus and Robison (2019)	Exploring perceptions of sustainable proteins and meat attachment	Survey	UK (139)	

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Table A1 (continued)

Author (year)	Paper title	Method (Stimuli)	Country (Sample size)	Main finding
Dupont and Fiebelkorn (2020)	Attitudes and acceptance of young people toward the consumption of insects and cultured meat in Germany	Survey (cultured meat burger and insect burger)	Germany (718)	Plant-based alternatives were favoured most in comparison with cultured meat due to ethical reasons.
Egolf et al. (2019)	When evolution works against the future: disgust's contributions to the acceptance of new food technologies	Survey	Switzerland (330)	They found that children and adolescents' attitudes toward cultured meat burgers were significantly higher than insects burgers. Respondents with higher levels of food disgust perceive fewer benefits and have less acceptance of new foods (including cultured meat and).
Gasteratos and Sherman (2018) [#]	Consumer Interest Towards Cell-based Meat	Pre and post-test experiment (ex-vivo cultivated meat)	US and Australia (5,071)	Provision of potential benefits of cultured meat increased willingness to pay.
Gere et al. (2020)	Creating a Mind Genomics Wiki for Non-Meat Analogues	Experimental	USA (100)	Results of experiments suggest that gender or age will not reveal the dramatically different mindsets regarding cultured meat.
Gómez-Luciano et al. (2019)	Consumers' willingness to purchase three alternatives to meat proteins in the United Kingdom, Spain, Brazil, and the Dominican Republic	Survey (plant-, cultured meat- and insect-based proteins)	United Kingdom, Spain, Brazil, and the Dominican Republic (729)	The sensory characteristics are more important factors affecting attitude towards cultured meat than environmental attributes.
Grasso et al. (2019)	Older consumers' readiness to accept the alternative, more sustainable protein sources in the European Union	Survey (protein alternatives including cultured meat)	The United Kingdom, the Netherlands, Poland, Spain, and Finland (1825)	Cultured meat was the least accepted protein alternative compared to dairy-based, seafood, plant-based, single-cell, and insect-based protein.
Hallman and Hallman (2020)	An empirical assessment of common or usual names to label cell-based seafood products	Experiment	USA (3,186)	'Cell-based seafood' was chosen as the best name by consumers to differentiate fish meat alternative products.
Heidemann et al. (2020)	Critical perspective of animal production specialists on cell-based meat in Brazil: from bottleneck to best scenarios	Survey	Brazil (272)	Lack of knowledge led to the resistance of veterinarians and animal scientists to accepting cell-based meat.
Hocquette et al. (2015) [#]	Educated consumers do not believe artificial meat is the solution to the problems with the meat industry	Two surveys and one interview of scientists	International (817), French survey (865), and interview (208)	Although most participants believed that cultured meat was feasible to produce, only a minority of respondents considered it healthy or tasty.
Hwang et al. (2020)	Factors affecting consumers' alternative meats buying intentions: plant-based meat alternative and cultured meat	Survey	Korea (two separate sections of cultured meat n = 513 and plant-based meat n = 504)	Consumers willing to buy cultured meat and plant-based meat varied according to the concepts of ambivalence.
Laestadius and Caldwell (2015) [#]	Is the future of meat palatable? Perceptions of in vitro meat as evidenced by online news comments.	Qualitative content analysis	Across seven US-based online news sources	An analysis of the comments on online news articles revealed that concerns over naturalness and risks appear to be a substantial barrier to public acceptance of this technology.
Van Loo et al. (2020) [#]	Consumer preferences for farm-raised meat, lab-grown meat, and plant-based meat alternatives: Does information or brand matter?	Experiment (lab-grown, plant-based with pea protein, and plant-based with animal-like protein)	U.S. (1800)	Farm-raised beef was the preferred choice even with a significant reduction (e.g., 50%) of price for plant-based and lab-grown alternatives.
Lupton and Turner (2018)	Food of the Future? Consumer Responses to the Idea of 3D-Printed Meat and Insect-Based Foods	Experimental	Australia (30)	Using 3D printing technologies to render ingredients such as cultured meat and insects more acceptable and appealing to consumers.
Mancini and Antonioli (2019)	Exploring consumers' attitude towards cultured meat in Italy	Survey	Italy (525)	Young, educated consumers who are willing to decrease meat consumption were more likely to consume cultured meat.
Mancini and Antonioli (2020)	To What Extent Are Consumers' Perception and Acceptance of Alternative Meat Production Systems Affected by Information? The Case of Cultured Meat	Survey	Italy (525)	This study showed that positive information affected the perception of cultured meat's safety and nutritional properties and, accordingly, affected consumers' willingness to purchase.
Rolland et al. (2020)	The effect of information content on acceptance of cultured meat in a tasting context	Survey	Netherlands (193)	Level of information affected the acceptance of unfamiliar food like cultured meat and even willingness to pay a price premium.
Ruzgys and Pickering (2020)	Perceptions of cultured meat among youth and messaging strategies	Survey	Canada (214)	Young consumers considered taste to be the most important factor in cultured meat acceptance.
Elaine (2019)	A comparative analysis of the attitudes of rural and urban consumers towards cultured meat	Survey	Ireland (312)	The safety of the technology was found to be the biggest concern for both urban and rural consumers
Siegrist and Hartmann (2020b)	Perceived naturalness, disgust, trust and food neophobia as predictors of cultured meat acceptance in ten countries	Survey	Australia, China, England, France, Germany, Mexico, South Africa, Spain, Sweden, and the US (6128)	Cross-cultural differences and perceived naturalness were important factors affecting consumer acceptance of cultured meat.
Siegrist and Sütterlin (2017)	Importance of perceived naturalness for acceptance of food additives and cultured meat	Experimental	Switzerland (497)	Symbolic information leads to biased judgments and influences on consumers when evaluating foods.
Siegrist et al. (2018)		Experimental	Switzerland (363)	

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Table A1 (continued)

Author (year)	Paper title	Method (Stimuli)	Country (Sample size)	Main finding
Slade (2018)	Perceived naturalness and evoked disgust influence acceptance of cultured meat If you build it, will they eat it? Consumer preferences for plant-based and cultured meat burgers	Hypothetical choice experiment (stimuli: a burger made from beef, plant-based protein, or cultured meat)	Canada (533)	Perceived unnaturalness was the main reason for consumer aversion towards cultured meat. A hypothetical choice experiment revealed higher preferences for plant-based burgers than cultured meat. Only 11% of the respondents would buy cultured meat burgers compared to beef burgers assuming the same taste and price.
Tucker (2014)	The significance of sensory appeal for reduced meat consumption	Focus group	New Zealand (69)	55% of interviewees opposed cultured meat, 32.5% were favourable, whereas the rest (12.5%) showed mixed feelings.
Valente et al. (2019)	First glimpse on attitudes of highly educated consumers towards cell-based meat and related issues in Brazil	Online-survey	Brazil (626)	Consumers were willing to eat cultured meat, but they considered it mostly an additional option to their conventional meat diets.
Verbeke, Marcu, et al. (2015)	Would you eat cultured meat?: Consumers' reactions and attitude formation in Belgium, Portugal and the United Kingdom	Focus groups	Belgium, Portugal and the United Kingdom (179)	Consumers envisaged few direct personal benefits of cultured meat but expressed disgust, unnaturalness, and uncertainty over its safety and health.
Verbeke, Sans, and Van Loo (2015)	Challenges and prospects for consumer acceptance of cultured meat	Survey	Belgium (180)	The provision of information increases the likelihood of willingness to try cultured meat.
Vinnari and Tapio (2009)	Future images of meat consumption in 2030	Delphi survey (laboratory-grown meat)	Finland (215)	The analysis showed that both experts and consumers considered cultured meat to be a preferable future food choice.
Weinrich et al. (2020)	Consumer acceptance of cultured meat in Germany	Online survey	Germany (713)	Ethics (e.g., animal welfare, ecological) and emotional objections (e.g., unnatural) were the strongest drivers affecting attitude towards cultured meat.
Wilks and Phillips (2017)	Attitudes to in vitro meat: A survey of potential consumers in the United States	Survey	United States (673)	While most respondents were willing to try cultured meat, only around 30% were certainly or probably willing to eat it regularly.
Wilks et al. (2019)	Testing potential psychological predictors of attitudes towards cultured meat	Survey	United States (1193)	The most robust factors predicting individuals' willingness to try cultured meat were food neophobia followed by political conservatism and distrust of food scientists.
Wilks et al. (2020) [#]	What does it mean to say that cultured meat is unnatural?	Survey	USA (n = 904)	Results showed that the perception of unnaturalness flowed from affective factors such as disgust and fear rather than information processing and a rational decision-making process.
Zhang et al. (2020)	Consumer acceptance of cultured meat in urban areas of three cities in China	Survey	China (1004)	Information provision was found to be an effective factor in improving consumer attitudes towards cultured meat.

[#] Note: Eight articles incorporated in Table A1 are added manually and include Asioli et al. (2018); Bryant, Szejda, et al. (2019); Bogueva and Marinova (2020); Gasteratos and Sherman (2018); Hocquette et al. (2015); Laestadius and Caldwell (2015); Van Loo et al. (2020); Wilks et al. (2020).

Table A2
Factors affecting consumer acceptance of cultured meat derived from the literature review.

Papers	Sub-studies	Sample size	Public awareness & knowledge	Risk-benefit perceptions	Ethical and environmental concerns	Emotions	Personal factors	Product properties	Alternatives & availability
Asioli et al. (2018)		625	**				**	**	
Arora et al. (2020)		394			*		**		**
Bekker, Fischer, et al. (2017)	Experiment 1	190	**						
	Experiment 2	194	**						
	Experiment 3	192	**						
Bekker, Tobi, and Fischer (2017)		30		**	**			*	
Bryant and Barnett (2019)		185	**	*	*	*		*	
Bryant and Dillard (2019)		480		*	*		**	*	
Bryant, Szejda, et al. (2019)		3030	**		**	**	**	**	**
Bryant, Anderson, et al. (2019)		1185	**	*	**				*
Bryant et al. (2020)		2000			**		**		
Bogueva and Marinova (2020)		227	**	**	**	**	**	**	**

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Table A2 (continued)

Papers	Sub-studies	Sample size	Public awareness & knowledge	Risk-benefit perceptions	Ethical and environmental concerns	Emotions	Personal factors	Product properties	Alternatives & availability
Circus and Robison (2019)		139	**		**				*
Dupont and Fiebelkorn (2020)		718	**	*	**	**	**		*
Egolf et al. (2019)		330		**		**			
Gasteratos and Sherman (2018)		5071	**		**				
Gere et al. (2020)		100			**		**	**	**
Gómez-Luciano et al. (2019)		729	*	*	**	**		**	**
Grasso et al. (2019)		1825	*		**	**	**	**	*
Hallman and Hallman (2020)		3186			**				
Heidemann et al. (2020)		272	**		*		**		
Hocquette et al. (2015)		1890	**		**		**	**	
Hwang et al. (2020)		513	**		**	**	**		**
Laestadius and Caldwell (2015) ¹		462		**	**			**	
Van Loo et al. (2020)		1800	**	**	**		**	**	**
Lupton and Turner (2018)		30	**	**	**	**		**	**
Mancini and Antonioli (2019)		525	**		**		**	**	
Mancini and Antonioli (2020)		525	**	**	**		*	**	
Rolland et al. (2020)		193	**	**			*	**	
Ruzgys and Pickering (2020)		214		**	**	**	**	**	
Shaw and Iomaire (2019)		312			**	**	**		
Siegrist and Sütterlin (2017)	Experiment 1	Not relevant							
	Experiment 2	244		**					
	Experiment 3	253		**	**				
Siegrist and Hartmann (2020b)		6128			**	**			
Siegrist et al. (2018)	Experiment 1	204			**				
	Experiment 2	159			**	**			
Slade (2018)		533	**		*		**	**	**
Tucker (2014)		69			**	**	**	**	*
Valente et al. (2019)		626		**	**		*	*	
Verbeke, Marcu, et al. (2015)		179	**	**	**	**		**	
Verbeke, Sans, and Van Loo (2015)		180	**	**	**			**	
Vinnari and Tapio (2009)		215	**		**				
Weinrich et al. (2020)		713	*	**	**		*		
Wilks and Phillips (2017)		673		**	**		**	**	
Wilks et al. (2019)		1193		**	**	**	**		
Wilks et al. (2020)		904	**		**	**	**		
Zhang et al. (2020)		1004	**				**		
Total sample size		40,843	23,786	11,169	37,871	16,745	21,358	15,100	11,292
Average sample size²		939	850	487	959	985	821	636	807
Frequency of factors examined			28	22	39	17	26	23	14
Frequency of factors found to be significant			25	17	34	16	22	18	9

* Factors examined in the retrieved studies, ** Factors found to be significant.

¹ The research by Laestadius and Caldwell (2015) conducted a qualitative content analysis of the comments made on online news articles (across seven US-based online news sources), highlighting the development of cultured meat technology. A total of 814 unique comments from 462 commenters were included for analysis. However, the sample size and significant results are not included since the method was not comparable with other included studies.

² The average sample size is derived from the total sample size (of studied examined factors) divided by the frequency of factors examined.

Table A3

Summary of consumers' willingness to try, purchase, and pay for cultured meat across retrieved articles.

Papers	Title	Country (sample size of respondents)	Overall support for cultured meat	Overall disfavour results
Bryant et al. (2020)	European Markets for Cultured Meat: A Comparison of Germany and France	Germany and France (2000)	On average, 51.25% of respondents were willing to try, and 45.01% willing to buy cultured meat.	39.8% of them were willing to try, and 41.65% were unwilling to buy cultured meat.
Bryant and Dillard (2019)	The Impact of framing on acceptance of cultured meat	United States (480)	64.6% were willing to try, 48.5% were willing to eat, 49.1% were willing to buy.	18.4% were unwilling to try, 26.6% were unwilling to eat, and 24.5% were unwilling to buy.
Bryant, Szejda, et al. (2019)	A survey of consumer perceptions of plant-based and clean meat in the USA, India, and China	China, India, and the U.S. (total sample size was 3,030, of which 987 in the USA, 1024 in India, and 1019 in China)	29.8% of USA respondents were very likely to purchase cultured meat, while 59% of Chinese and 56% of Indian consumers stated they were very likely to try it.	23.6% of US respondents were unwilling to purchase, while 6.7% in China and 10.7% in India were unwilling to purchase.
Bryant, Anderson, et al. (2019)	Strategies for overcoming aversion to unnaturalness: The case of clean meat	United States (1185)	66.4% of participants were 'probably or definitely' willing to try clean meat, but only 48.9% were willing to buy it.	12.1% were 'probably or definitely' not willing to try it.
Bogueva and Marinova (2020)	Cultured Meat and Australia's Generation Z	Australia (227)	19% accepted cultured meat as a food option.	72% believe that cultured meat is not acceptable as a food option (9% being hesitant).
Circus and Robison (2019)	Exploring perceptions of sustainable proteins and meat attachment	UK (139)	Overall, 41% would eat cultured meat personally.	Overall, 59% would not eat personally.
Dupont and Fiebelkorn (2020)	Attitudes and acceptance of young people toward the consumption of insects and cultured meat in Germany	Germany (718)	56.4% of the respondents were willing to consume the cultured meat burger.	NA
Gasteratos and Sherman (2018)	Consumer Interest Towards Cell-based Meat	US and Australia (5,071)	63.3% of participants were 'probably or definitely' willing to consume clean meat.	17% of participants were 'probably or definitely' not willing to consume clean meat. (and 19.7% of participants were unsure).
Gómez-Luciano et al. (2019)	Consumers' willingness to purchase three alternatives to meat proteins in the United Kingdom, Spain, Brazil and the Dominican Republic	United Kingdom, Spain, Brazil, and the Dominican Republic (729)	The willingness to purchase was 11.5% in Brazil, 15% in the Dominican Republic, 19% in the UK and 42% in Spain for cultured meat-based proteins.	NA
Grasso et al. (2019)	Older consumers' readiness to accept the alternative, more sustainable protein sources in the European Union	The United Kingdom, the Netherlands, Poland, Spain, and Finland (1825)	Only 6% of the respondents found it acceptable to consume cultured meat.	59% of respondents stated that consuming cultured meat was unacceptable. About 24% of respondents were indifferent about consuming cultured meat (in addition, 11% stated "I don't know").
Mancini and Antonioli (2019)	Exploring consumers' attitude towards cultured meat in Italy	Italy (525)	More than half of the respondents (54%) stated that they would be willing to try cultured meat, 44.2% were willing to buy it, and 23.2% were willing to pay a premium (10–30%) over conventional meat)	21% were sure that they did not want to try it, and 24% were unsure. 21% were unwilling to try, 8.2% were unwilling to buy, and 26.7% were unwilling to pay.
Rolland et al. (2020)	The effect of information content on acceptance of cultured meat in a tasting context	Netherlands (193)	58% of participants were willing to pay a premium price (37% above the price of regular meat).	NA
Shaw and Iomaire (2019)	A comparative analysis of the attitudes of rural and urban consumers towards cultured meat	Ireland (312)	Urban consumers were more willing to try cultured meat, with 62% stating they would try it compared to 46% of rural consumers.	NA
Slade (2018)	If you build it, will they eat it? Consumer preferences for plant-based and cultured meat burgers	Canada (533)	Assuming an equal price, 11% of respondents were willing to purchase the cultured meat burger.	NA
Verbeke, Sans, and Van Loo (2015)	Challenges and prospects for consumer acceptance of cultured meat	Belgium (180)	36% of consumers were willing to purchase, and 35.8% were even willing to pay more for cultured meat. After providing additional information on the benefits, willingness to try cultured meat increased slightly to 42.5%.	About 58% were unsure of their willingness to try cultured meat, while about 6% were unwilling to try it. Even after providing information, 6% were still unwilling to try it (and 51% were unsure).
Weinrich et al. (2020)	Consumer acceptance of cultured meat in Germany	Germany (713)	57% of respondents were willing to try cultured meat, and 30% were willing to eat cultured meat regularly.	NA
Wilks and Phillips (2017)	Attitudes to in vitro meat: A survey of potential consumers in the United States	United States (673)	Overall, 67% of respondents were 'definitely or probably' willing to try cultured meat, and 36.3% were willing to consume it regularly.	21% of respondents stated they were 'definitely or probably' not willing to try cultured meat (and 12% were unsure). In contrast, 29.3% of consumers were

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Table A3 (continued)

Papers	Title	Country (sample size of respondents)	Overall support for cultured meat	Overall disfavour results
Zhang et al. (2020)	Consumer acceptance of cultured meat in urban areas of three cities in China	China (1,004)	More than 70% were willing to taste or purchase cultured meat after reading the given information. An estimated willingness to pay 2.2% more than the price of conventional meat	'definitely or probably' unwilling to eat cultured meat (and 34.4% were unsure). NA

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