Cell-based Meat: Hype or Industry Disruptor?

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Abstract

Churchill (1931) said, “we shall escape the absurdity of growing a whole chicken in order to eat the breast or wing by growing these parts separately under a suitable medium” (para. 12). Global demand for protein is colliding with sustainability imperatives, making meat produced *in vitro* an emerging reality. This work investigates cell-based meat (CBM), grown from stem cells within nutrient-rich media, as a food solution and potential disruptor of the conventional meat industry.

A mixed methods approach employed quantitative and qualitative approaches with a consumer survey, expert interviews, and review of the literature. Consumers demonstrated considerable acceptance towards CBM perceiving it as safe, healthy, and natural. However, misgivings persisted about the technology. Prior familiarity and emotional engagement with CBM emerged as determinants of acceptance. Consumers also exhibited strong willingness to pay a premium for CBM. Experts noted various hurdles faced by CBM, *inter alia* its technological immaturity, lack of mainstream acceptance, and ambiguous regulatory environments.

Overall, CBM’s potential to emerge as a short or mid-term disruptor in the meat industry appeared improbable. Instead, we predicted that CBM will remain a niche product in the foreseeable future.

Keywords: Cell-based meat, cultivated meat, cultured meat, alternative proteins, food technology, consumer acceptance, investments, disruption, scenarios

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Sumário

Churchill (1931) disse: "escaparemos ao absurdo de cultivar um frango inteiro para comer o peito ou a asa, cultivando estas partes separadamente num meio adequado" (para. 12). A procura global de proteínas está a colidir com imperativos de sustentabilidade, tornando a carne produzida in vitro uma realidade emergente. Este trabalho investiga a carne baseada em células (CBM), cultivada a partir de células estaminais em meios ricos em nutrientes, como uma solução alimentar e um potencial disruptor da indústria da carne convencional.

Uma abordagem de métodos mistos utilizou abordagens quantitativas e qualitativas com um inquérito aos consumidores, entrevistas a peritos e revisão da literatura. Os consumidores demonstraram uma aceitação considerável em relação à CBM, considerando-a segura, saudável e natural. No entanto, persistiram dúvidas sobre a tecnologia. A familiaridade prévia e o envolvimento emocional com o CBM surgiram como factores determinantes da aceitação. Os consumidores mostraram também uma forte vontade de pagar um prémio pela CBM. Os peritos assinalaram vários obstáculos enfrentados pela CBM, nomeadamente a sua imaturidade tecnológica, a falta de aceitação generalizada e ambientes regulamentares ambíguos.

De um modo geral, o potencial da CBM para emergir como um factor de perturbação a curto ou médio prazo na indústria da carne parecia improvável. Em vez disso, previmos que o CBM continuará a ser um produto de nicho num futuro previsível.

Palavras-chave: Carne baseada em células, carne cultivada, carne cultivada, proteínas alternativas, tecnologia alimentar, aceitação do consumidor, investimentos, disrupção, cenários

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AP	Alternative protein
B2B	Business-to-business
CAGR	Compound annual growth rate
CBM	Cell-based meat
CVC	Corporate venture capital
DCF	Discounted cash flow
DI	Disruptive innovation
EI	Efficiency innovation
EPU	Economic policy uncertainty
ESG	Environmental, Social, and Governance
EU	European Union
FMCG	Fast-moving Consumer Goods
GDP	Gross domestic product
GHG	Greenhouse gas(es)
MBM	Microorganism-based meat
OECD	Organisation for Economic Cooperation and Development
PBM	Plant-based meat
PEOU	Perceived ease of use
PU	Perceived usefulness
R&D	Research and development
ROI	Return on investment
SI	Sustaining innovation
TAM	Technology Acceptance Model
UNSDG(s)	United Nations Sustainable Development Goal(s)
VC	Venture capital
WTP	Willingness to pay

Chapter 1: Introduction

Rising populations and disposable incomes along with changes in dietary preferences are driving the global demand for meat. The UN projects the global population to reach 8.5 billion by 2030, 9.7 billion in 2050, and by 2080 to surpass 10 billion (UN, 2022, p. 3). |Contributing factors include declining mortality, increased life expectancy, and higher fertility worldwide. Emerging economies, such as Sub-Saharan Africa, Middle East, and North Africa, and Asia are centers of population growth. Rising GDP per capita correlates with increased meat consumption, particularly in emerging economies (OECD-FAO, 2022). Dietary preferences are also shifting and, beyond a certain income threshold, higher-value foods such as animal proteins are favored (OECD-FAO, 2022). However, GDP per capita above $40,000 does not necessarily lead to increased meat consumption (Whitton et al., 2021) as it tends to follow an inverted U-shaped curve – consumption increases with rising income but eventually reaches an inflection point when it plateaus or declines (Rubio, Xiang & Kaplan, 2020).

Nevertheless, consumption of poultry, pig, beef, and lamb is projected to increase by 15% by 2031 (OECD-FAO, 2022) with the meat industry growing at a 7.47% CAGR from $897.5 billion in 2021 to over $1.3 trillion by 2027 (Statista, 2023). After COVID-19 and African Swine Flu, meat prices surged from $7.53 in 2019 to $8.70 in 2023. The Russia-Ukraine war is continuing the trend, with unit prices set to reach $9.83 in 2027 (Statista, 2023). The largest meat markets are the US, China, Japan, Germany, and France; major meat producers are the US, Brazil, China, Russia, and Germany (Statista, 2023).

Livestock account for approximately 14.5% of greenhouse gas emissions (Grossi et al., 2019), with methane and nitrous oxide 28 and 256 times higher, respectively, worse than carbon dioxide[1]. Greenhouse gases related to meat production thus make the industry a major source of climate change (Grossi et al., 2019). Additionally, livestock and animal feed have detrimental effects on the global water footprint, water pollution, and water scarcity (González et al., 2020). Gerbens et al. (2013) estimate that "agriculture accounts for 92% of the global freshwater footprint; [whereas] 29% of the water used in agriculture is directly or indirectly related to animal production" (p. 26). The sector is further one of the leading causes of biodiversity loss, through land expansion for pastures and habitat destruction for cropland (Parlasca & Qaim,

[1] The carbon dioxide equivalent is a standard unit used to account for the global warming potential.

2022). Bonnet et al. (2020) assert that 35% of cropland is devoted to animal feed – in Europe, the share is even higher. Among other factors, habitat modification, deforestation, bushmeat hunting, and excessive fertilization also contribute to the "loss of species, often with devastating ripple effects on biodiversity and ecosystems functioning" (Parlasca & Qaim, 2022, p. 26).

Billions of animals are killed or suffer because of human food systems (Parlasca & Qaim, 2022). The OECD-UN FAO (2022) estimated that animals slaughtered for human consumption exceeded 70 billion in 2021. In addition, meat consumption – especially within highly developed countries – has been associated with increased risks of heart disease, cancer, type 2 diabetes, and obesity (Rubio, Xiang & Kaplan, 2021). However, despite these negative externalities, a decrease in meat demand is not evident nor expected (Whitton et al., 2021).

Meanwhile, alternative proteins – plant, insect, algae, and cell-based meat substitutes – are gaining traction. A Boston Consulting Group and Blue Horizon Corporation study found that alt-protein will reach $290 billion by 2035 (Boston Consulting Group, 2021). The market for alt-proteins will grow from the current 13 million metric tons a year to 97 metric tons by 2035 when it will constitute approximately 11% of the overall protein market. In this scenario, Europe and North America are expected to attain "peak meat" by 2025, and subsequently, animal protein consumption will begin to decrease (Witte et al., 2021). However, this forecast is premised on alt-proteins reaching parity with animal proteins in taste, texture, and price. While plant-based meats (PBM) currently lead within alt-proteins, microorganism-based meats (MBM) and animal cell-based meats (CBM) have also come to the fore, with CBM attracting substantial attention.

Cell-based meat alternatives, also known as cultured or artificial meat, are produced by taking a small sample of animal cells and growing them in a controlled environment. Among other alt-proteins, CBM has the potential to replicate the taste, texture, smell, nutritional composition, and appearance of conventional meat. The Good Food Institute project estimates that annual sales of CBM will exceed $25 billion by 2030 (Cohen et al., 2022). Consumer acceptance is key. Although environmental, ethical, and health concerns are strong acceptance drivers, the CBM sector must push to improve taste, texture, and price if CBM is to become a viable alternative. This requires substantial upfront capex (Cohen et al., 2022).

The CBM sector, presently comprising roughly 100 start-ups, has only attracted approximately $1.93 billion since 2016 (Cohen et al., 2022), despite an unprecedented venture capital boom in recent years (Nolting, Višić & Singh, 2021). Given the economic potential and environmental advantages, is cultivated meat a serious contender to disrupt the global meat industry? With all the ESG tailwinds and economic potential, why is this sector not more liberally funded, particularly during a period where start-ups were flush with VC capital? This paper attempts to shed light on CBM as a disruptive force investigating the following research question:

RQ: Can CBM become a disruptor in the meat industry?

Forecasting disruption is challenging (Schuelke-Leech, 2018; Klenner, Hüsig, & Dowling, 2013). For over two decades researchers have discussed how a firm's internal factors influence disruptive innovation. Factors identified that determine a technology's disruptive potential notably are: (a) industry dynamics, (b) incumbent behavior, (c) the pace of technology maturation and diffusion driven by consumer acceptance, and (d) investments. Antonio and Kanbach (2023) suggest that the first two categories define an industry's susceptibility to disruption, while the last determine emergence and diffusion of disruptions. Our focus here is on the last two categories.

Chapter 2: Literature review

The following chapters review the literature on key concepts and innovation as well as the alt-protein and CBM sectors.

2.1 Key concepts of innovation

Schumpeter (1970) introduced the notion of "creative destruction" described as "the process of industrial mutation […] that incessantly revolutionizes the economic structure from within, incessantly destroying the old one, incessantly creating the new one'' (p. 83). This is framed as an essential fact about competitive capitalism, a dynamic system where innovations continuously disrupt the status quo.

Rogers (1983) defines *innovation* broadly as "an idea, practice, or object that is perceived as new by an individual or other unit of adoption" (p. 135). Various elaborations of drivers of innovation, as well as their diffusion and acceptance, have emerged speaking to Schumpeter's (1970) creative destruction concept. Disruptive, sustaining, and efficiency innovation, coined by Christensen, are an example, as well as demand-pull and technology-push, the diffusion of innovation, and the technology acceptance model, all of which have gained traction in management discourse (Christensen, 1997; Christensen & Van Bever, 2014; Von Hippel, 1976; Rogers, 1983; Davies, 1989).

2.1.1 Disruptive, sustaining, and efficiency innovation and the DCF trap

The term "disruptive innovation" first appeared in the Harvard Business Review, coined by Clayton Christensen (1995) based on examining disk drive evolution. He elaborated upon the concept in *The Innovator's Dilemma* (1997), and Christensen, Raynor, and McDonald (2015) framed disruption as a process whereby a smaller company with fewer resources can successfully challenge incumbents. Incumbents tending to focus on improving existing products and services for their most demanding and usually most profitable customers concentrate on sustaining innovation (SI). As a result, they exceed the needs of particular market segments while ignoring others (Christensen, Raynor & McDonald, 2015). This tendency to overshoot performance requirements of existing customers, and ignore untapped areas, exposes incumbents to being displaced by disruptors. The latter acquires low-end footholds by providing less-demanding consumers with "good enough" products and creates

new markets by turning non-customers into customers (Christensen, Raynor & McDonald, 2015).

Christensen (1997) claimed that "the reason [incumbents fail] is that good management itself was the root cause" (p.86), skewing strategy and resource allocations away from disruptive innovation. Instead, sustaining and efficiency innovation are favored, with the latter focusing on lowering costs. This constitutes the innovator's dilemma that plagues all incumbent firms (Christensen & van Bever, 2014).

Incumbents also fall victim to the discounted cash flow trap – the tendency to overvalue short-term financial metrics and undervalue longer-term strategies (Christensen, Kaufman, & Shih, 2013). The innovator's dilemma and the DCF trap yield the "capitalist's dilemma", which Christensen and van Bever (2014) describe as "doing the right thing for long-term prosperity is the wrong thing for investors, according to the tools that guide investments" (p.60). The authors critique metrics that require firms to "[…] always show efficiency and performance improving innovations to be better opportunities" (p.60).

2.1.2 Market pull and technology push innovation

The literature further points to market-pull and technology-push innovations as two common ways innovation differs (Brem & Voigt, 2009). A quote attributed to Henry Ford highlights the point: "If I had asked people what they wanted, they would have said faster horses" (Vlaskovits, 2011). According to Brem and Voigt (2009), market-pull scenarios occur when an "innovation's source is a currently inadequate satisfaction of customer needs, which results in new demand for problem-solving" (p. 355). Alternatively, technology-push products stem from internal or external R&D commercializing know-how (Brem & Voigt, 2009). Walsh, Kirchoff, and Newbert (2002) characterize technology-push as creative, radical, or destructive forces that lead to new or significant improvements to several product or service performance attributes. Differences, according to Gerpott (2005), are outlined in *Table 1*.

Attribute	**Technology push**	**Market pull**
(1) Technology uncertainty	High	Low
(2) R&D expenses	High	Low
(3) R&D duration	Long	Short
(4) Sales market-related uncertainty	High	Low

(5) Time-to-market	Uncertain/unknown	Certain/known
(6) R&D customer integration	Difficult	Easy
(7) Need for change in customer behaviour	Extensive	Minimal

Table 1: Differentiation between technology push and market pull

2.1.3 Diffusion of innovation and the technology acceptance model

The diffusion of innovation and the technology acceptance model (TAM), introduced by Rogers (1983) and Davies (1989), respectively, explain adoption, diffusion, and acceptance of new technologies. Rogers focuses on social aspects of innovation diffusion and adoption, while Davies emphasizes cognitive consumer components of technology acceptance. Rogers (2003) defines *diffusion* as "the process in which an innovation is communicated through certain channels over time among the members of a social system" (p.5). Innovation diffusion relates to characteristics of the innovation, communication channels used to disseminate information, time, and members of the social system. Rogers (2003) characterizes innovation-diffusion as an "uncertainty reduction process" (p. 232).

In addition, "the relative speed with which the members of a social system adopt an innovation" (Rogers, 2003, p. 221) depends on communication channels used to disseminate information. Rogers (2003) also discusses "the degree to which an individual […] is relatively earlier in adopting new ideas" (p. 22), which characterizes people as innovators, early adopters, members of the early majority, the late majority, or laggards. If innovations diffuse successfully, the distribution of adopters follows a normal distribution.

Davis (1989), noting limitations with Rogers' model, chooses to focus on psychological disposition in his technology acceptance model (TAM). While TAM was initially developed to explain information technology acceptance, it can readily be applied to other domains. There are two key criteria: perceived usefulness (PU) describing "the degree to which a person believes that using a particular system would enhance his or her [job] performance" and perceived ease of use (PEOU) which is "the degree to which a person believes that using a particular system would be free of effort" (Davis, 1989, p. 320). People are thus more likely to adopt a technology if they perceive it as valuable and easy to use. The revised version of TAM, known as "the unified theory of acceptance and use of technology" (UTAUT), introduced by Venkatesh et al. (2003), confirms PU and PEOU as determinants and adds social influence and enabling conditions.

2.2 Alternative protein sector

While plant-based meats (PBM) and plant-based dairy products have established themselves within the food FMCG industry, micro-organism-based meats (MBM) and cell-based meats (CBM) remain commercially underrepresented. Driven by the promise of parity, "alternative proteins could soon match animal protein in taste, texture, and price, fueling widespread adoption" (Witte et al., 2021, p. 4).

2.2.1 Status quo

Boston Consulting Group and the Blue Horizon Group found that only 13 million metric tons were consumed globally in 2020, representing merely 2% of the animal protein market (Witte et al., 2021). A UBS survey of US, UK, and German consumers who had not yet tried alt-proteins found that "consumers […] are very interested in alt-proteins; 66% are somewhat interested, indifferent or somewhat not interested; and only 23% are not interested at all" (Witte et al., 2021).

Even though curiosity might drive first-time consumption, alt-proteins must attain parity with animal proteins in three key areas: they need to imitate taste and smell, replicate the fibrous texture of conventional meats, and match or even undercut costs of animal protein farmed under non-organic conditions (Morach et al., 2022). PBM, MBM, and CBM are currently at differing stages of development. It is expected that "plant-based alternative proteins will achieve parity by 2023, those based on microorganisms by 2035, and animal cells by 2032" (Witte et al., 2021, p. 5).

Meanwhile, hybrid products[2] are emerging as a way for fermentation-based and animal cell-based ingredients to reach consumers more quickly (Morach et al., 2023). Witte et al. (2021) forecast that the alt-protein[3][4] market will increase "from the current 13 million metric tons a year to 97 million metric tons by 2035 when it will make up 11% of the overall protein market" (p. 9). Thus, meat alternatives will rise from 21 percent of total alternative-protein consumption in 2020 to almost 37 percent in 2035 (Witte et al., 2021). North America and Europe remain the most mature markets for alt-protein with adoption expected to grow along with consumer preferences for climate-aware and health-conscious lifestyles. The highest potential, however,

[2] Hybrid products have not been subject to (consumer) studies, hence will be excluded from the following analysis.
[3] Estimates refer to the entire alternative protein industry (i.e., including alternative dairy products).
[4] The market share estimate does not consider the possibility of using alternative proteins as basis for animal feed.

lies in the Asia-Pacific region, driven by rising populations and demand for protein. Overall, the global alt-protein market is predicted to be between $250[5] to $500+ billion in annual sales by 2050. Capturing a fraction of this is a colossal market opportunity. But taste, texture, and price will determine outcomes; challenges vary per alternative[6] along with issues pertaining to the AP industry as a whole.

2.2.2 Key challenges

Key matters constraining alt-proteins relate to government subsidies and regulatory support, financial investments, and consumer acceptance.

2.2.2.1 Governmental subsidies and regulatory support

Lisa Sweet of the World Economic Forum argued that "political willingness to repurpose subsidies to a resilient and planet-smart food system" (Morach et al., 2022, p. 34) is essential for the global protein industry. Morach et al. (2022) assert that investment needed is often greater than funders are willing to underwrite due to the capital-intensive nature of most alt-protein ventures. Hence, governmental funding and regulatory incentives are required (Morach et al., 2022). Regulations remain vague and fragmented, leaving customers questioning whether products are safe and ingredients accurately labeled (Witte et al., 2021). Additionally, even though approval processes exist for many novel foods and ingredients, regional differences and bureaucratic processes discourage investment in alt-proteins.

2.2.2.2 Financial investments[7]

Despite considerable emissions savings and market potential, there is significant underfunding with $40 billion in annual investment needed to develop the sector (Kozloski et al., 2022). Compared to typical VC investments, upfront capex is larger and holding periods longer (Morach et al., 2022). This implicates the capitalist's dilemma (*see Chapter 2.1.1*), where shorter-term ROIs are privileged over DI. Furthermore, established players in the protein industry with financial muscle and operational scale have yet to explore strategic partnerships with VCs or alt-protein startups (Morach et al., 2022).

[5] Based on a compound annual growth rate (CAGR) of < 15%.
[6] The technological and techno-economic challenges for plant-based and micro-organism-based meat will not be further elaborated. Respective challenges within the cell-based meats industry will be elaborated in 2.3.2.
[7] A more granular analysis of investments in alternative protein ventures will be conducted in 2.4.1.

2.2.2.3 Consumer acceptance[8]

The fate of alt-proteins ultimately depends on consumer acceptance. As described above, acceptance entails reaching parity on product attributes of taste (including smell), texture, health (including nutritional values), and price. These factors drive purchasing decisions (*see 2.1.3*). Health, environmental, and animal welfare concerns are also strong motivators (Morach et al., 2021). Overall, moving alt-proteins from a lifestyle and niche product to the mainstream at scale requires appealing not only to innovators or early adopters but also to laggards, as Rogers (1983) described. This is imperative for the transformation of sustainable food systems.

2.3 Cell-based meat

The subsequent paragraphs discuss current dynamics within the CBM sector.

2.3.1 Status quo

Brennan et al. (2021) estimated that CBM may reach $25 billion by 2030 if players can "replicate a wide variety of both processed meat and whole cuts" (p.5) and penetrate multiple large meat-consuming countries and regions, such as China, the US, the European Union, Brazil, and India. Barclays even expects that "adoption will be faster than for other food alternatives" and predicts a base case scenario of $450 billion in annual sales of CBM by 2040 (Cohen et al., 2022). These bright prospects will bring new CBM players into the market.

As of 2021, the sector was comprised of 107 companies seeking to develop, manufacture and commercialize[9] cell-based meat. In 2019, leading companies began transitioning from the pre-commercial, proof-of-concept phase toward commercialization[10]. Today, companies run pilot facilities producing hundreds of metric tons of saleable products to assess viability of industrial-scale production (Cohen et al., 2022).

In general, companies are geographically dispersed; the US (26), Israel (14), the UK (12), and Singapore (9) have the highest concentration of CBM companies to date. In addition to companies squarely focused on CBM, more than 60 additional firms have dedicated cultivated meat product and service offerings along the value chain (Cohen et al., 2022).

[8] Consumer acceptance towards cell-based meat alternatives will be discussed in more detail in 2.3.2.2.
[9] No differentiation is made between business-to-consumer (B2C) or business-to-business (B2B) approaches.
[10] Scale up usually occurs in four phases: (1) lab scale, (2) pilot scale, (3) demonstration scale, (4) industrial scale.

Along with technological advancements from vertically integrated CBM companies, emerging business-to-business products and services are accelerating sector maturation. A B2B ecosystem of horizontally integrated companies has begun, enhancing progress toward large-scale production and commercialization (Cohen et al., 2022). However, despite the disruptive potential of alt-proteins, investment in CBM companies has been moderate. So far, 453 entities have committed a total of $1.93 billion across 188 deals. In 2021, this may have changed with more than a hundred new investors contributing over $1.38 billion, more than doubling previous cumulative investments received (Cohen et al., 2022). However, massive capital from private and public entities is still required.

2.3.2 Key challenges

The biotechnological challenges are complex and will determine how alt-proteins develop and mature. The following paragraphs focus on CBM's challenges.

2.3.2.1 Technology and techno-economics

CBM's technological hurdles revolve around scalability, medium development, and tissue engineering. Annual production of 1.5 million tonnes of CBM is required to fulfill the forecasted $25 billion market valuation. This means, according to Brennan et al. (2021), that "at current levels of cell-culture productivity, the industry would need anywhere from 220 million to 440 million liters of fermentation capacity" (p. 8). This outstrips current bioreactor capacities as existing pharmaceutical-grade cell culture volumes contribute between 10 to 20 million liters annually (Cohen et al., 2022). The gap is due to a lack of infrastructure that prevents CBM scalability. Simultaneously, metabolic efficiency, which directly impacts cell-culture productivity, must be increased (Morach et al., 2022). CBM further requires a nutrient-rich medium which, according to Swartz (2021), "accounts for approximately ~99% current baseline production costs" (p.10). To reach cost parity, the media must become less expensive and more efficient (Morach et al., 2022). Lastly, challenges persist concerning tissue engineering essential for three-dimensional muscle and fat cells and non-muscle ingredients that contribute flavor, appearance, and texture (Post et al., 2020). Research has intensified into 3D scaffolding techniques focused on identifying the best combination of materials for cell structures. However, no dominant designs (*see Chapter 2.1.2*) have been established.

Humbird (2021) argues that "the costs of pharma-grade engineering and equipment is inconsistent with the food-scale commoditization of animal cell-culture" (pp. 69-70).

According to Risner et al. (2020), current technology only allows viable commercialization of "low-volume high-value specialty products" (p. 1), which, in turn, would target select price-insensitive "niche adopters" rather than the mainstream (*see Chapter 2.1.3*), preventing wholesale transformation of the global food system. Conversely, Brennan et al. (2021) point out that since 2013[11], the "cost of cultivated meat has come down at an even faster rate than another well-known biotechnology – genome sequencing" (p. 7).

2.3.2.2 Consumer acceptance

Consumer acceptance of cultured meat is discussed in the literature. Most studies find that a majority of consumers would be willing to try CBM, and "substantial portions say they would eat it regularly or as a replacement for conventional meat" (Bryant and Barnett, 2020, p. 9). On the other hand, Onwezen et al. (2021) and Pakseresht, Ahmadi Kaliji, and Canavari (2022) state that the acceptance level of cultured meat is relatively low. Consumer surveys from governments, consulting, and investment firms paint a more optimistic picture. Studies from the US and UK indicate that over one-third of consumers 12 are very or extremely likely to try CBM alternatives when commercialized (Cohen et al., 2022).

A review of the factors that determine consumer acceptance has been included in *Appendix I.* These form the basis for the conceptual model (*Appendix III*), which underpins the consumer behavior investigation described in *Chapter 3.2.1*.

2.3.2.3 Governmental subsidies and regulatory support

Governments recognizing the importance of CBM have begun investing in R&D through grants and other funding programs. In response to COVID-19, the EU launched REACT, a government program under which a leading CBM company, Mosa Meat, received a grant of $2 million (Cohen et al., 2022). Other countries have also launched programs, though progress has been moderate (Cohen et al., 2022). Commercialization strongly depends on a clear regulatory path to market. In 2020, Singapore and Israel[13] became the first countries to grant regulatory approval to CBM products. Last year, UPSIDE Food and GOOD Meat's products achieved US FDA approval[14]. So far, no approval has been sought from the European Food Safety Authority. However, the European Commission acknowledged that CBM "could be considered as a

[11] In 2013, Post developed and produced the first cultivated meat at ~$300.000 a burger.
[13] Thus far, Israel only permits the sale of CBM within select restaurants as part of a nationwide pilot.
[14] Final inspection from the US Department of Agriculture is pending.

promising and innovative solution to help achieve […] healthy and environmentally-friendly food system" (European Food Safety Authority, 2022). While several European countries are eager to unlock the benefits of CBM, Italy enforced a categorical ban on "meat which is the result of a cell cultivation process" (Good Food Institute Europe, 2023, para. 1). This emphasizes ongoing controversies surrounding CBM.

Overall, issues with regulatory uncertainties, extensive approval processes, bureaucratic inertia, and untransparent product labeling stymie growth and consumer acceptance (Cohen et al., 2022; Post, 2020).

2.3.2.4 Financial investments

Insights into CBM's investment landscape have been provided above (*see Chapter 2.3.1*). Further insights into the current state, drivers, and challenges will be discussed in *Chapter 2.4.1*.

2.4 ESG and climate technology investments

Introduced at the UN Sustainable Development Summit in 2015, the UN Sustainable Development Goals (UNSDGs) have environmental components that were reinforced by the Conférence de Paris (COP15) later that year. Under the UN Framework Convention on Climate Change, countries pledged to reduce carbon emissions and mitigate climate change (Dhayal, 2023). Low-carbon initiatives have gained considerable attention from individual and institutional investors (Dhayal et al., 2023). This is also true for VCs, who serve as "mediator[s] between the people who need capital for business ventures and those with excess capital" (Dhayal et al., 2023, p. 2). VCs embracing ESG as an investable theme are making allocations into sustainable ventures. PitchBook estimates that private impact funds hold $113 billion in dry powder (Wiek, Le & Mei, 2022). Although investments in sustainable protein were up by 24% in Europe in 2022, the alt-protein sector remains underfunded, despite its ESG potential (O'Donnell & Murray, 2023). Given current economic uncertainties, alt-proteins provide "very low exposure to recession and cyclicality, making them strongly resilient against any 'unknown unknowns' that might influence the overall economy" (Witte et al., 2021, p. 30). Yet, the question remains why investment flows into alt-proteins are relatively weak.

2.4.1 Investments in climate tech-, alt-protein- and cell-based meat ventures

What follows compares sustainable investments and notes the impact of capital deployed in billions per trillion invested[15]. This metric, suggested by Morach et al. (2022), provides a measure of a sector's decarbonization potential per dollar invested[16].

2.4.1.1 Recent dynamics in the climate investment landscape

In general, climate tech is defined as technologies that focus on reducing greenhouse gases or addressing global warming. Applications can be clustered into three groups: solutions that mitigate or remove emissions; help adapt to the externalities of climate change; and enhance understanding of climate change.

Numbers are based on PitchBook data consolidated within PwC's "State of Climate Tech 2022" report (Cox et al., 2022). PwC's latest NZEI[17] stated that the "global rate of decarbonization declined just 0.5% per year over the past 12 months, far below the 15.2% rate needed to limit warming to 1.5°C" (Cox et al., 2022, para. 1). Climate tech investment has shown resilience over the past decade and the share of global venture funding in climate tech was "more than a quarter of every venture dollar invested" (Cox et al., 2022, para. 2) in the 12 months leading up to Q3 in 2022. However, compared to megadeals primarily facilitated by special purpose acquisition companies (SPACs) in 2021, there was a cyclical downturn. Venture funding for climate tech start-ups fell to $52 billion over the first three quarters of 2022 (Cox et al., 2022). In addition, early-stage funding of small deals less than $5mil, required for climate tech growth for the future, declined over the past 24 months. Cox et al. (2022) observed that the "flow of investments into climate technology is not in proportion to each's sector's contribution to the flow of GHGs into the atmosphere" (para. 22), indicating an inefficient market for climate outcomes. Responsible for only 15% of global GHGs, the mobility sector absorbed 48% of climate tech investment between Q3 2021 and Q3 2022 (Cox et al., 2022). On the other hand, food, agriculture, and land use, causing 22% of GHGs, received only 12% of funding (Cox et al., 2022). Comparing technological maturity with future emissions-reduction potential reinforces the puzzle about underfunding. The consolidated findings in *Table 6* in *Appendix II* illustrate the climate opportunity associated with alt-proteins. The underfunded alt-meat sector

[15] The top three climate technology sectors (by investments and ROC) will be reviewed.
[16] The impact on capital employed (IoCE) assumes a market value for avoided tons of CO_2 per dollar invested of $50 to $80 per ton.
[17] Net zero economy index.

represents the most efficacious decarbonization lever compared to light and heavy transportation and power, which received most of VCs climate tech funding. The sector also offers a high potential ROI. Based on the foregoing, substantial barriers are assumed to be present.

2.4.2 Barriers to investments in cell-based meat ventures

The challenges for CBM discussed in *Chapter 2.3.2* are treated as the main investment impediment. CBM technology requires significant upfront capital which, in turn, is perceived as risky (Morach et al., 2021).

Additionally, investors remain hesitant due to uncertainties about consumer acceptance. Furthermore, lack of governmental support, both from funding and regulatory perspectives, aggravates these barriers. Huang et al. (2022) investigated VC capital deployment under economic policy uncertainty (EPU). They found that VCs often delay investing in high EPU times "because VC investments are partially irreversible, [so] there is a value of waiting for new information about portfolio companies and the investments environment before VCs provide financing" (p. 575). Cox et al. (2022) suggested that reporting requirements for ESG funds are often onerous, and funds targeting earlier funding rounds may not have economies of scale to cover transaction costs. Johnson et al. (2021) further argued that a new class of investors is required who "look beyond the low-hanging fruit to help scale technologies in harder-to-abate sectors" (p. 51). Short-term investment horizons and investor risk aversion will be illuminated by experts (*see Chapter 3.2.2*) and analyzed in *Chapter 4.2*.

Chapter 3: Research methodology

Hornik (2021) defines research as "a process of intellectual discovery, which has the potential to transform knowledge and the understanding of the world around us" (p. 1). This requires a systemized research design and suitable methods.

3.1 Research design

Our research design sought to understand CBM's under-investment relative to other climate technologies which limits its disruptive potential in the meat industry. *Figure 1* below describes the methodology.

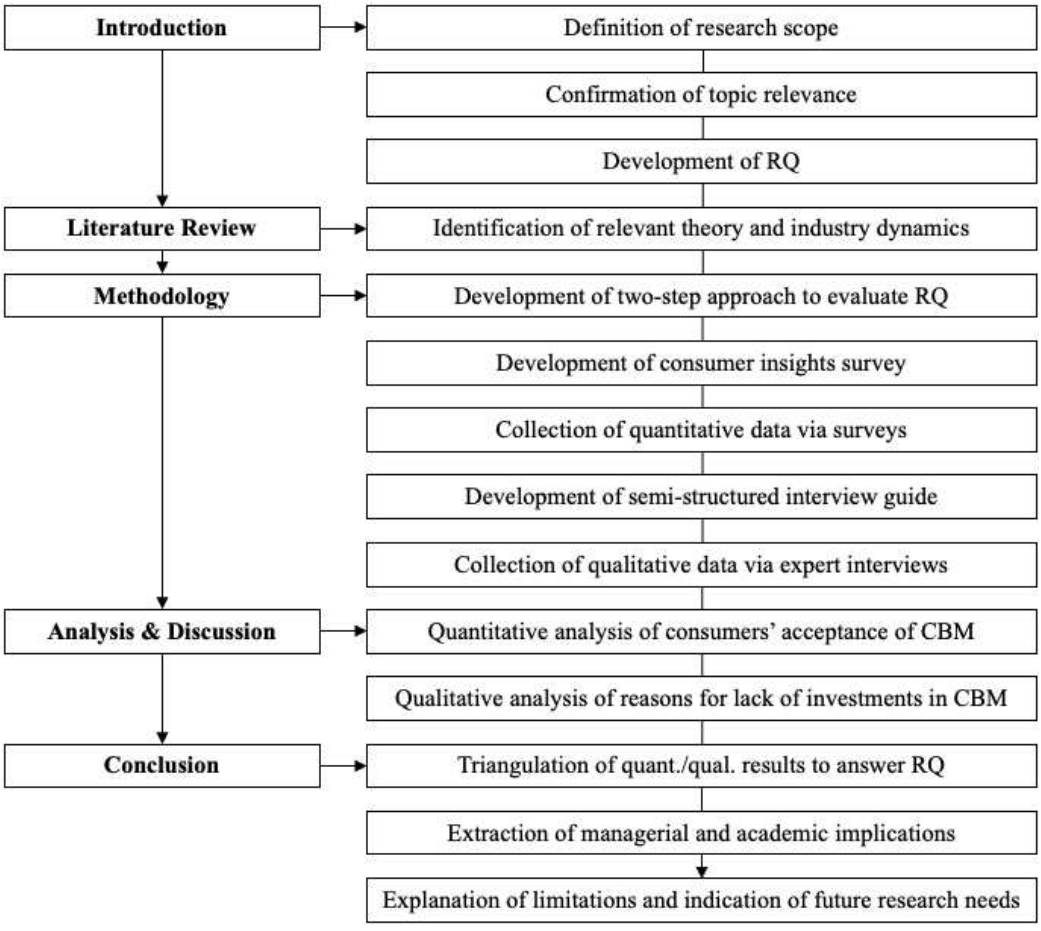

Figure 1: Research design

A mixed methods approach using triangulation was chosen (Sekaran & Bougie, 2016), combining quantitative and qualitative data and inductive and deductive thinking (Sekaran & Bougie, 2016). First, a survey was created to discern perceptions and acceptance of cell-based meat alternatives (*see Chapter 3.2.1*). Next, semi-structured expert interviews (Pink, 2009)

were conducted with VCs and Founders, CEOs, CFOs, and COOs of CBM start-ups, (*see Chapter 3.2.2*).

3.2 Data collection

The following paragraphs discuss data collection methods used in *Chapter 4*.

3.2.1 Primary data – Consumer insights survey

The literature survey (*see Chapter 2*) showed the need for consumer acceptance in the diffusion of disruptive innovations. Hence, with consumer acceptance as a key determinant, this influences CBM's disruptive potential. However, given limited consensus around current levels of acceptance (*see Chapter 2.4.2.5*) we designed a survey to test the phenomenon. Our conceptual model in *Appendix III*, based on the literature elucidating consumer acceptance (*see Appendix I*), provided the theoretical framework for our survey questions illustrated in *Appendix IV*. The survey consisted of 26 questions[18] across six areas: (1) demographics, (2) consumption patterns, (3) awareness of and intention to consume CBM, (4) risk perception and emotions, (5) ethical and environmental concerns and (6) product attributes and willingness to try, buy and pay. It was conducted once, online, without researcher interference[19] among an international population above 18 years and was designed and administered with Qualtrics. A form of non-probability convenience sampling was utilized as survey participants were recruited via Amazon Mechanical Turk. Participants were sampled according to pre-defined criteria. One qualifying question tested respondents' attention to identify invalid responses[20].

The limitations of the survey are outlined in *Chapter 5*. Overall, 354 respondents began the survey and 320 finished[21] it. Of these, 22 did not pass qualifying questions. Additionally, an embedded CAPTCHA flagged five respondents as potential bots. Consequently, 27 responses were excluded, resulting in a sample size (n) of 293. Based on consumer studies conducted in the context of CBM (*see Chapter 2.3.2.2* and *Appendix I*), the sample size may be deemed representative[22].

[18] Question types included demographic questions, multiple choice questions, 5-point Likert scale questions, matrix questions, and ranking questions.
[19] Solely two information boxes concerning the concept and the underlying technology of CBM and the benefits of CBM were provided.
[20] Both questions must be answered correctly for response to be included.
[21] Respondents had the opportunity to finish the survey within one week.
[22] Sample sizes of surveys conducted in the field of CBM ranged from 250 to 1,800.

3.2.2 Primary data – Expert interviews

According to Rowley (2012), interviews are "generally used to conduct qualitative research, in which the researcher is interested in collecting 'facts', or gaining insights into […] opinions, attitudes, experiences, processes, behaviors or predictions" (p. 261). In business research, semi-structured interviews are common (Rowley, 2012). While guidelines establish a structure, there is latitude to follow topical threads as the conversation unfolds (Magaldi & Berler, 2020).

The guide was developed inductively relying on prior knowledge of the topic (Rowley, 2012). It consisted of three main and two sub-questions (*see Appendix V*), and the average interview duration was approximately 30 minutes. Interview requests were sent out to 117 potential interviewees via e-mail, LinkedIn, or private networks. The 12 experts who agreed to be interviewed, their current positions, expertise, and experience in either the CBM, VC or CVC domain, are outlined anonymized in *Table 2*. The interviews were conducted via Zoom or cellphone and recorded. Responses were analyzed using a combination of open coding and thematic analysis to identify themes, patterns, and trends (Krippendorff, 2004). The responses per expert are summarized in *Appendix VII*.

Code	Current position, experiences and expertise
ES1	Co-Founder and CEO at early-stage, B2B, CBM venture – focus on end-to-end bio-processing systems to enable meat producers transition to cell-based meat. Raised $700.000 in pre-seed round. 10+ years of experience in FMCG and agricultural industry.
ES2	Former CFO of US-based, CBM venture – focus on B2C end products. Raised $25mil in undisclosed round(s). Moreover, 20+ years of experience in leading financial roles at several high-growth technology companies.
ES3	Founder and CEO of B2B service provider for chemical and microbiological processing for pharma and bio-tech. Investor, board member and technology consultant at early-stage, B2B CBM venture – focus on catalyzing industrial-scale production of cultivated meat. Have not yet raised capital.
ES4	Co-Founder and Managing Director of plant/cell-based meat venture – focus on B2C end products. Seed funding imminent. Moreover, Co-Founder and prior CEO of FMCG venture
ES5	Independent consultant for Business/Sales-Development and Fundraising within food tech accelerators, previously Founder and CEO of US-based food and agri-tech venture
ES6	Co-Founder and CEO of early stage CBM venture. Raised undisclosed amount in pre-seed stage backed by angels. 10+ years of experience in consulting and venture building, primarily focused on FMCG
EVC1	Partner at US-based VC and former board member at one of the largest CBM ventures – focus on B2C products. Raised $400mil in Series C. Moreover, 30+ years of experience in founding and scaling successful technology companies across several industries.
EVC2	Investor at UK-based, alt-protein focused family office – so far, eight investments in seed and early-stage CBM ventures. Moreover, 4+ years in VC, background in Biomedical Sciences from leading university in the United Kingdom.
EVC3	Senior Vice President and Chief Growth Officer for Middle East, Africa and East Asia at French multinational food products corporation. Firm's VC arm invested in cell-based milk venture. 20+ years of experience in leadings positions across several multinational FMCG corporations.
EVC4	Co-Founder and Chief Investments Officer of venture network and investment vehicle (co-invested alongside leading VCs), 8+ years of experience in venture capital, private equity and investment consulting across Europe, the US and South America
EVC5	Investor within corporate venture capital arm of FMCG company, focused on early-stage ventures in food and beverage industry. 8+ years of experiences across different investment and consulting roles, primarily with a focus on FMCG
EVC6	Senior Advisor for impact investments at venture capital and private equity firm. 20+ years of experience in capital markets with a focus on sustainable investing

Table 2: Overview of interviewees

Chapter 4: Analysis and discussion

The consumer survey is analyzed in *Chapter 4.1* and expert interviews in *Chapter 4.2*. A triangulation approach, combining insights from the primary and secondary data (*see Chapter 2*) then assessed CBM's disruptive potential (*see Chapter 5.1.3*).

4.1 Current levels of consumer acceptance of cell-based meat alternatives

Consumer acceptance was generalized from the survey and applicable connections to the literature reviewed in *Chapter 2* and *Appendix I* were also made. Final conclusions concerning consumer acceptance are discussed in *Chapter 5.1.1.*

4.1.1 Demographics

Most of the population identified as male (n = 156), while a smaller proportion identified as female (n = 137).

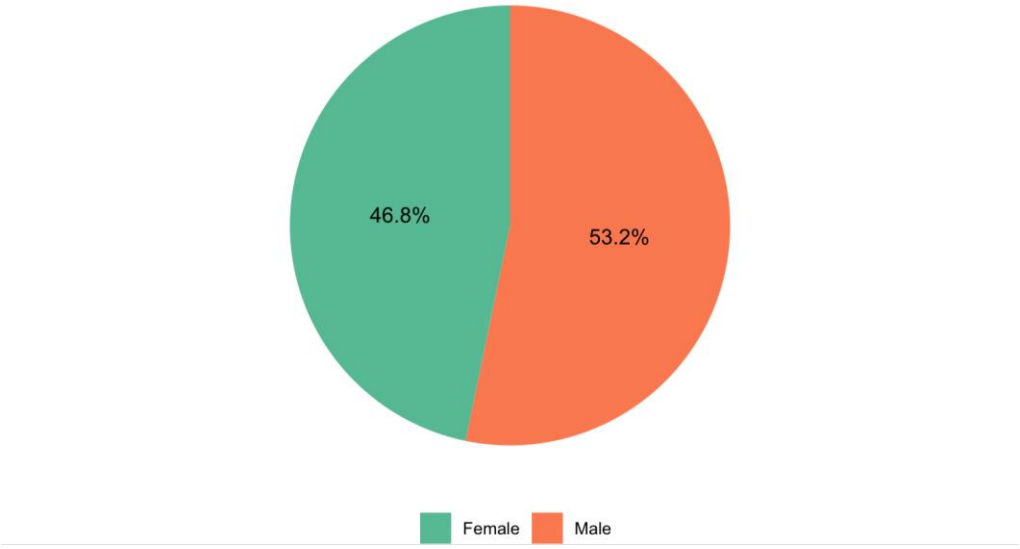

Figure 2: Gender distribution (n = 293)

Most respondents were located in the US (279), while a smaller part of the respondent cohort was from Germany (9) and Italy (6). Age distribution was skewed towards the younger and middle-aged groups (*see Figure* 3), with over half of respondents falling within the 25 to 44 age range (52%). A smaller proportion of respondents were aged between 45 and 54 (14%), while only a few were 55 years and older (3%).

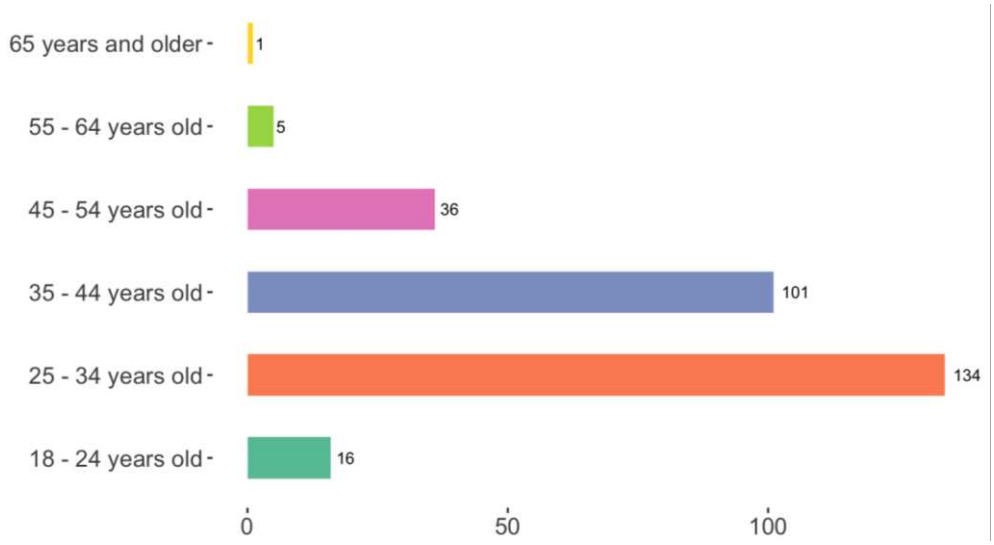

Figure 3: Age distribution (n = 293)

Most respondents identified as White or Caucasian (82.65%), followed by African American (5.4%), Hispanic (4.76%), Native American (2.72%), and Asian (4.08%). The religious background was predominantly Christian (79.25%) and included Hindu (7.14%), Muslim (5.44%), and other religious affiliations (5.45%).

Figure 4: Total household income (in USD) before taxes (n = 293)

Most respondents reported incomes before taxes between $50,000 - $99,999, followed by $25,000 - $49,999 and $100,000 - $199,999. A smaller proportion reported less than $25,000 or more than $200,000. Most respondents had a bachelor's degree, and a significant number also had a master's. A smaller proportion reported having a high school degree or some sort of vocational training and certification, with only a few having less than a high school degree.

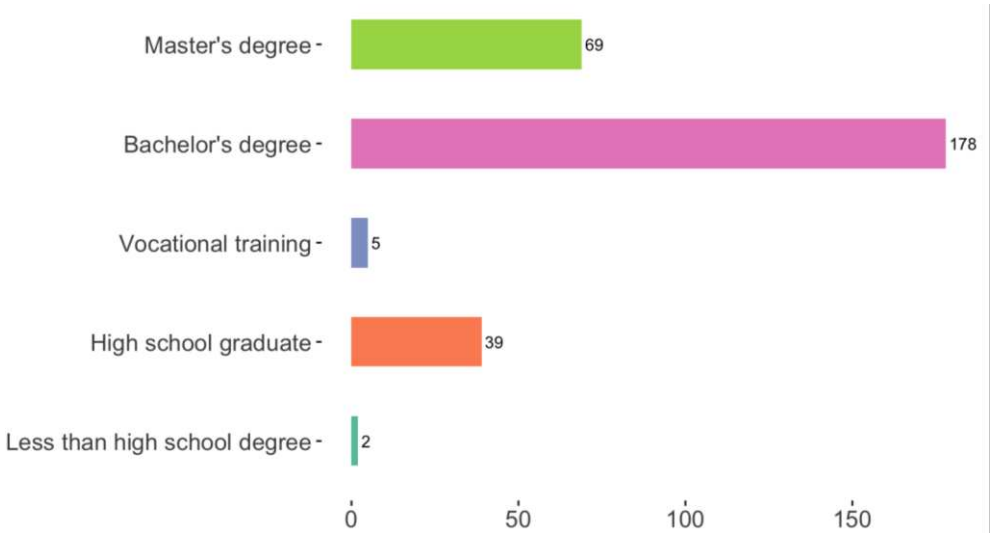

Figure 5: Educational level (n = 293)

As illustrated in *Figure* 6, political orientations varied, with a sizeable proportion identifying as somewhat conservative or extremely conservative, and a significant proportion identifying as somewhat liberal. Smaller cohorts were either extremely liberal or neutral.

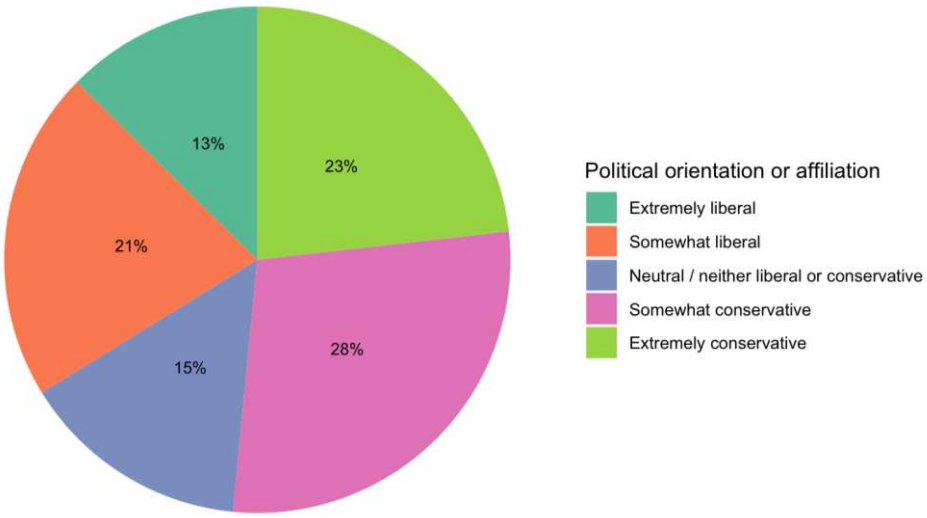

Figure 6: Political orientation or affiliation (n = 293)

Limitations associated with the sample demographic are discussed in *Chapter 5.2.1*.

4.1.2 Consumption pattern

Regarding dietary preferences[23], most respondents identified as either carnivores (n = 97) or omnivores (n = 93). Many classified themselves as flexitarians (n = 66), indicating occasional meat consumption. A small proportion of respondents reported being vegetarians (n = 26), pescatarians (n = 8), or vegans (n = 3). This suggests that the majority of participants incorporated meat into their diets.

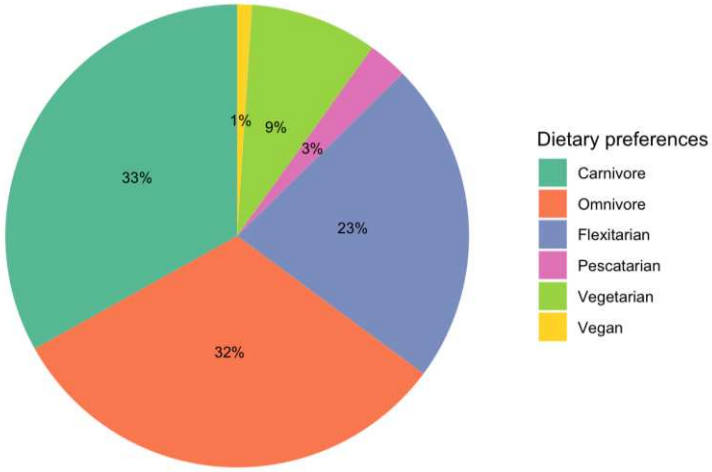

Figure 7: Political orientation or affiliation (n = 293)

The frequency of meat consumption illustrated in *Figure* 8 presents a conflicting picture. Among the 293 respondents, only 6 reported not consuming meat, which is inconsistent with the proportion of vegetarians and vegans (10%). The discrepancies between the self-reported dietary preferences and the subsequent results may be attributed to several reasons that affect research findings[24].

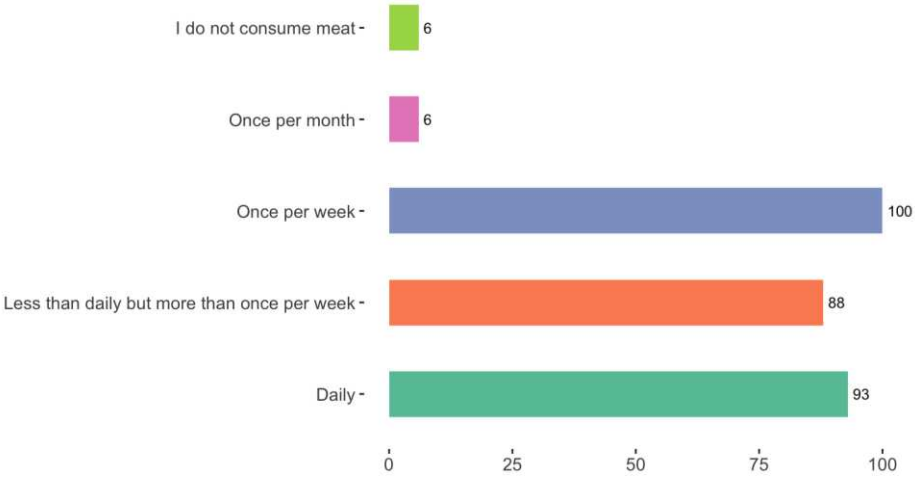

Figure 8: Meat consumption frequency (n = 293)

[23] Complementary information concerning the terminology of dietary preferences was provided (*see Appendix IV*)
[24] The limitations resulting from the inconsistent data are emphasized in *Chapter 5.2.1.*

Despite the discrepancy noted above, it was still useful to examine meat consumption. The majority (96%) consumed meat to some extent and once per week was most common frequency, followed by daily consumption and less than daily but more than once per week. As suggested by Bryant and Barnett (2020), self-reported carnivores and omnivores who score high on meat attachment and consume meat regularly, tend to perceive CBM as more appealing than meat-restricted consumers (*see Appendix I*). The high concentration of this dietary type (65%) in the cohort provided insights for *Chapter 4.1.7*.

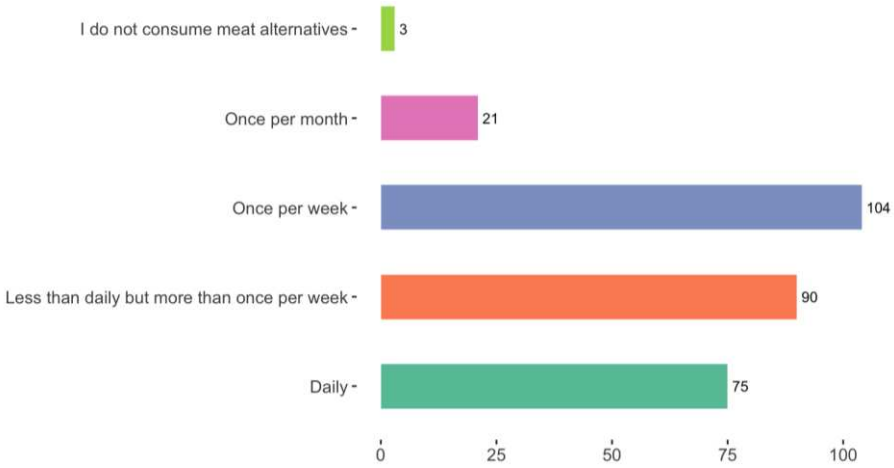

Figure 9: Alternative meat consumption frequency (n= 293)

Regarding alternative meat consumption, 35% said they consumed alternatives once per week, 30% less than daily but more than once per week, and 25% daily. In addition, 7% reported monthly consumption of meat alternatives, while less than 1% stated no alternative meat consumption at all. As illustrated in *Figure* 10, the principal drivers for alt-meat consumption were health, followed by environmental, and then ethical reasons. This contrasts with the literature where environmental and ethical concerns were primary reasons (*see Appendix I*). Culture or religion and taste were also mentioned, but to a lesser extent. A more granular account of respondents' environmental and ethical notions follows below.

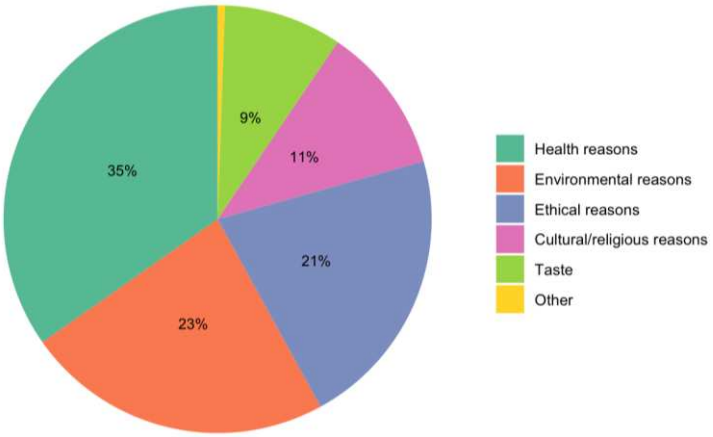

Figure 10: Reasons for alternative meat consumption (n = 290)

4.1.3 Environmental and ethical concerns

The literature established environmental and ethical concerns as the strongest drivers of consumer acceptance of CBM (*see Appendix I*). Respondents were presented with four statements[25] pertaining to negative externalities of meat consumption for the environment, climate change, ethics, and animal welfare. On a scale from one (strongly disagree) to five (strongly agree), respondents recorded levels of agreement with each statement.

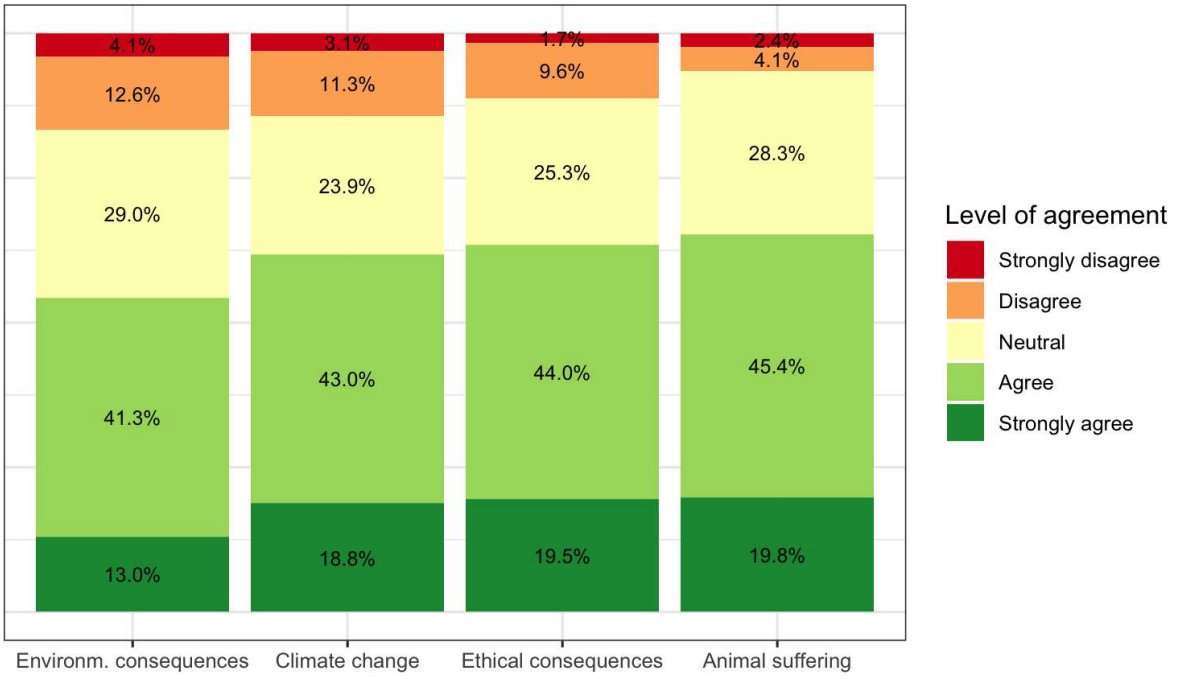

Figure 11: Levels of agreement with statements on meat consumption (n = 293)

Overall, most respondents either agreed or strongly agreed with statements about meat consumption being bad for the environment, climate change, ethics, and, in particular, animal suffering. Surprisingly, roughly one-third expressed neutral, disagreeing, or strongly disagreeing opinions about the statements provided. This challenges reported trends of rising consumer awareness of the adverse effects of meat consumption (*see Chapter 1*). Our findings provide an opportunity to examine whether differing awareness levels impact consumer willingness to try, buy, substitute, and pay for cell-based meat at the same and a premium price (*see Chapter 4.1.7*).

4.1.4 Awareness and knowledge

The literature (*see Appendix I*) showed that prior awareness of CBM and its underlying technology were factors for acceptance with lack of knowledge leading to skepticism

[25] The exact statements are specified in *Appendix IV*.

(Pakseresht, Ahmadi Kaliji, & Canavari, 2022). Correspondingly, two separate question blocks[26] were deployed to assess familiarity with the concept and technology of CBM and the environmental and ethical benefits on a scale of one (not at all familiar) to five (extremely familiar).

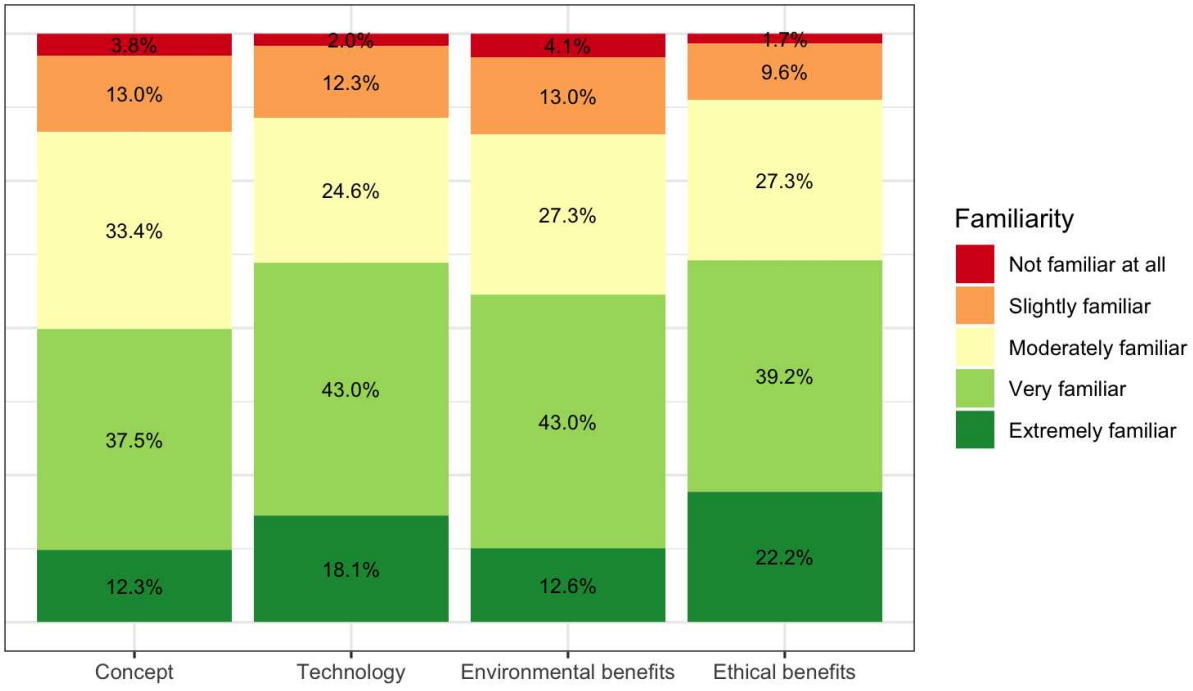

Figure 12: Familiarity with the concept and benefits of CBM (n = 293)

Participants showed varying levels of familiarity with the concept and technology of CBM and its environmental and ethical benefits. Surprisingly, about 85% of respondents reported being at least moderately familiar. This contrasts with the literature which has pointed to a lack of consumer awareness and knowledge deficiencies concerning CBM (*see Appendix I*). Given the complex nature of CBM's enabling technology, the pronounced familiarity found was noteworthy. Overall, familiarity tended to increase as questions progressed toward benefits. In *Chapter 4.1.8*, this data will be utilized to examine impacts on willingness to try, buy, substitute, and pay.

4.1.5 Perception of risks and emotions

Rogers (1983) and Davis (1989) established that accepting and adopting novel technologies entail complex processes influenced by various social, psychological, and cognitive factors. Thus, consumer emotions and perceptions of risk determine CBM acceptance .

[26] The exact questions are specified in *Appendix IV*.

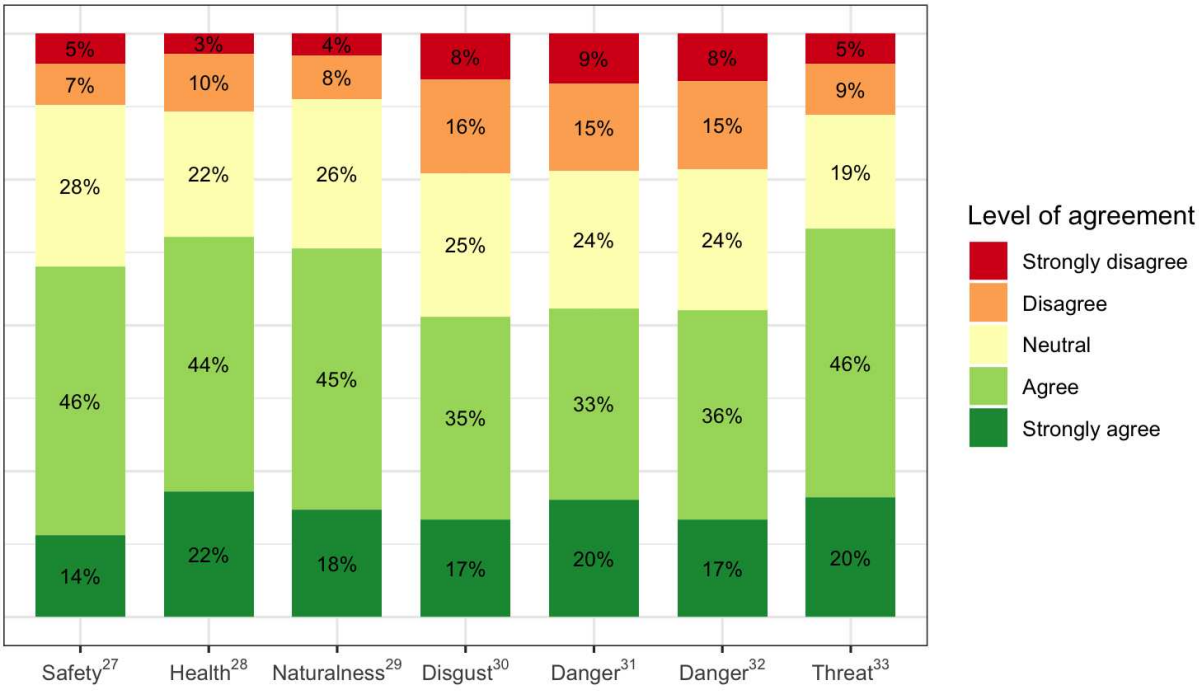

Figure 13: Risk perception and emotions concerning CBM (n = 293)

Overall, most respondents perceived CBM as safe (60%), healthy (66%), and natural (63%). However, feelings of disgust (52%), inhibiting acceptance of novel foods (*see Appendix I*), persist. Perceptions of danger concerning the end product or the technology trumped respondents' prior claims about product safety. Here, more than half the population reported misgivings about CBM safety and the underlying technology. This emphasizes the significance of food neophobia and technophobia on acceptance (*see Appendix I*).

On average, 24% of respondents reported neutral feelings towards CBM across all seven dimensions. Lack of commercialization and attendant attitude-forming consumer experiences may explain this neutrality. This finding reinforces the role of framing effects in shaping consumer acceptance (*see Appendix I*). Additionally, Italy's ban on CBM development and commercialization[34] appears reasonable, as 66% of respondents viewed CBM as a threat to cultural heritage, highlighting the importance of local cultural norms for acceptance.

[27] Statement: "I perceive cell-based meat as safe".
[28] Statement: "I perceive cell-based meat as healthy".
[29] Statement: "I perceive cell-based meat as natural".
[30] Statement: "I perceive cell-based meat as disgusting".
[31] Statement: "I perceive cell-based meat as dangerous".
[32] Statement: "I perceive the enabling technology of cell-based meat as dangerous".
[33] Statement: "I perceive cell-based meat as a threat to my cultural heritage".
[34] Italy's ban presents CBM as a threat to the cultural heritage of the country (*see Chapter 2.3.2.3*).

4.1.6 Product attributes

Product attributes influencing purchase decisions were evaluated using a 100-point scale to reflect the relative weights of each attribute (*see Figure 14*). Mean scores were calculated for each. The results suggest that affordability and taste were most critical for respondents, followed by visual appearance, texture, and smell.

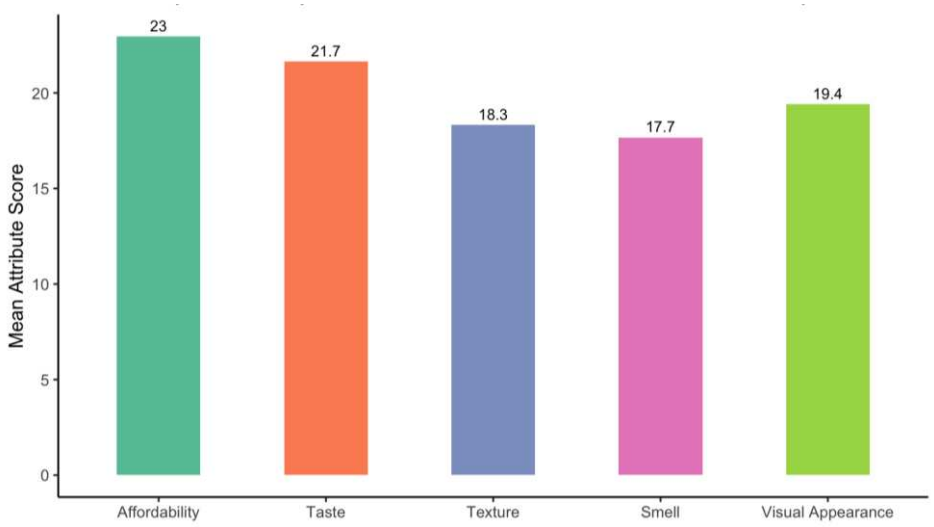

Figure 14: Importance of product attributes in meat and alt-meat purchases (n = 293)

We created a multi-attribute model depicting consumer perceptions of three meat types: conventional, plant-based, and CBM. Respondents were asked to evaluate each type based on the five attributes, using a 1 (low) to 5 (high) Likert scale. The mean scores for each attribute are shown in *Figure 15*.

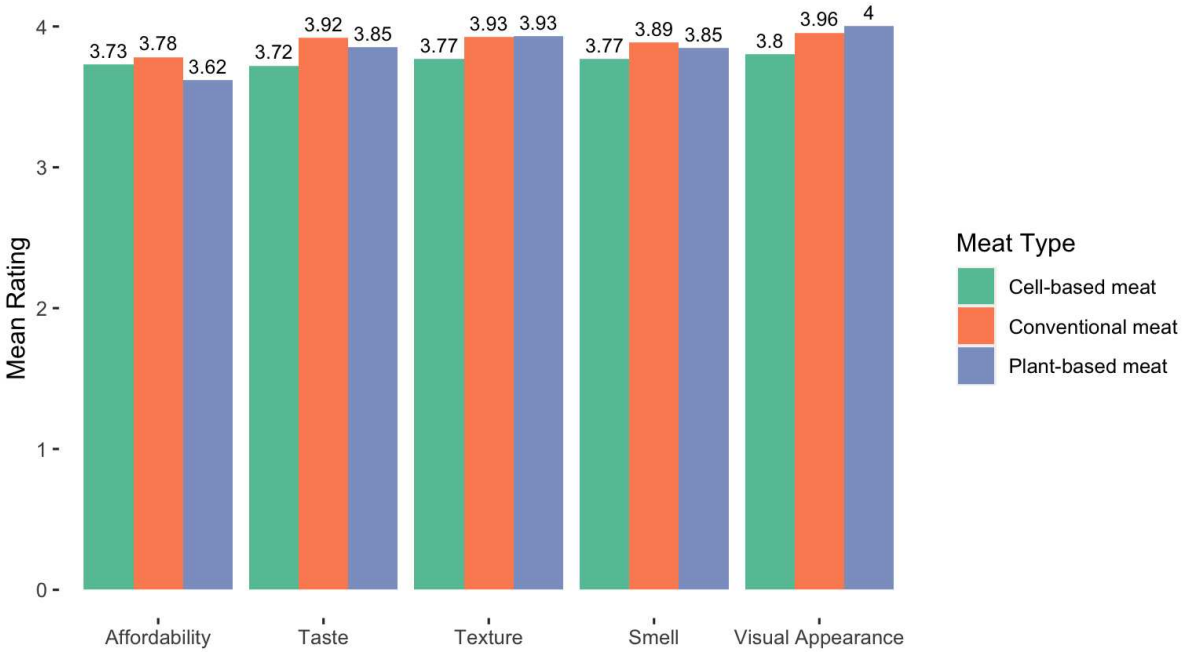

Figure 15: Mean rating of product attributes per meat type (n = 293)

The results indicated that consumers perceived conventional meat as superior to PBM and CBM on almost all product attributes, with marginal differences. Surprisingly, plant-based meat received the highest mean score on visual appearance. The literature showed that affordability and taste drive purchases of meat and meat alternatives. This suggests that relatively low scores for PBM (3.62) and CBM (3.73) on affordability and taste (3.85 and 3.72, respectively) could present barriers to adoption. Additionally, CBM received the lowest overall mean scores for taste, texture, smell, and visual appearance.

These findings are congruent with the literature (*see Appendix I*) where sensory characteristics were key determinants of consumer acceptance and purchase intent for meat and meat alternatives. Improvements in CBM sensory appeal were deemed important for achieving mainstream acceptance and adoption (Bryant and Barnett, 2022; Verbeke et al., 2015; Wilks and Philips, 2017; Gomez-Luciano et al., 2019). The findings further reinforce the literature regarding parity needed on key product attributes.

4.1.7 Willingness to try, buy, substitute and pay

In line with Rombach et al. (2022), several willingness measures were assessed to determine overall acceptance levels. Using willingness to try, buy, substitute conventional with cell-based meat, and pay for it as proxies for acceptance yielded further attitudinal for predicting CBM's potential market share. First, representations of consumer willingness levels are graphed to show attitudes towards CBM. Then, we performed regressions to investigate the impact of independent variables on willingness to engage with CBM.

4.1.7.1 Willingness to try, buy, substitute conventional with cell-based meat, and pay

Bryant and Barnett's (2022) review of quantitative studies showed that consumers are generally willing to try cell-based meat. Although there were various objections (*see Appendix I*), willingness levels illustrated in *Figure 16* confirm general consumer openness towards this novel food technology.

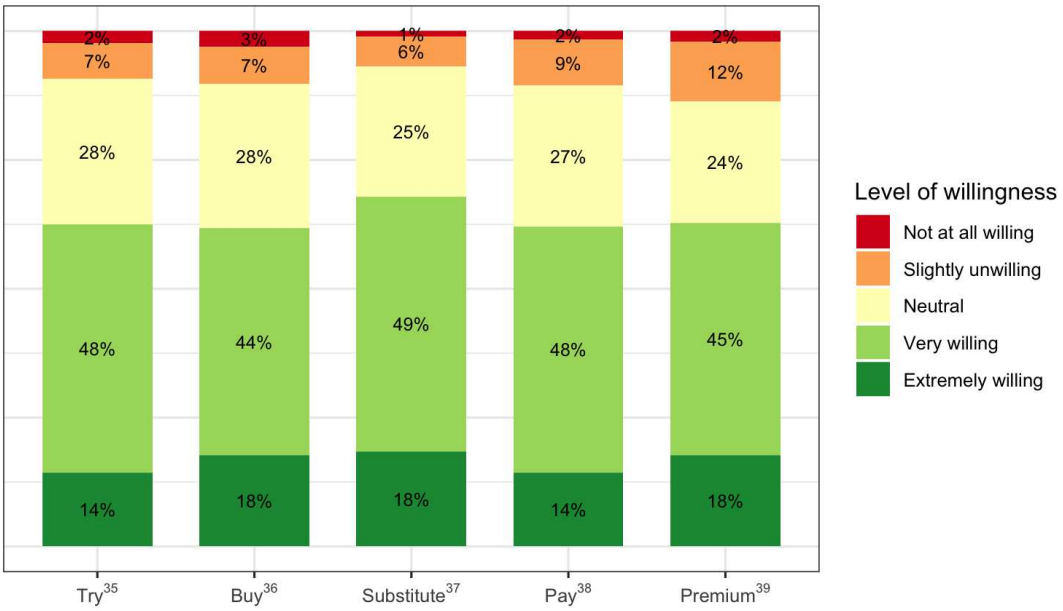

Figure 16: Consumer willingness levels concerning CBM (n = 293)

Of total respondents, 62% expressed a high level of willingness to try and frequently buy and consume CBM, whereas only 10% showed a degree of opposition to the idea. This distribution resembles the findings of Witte et al. (2022) presented in *Chapter 2.2.1*. Interestingly, 67% reported they would be willing to permanently substitute conventional meat with CBM if parity on key product characteristics (*see Chapter 4.1.6*) were guaranteed. As visualized in *Figure* 16, the primary drivers of substitution are health, followed by environmental, ethical, and cultural or religious concerns.

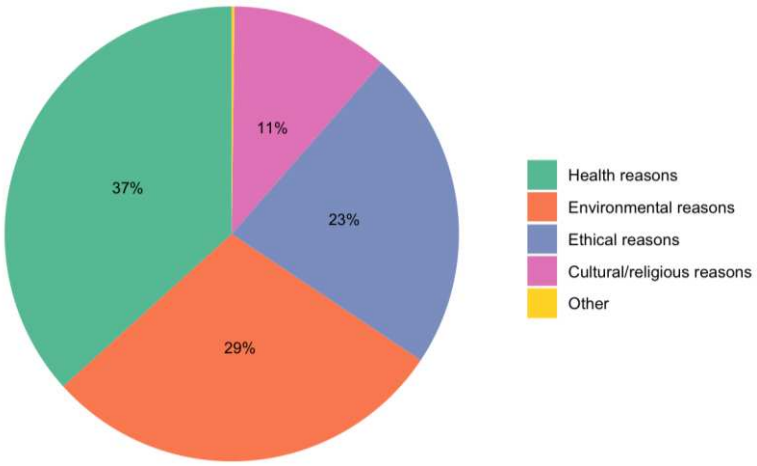

Figure 17: Reasons for using CBM as a substitute (n = 196)[40]

[35] Question: "Would you be willing to try CBM?"
[36] Question: "Would you be willing to buy and consume CBM on a frequent (at least once per week) basis?"
[37] Question: "Would you be willing to substitute ordinary meat with cell-based meat if parity [..] is guaranteed?"
[38] Question: "Would you be willing to pay the same amount [..] for CBM as for conventional meat?"
[39] Question: "Would you be willing to pay more for the same quantity of CBM as for conventional meat?"
[40] Respondents who reported to be "Slightly unwilling" or "Not at all willing" to use CBM as a substitute for conventional meat (n = 21) were not exposed to this question.

Analysis of willingness to pay (WTP) revealed an unexpected picture. Several researchers attested to consumer price sensitivity and elasticity in meat purchase decisions (*see Appendix I*). Results of the multi-attribute model, discussed in *Chapter 4.1.6*, reinforced this with affordability emerging as the most influential factor for purchase decisions. However, the data indicated that more than 60% of consumers were not only willing to pay the same amount but would even pay a premium for CBM. Among those willing to pay more (n = 253), 45% would pay up to 10% more, 40% up to 20% more, and 15% up to 30% more. Studies reported that consumer WTP for CBM was either indifferent or slightly above conventional meat (Wilks & Philips, 2017; Zhang & Bai, 2020).

Overall, willingness levels across different dimensions demonstrated an overall high acceptance of CBM. Analyzing determinants that either drive or inhibit acceptance provided a more nuanced understanding of consumer behavior. Several multiple linear regressions will be conducted in the following chapter.

4.1.8 Determinants of consumers' willingness to engage with cell-based meat

Linear regressions were created based on our analyses and the literature (*see Appendix* I), where the former yielded determinants influencing willingness. Results are discussed and conclusions drawn concerning acceptance levels in *Chapter 5.1*.

4.1.8.1 Demographics

The literature established several demographic variables as consumer acceptance predictors. For instance, Wilks and Phillips (2019) reported that men were generally more receptive than women. Bryant and Dillard (2019) indicated that CBM appeals more to younger people. Bryant and Barnett (2022) also identified education as a strong predictor of acceptance. Gomez-Luciano et al. (2019) added that household income correlated with a higher acceptance. Political affiliation also seemed to influence consumer perception (*see Appendix I*).

Regressions (*see Table 7 in Appendix VI*) of demographic predictors against willingness measures supported these findings only to a limited degree. Neither age nor gender had a consistent statistically significant effect on consumer willingness. On the other hand, education and political affiliation did affect consumer willingness to engage with CBM, with lower education and extreme conservatism reducing overall willingness. Moreover, willingness to engage with CBM did correlate with higher income levels.

4.1.8.2 Consumption patterns

Inconsistencies in the data concerning dietary preferences and meat consumption discussed in *Chapter 4.1.2* prevented reliable regressions. However, assuming that reported frequencies of meat consumption were valid data points, a statistically significant effect on several willingness measures was observed (*see Table 8 in Appendix VI*)[41].

Overall, willingness to engage with CBM increases with the frequency of meat consumption. This is consistent with the literature (*see Appendix I*). The low R-squared values, however, indicated that consumption frequency alone possesses relatively little explanatory power for changes in consumer willingness levels.

4.1.8.3 Environmental and ethical concerns

	Dependent variable:				
	Try	Buy	Substitute	Pay same	Pay more
	(1)	(2)	(3)	(4)	(5)
Disagreement (Environm. Cons.)	-0.397**	-0.206	-0.334**	-0.505***	-0.107
	(0.153)	(0.162)	(0.154)	(0.152)	(0.165)
Neutral (Environm. Cons.)	-0.308***	-0.201*	-0.108	-0.316***	-0.414***
	(0.110)	(0.116)	(0.110)	(0.109)	(0.118)
Disagreement (Climate Change)	-0.415**	-0.919***	-0.285*	-0.554***	-0.943***
	(0.165)	(0.174)	(0.165)	(0.163)	(0.177)
Neutral (Climate Change)	-0.312***	-0.322***	-0.166	-0.388***	-0.316**
	(0.117)	(0.124)	(0.118)	(0.116)	(0.126)
Disagreement (Ethical Cons.)	-0.220*	-0.161*	-0.219*	-0.163*	0.104*
	(0.176)	(0.186)	(0.177)	(0.175)	(0.190)
Neutral (Ethical Cons.)	-0.245**	-0.235*	-0.358***	-0.222*	-0.347***
	(0.116)	(0.123)	(0.117)	(0.115)	(0.125)
Disagreement (Animal suffering)	-0.602***	-0.548**	-0.371*	-0.426**	-0.622***
	(0.205)	(0.217)	(0.205)	(0.203)	(0.221)
Neutral (Animal suffering)	-0.378***	-0.330***	-0.312***	-0.252**	-0.299**
	(0.107)	(0.114)	(0.108)	(0.107)	(0.116)
Constant	4.174***	4.170***	4.180***	4.163***	4.198***
	(0.070)	(0.075)	(0.071)	(0.070)	(0.076)
Observations	293	293	293	293	293
R2	0.284	0.298	0.200	0.298	0.296
Adjusted R2	0.264	0.278	0.178	0.278	0.276
Note:					*p<0.1; **p<0.05; ***p<0.01

Table 3: Relationship between environmental and ethical concerns on willingness measures

The literature presented environmental and ethical concerns as drivers of acceptance (*see Appendix I*). These were reinforced by regressions presented in *Table 3*. Respondents who reported neutrality or disagreeing with negatives associated with meat consumption, particularly climate change and animal suffering, tended to show lower willingness to engage with CBM.

[41] The accuracy concerning self-reported meat consumption frequency is expected to be higher than the more abstract, self-classification into dietary type categories.

4.1.8.4 Awareness and knowledge

	Dependent variable:				
	Try	Buy	Substitute	Pay same	Pay more
	(1)	(2)	(3)	(4)	(5)
Unfamiliar (Product)	-0.324***	-0.396***	-0.263**	-0.344***	-0.419***
	(0.100)	(0.112)	(0.105)	(0.102)	(0.113)
Unfamiliar (Tech)	-0.280***	-0.266**	-0.259**	-0.240**	-0.307**
	(0.105)	(0.118)	(0.111)	(0.107)	(0.119)
Unfamiliar (Env. benefits)	-0.520***	-0.527***	-0.267**	-0.459***	-0.401***
	(0.103)	(0.115)	(0.108)	(0.105)	(0.116)
Unfamiliar (Eth. benefits)	-0.354***	-0.271**	-0.376***	-0.407***	-0.400***
	(0.105)	(0.117)	(0.110)	(0.107)	(0.118)
Constant	4.290***	4.302***	4.281***	4.268***	4.311***
	(0.061)	(0.068)	(0.064)	(0.062)	(0.069)
Observations	293	293	293	293	293
R2	0.414	0.357	0.282	0.394	0.369
Adjusted R2	0.405	0.348	0.272	0.386	0.361
Note:					*p<0.1; **p<0.05; ***p<0.01

Table 4: Relationship between familiarity with CBM and different willingness measures

Research showed that prior awareness and knowledge of novel food technologies, particularly CBM, positively affected consumer acceptance (Rolland, Markus & Post, 2020; Mancini & Antonioli, 2019). The regressions in *Table 4* strongly confirmed these findings. Consumer willingness to engage with CBM across all measured dimensions is substantially lower where there was pronounced unfamiliarity with the concept and technology of CBM.

4.1.8.5 Perception of risks and emotions

	Dependent variable:				
	Try	Buy	Substitute	Pay same	Pay more
	(1)	(2)	(3)	(4)	(5)
Safety	0.406***	0.276***	0.391***	0.359***	0.187***
	(0.050)	(0.055)	(0.053)	(0.048)	(0.058)
Healthy	0.211***	0.356***	0.105**	0.254***	0.327***
	(0.050)	(0.055)	(0.052)	(0.047)	(0.058)
Natural	0.073*	0.053*	0.080*	0.077*	0.098*
	(0.049)	(0.054)	(0.051)	(0.046)	(0.057)
Disgust	-0.081**	-0.045*	-0.139***	-0.046	-0.082
	(0.047)	(0.052)	(0.049)	(0.044)	(0.055)
Danger (Product)	-0.152***	-0.125**	-0.090*	-0.048	-0.022
	(0.048)	(0.053)	(0.051)	(0.046)	(0.056)
Danger (Technology)	-0.047***	-0.063**	-0.008	-0.070	0.088
	(0.053)	(0.058)	(0.056)	(0.050)	(0.062)
Threat to culture	-0.063**	-0.183***	-0.124**	-0.085*	-0.215***
	(0.047)	(0.051)	(0.049)	(0.044)	(0.054)
Constant	0.836***	0.856***	1.441***	0.578***	0.679***
	(0.184)	(0.203)	(0.193)	(0.174)	(0.214)
Observations	293	293	293	293	293
R2	0.504	0.471	0.394	0.558	0.432
Adjusted R2	0.492	0.458	0.379	0.547	0.418
Note:					*p<0.1; **p<0.05; ***p<0.01

Table 5: Relationship between perception of risks and emotions on willingness measures

Following the literature (*see Appendix I*), the results in *Table 5* confirmed that perceptions of risks and emotions were strong predictors of consumer attitudes. Individuals who deemed CBM

safe, healthy, and natural were more willing to engage with it across all dimensions. Alternatively, feelings of disgust or danger concerning CBM and its underlying technology reduced willingness to engage. Also, notions that CBM may pose threats to cultural heritage reduced willingness.

The foregoing analysis provided an overview of current levels of consumer acceptance towards CBM. Further, determinants of consumer acceptance were also identified. Our findings served as the basis for conclusions discussed in *Chapter 5.1.1.*

4.2 Investments in cell-based meat ventures

Expert interviews were also conducted with individuals from the venture capital and CBM domains. Outcomes were analyzed using open coding and thematic analysis (*see Chapter 3.2.2*). The coded thematic categories are outlined in *Appendix VIII*. Findings were triangulated using the literature review (*see Chapter 2*) and survey (*see Chapter 4.1*) to identify contradictions and convergences in the data. Final conclusions concerning the investment barriers are shown in *Chapter 5.1.2.*

4.2.1 Reasons for lack of investments in cell-based meat ventures

The order in which reasons are presented reflects their relative importance, as indicated by the frequency of mentions by the experts.

4.2.1.1 Technology and infrastructure immaturity

The literature described CBM being at a stage of technological and infrastructural immaturity, which are limiting factors. Technological challenges revolve around scalability, medium development, cell-culture productivity, and tissue engineering. Reaching parity on key product characteristics, such as taste, texture and visual appearance will take time (ES6). Further, unfavorable economics associated with producing CBM further currently preclude viable commercialization (*see Chapter 2.3.2.1*). The experts were unanimous that CBM's lack of maturity was the major barrier to higher investment allocations. More specifically, lack of infrastructure, for instance bio-processing plants, was raised by several experts (ES1, ES2, ES3, EVC1, EVC2, EVC3, EVC4, EVC5). The capital-intensive build-out required to transition from R&D and pilot phases to industrial-scale production raises questions concerning if and when price parity can be achieved (ES2, EVC1, EVC4, EVC5).

4.2.1.2 Lack of consumer awareness, knowledge and acceptance

Awareness and knowledge acquisition are critical for consumer technology acceptance (Rogers, 2003). Although consumers from WEIRD societies[42] tend to be more environmental, ethical, and health conscious, awareness of negative externalities regarding meat remains a "bubble" (EVC2, EVC3, EVC4). Since COP15 (*see Chapter 2.4*), public awareness of climate change has risen. However, the institutional focus has been on mobility, transportation, and energy, with comparatively little attention devoted to the food domain (ES1, ES3, EVC2). EVC2 noted that food was on the agenda at the COP-level for the first time in 2023. Our consumer survey reinforced this as only two-thirds of respondents acknowledged negative externalities associated with meat consumption (*see Chapter 4.1.4*).

Among alt-proteins, CBM remains the most controversial (ES2, EVC2) and even pre-commercialization, the sector faces adverse opinion. Research demonstrates conflicting results concerning overall consumer awareness and acceptance levels. Although consumer willingness to engage is high, concerns about food safety, healthiness, and naturalness, endure. These exacerbate issues such as food neophobia and technophobia (*see Appendix I*). Expert insights were reinforced by the survey (*see Chapters 4.1.5 and 4.1.7*). Several experts confirmed that consumers must be educated to fully understand CBM (ES1, ES2, ES3, EVC1, EVC2, EVC3, EVC5). Reaching mainstream consumer awareness, understanding, and acceptance of CBM will take years (ES1, ES2, EVC2, EVC6). This presents a significant barrier to investment into retail CBM ventures.

4.2.1.3 Uncertain regulatory environment and lack of institutional funding

Several governments and institutions have launched CBM programs. However, regulatory uncertainties surround novel food technologies, specifically regarding review and approval processes (*see Chapter 2.3.2.3*). This is particularly evident for CBM due to its deep-tech nature (ES1). Singapore, Israel, and the United States are frontrunners in establishing regulatory frameworks for CBM commercialization, but other countries remain reluctant. The fragmented regulatory environment within key regions, such as the EU, is perceived as a major barrier to investment by most experts (ES1, ES2, EVC2, EVC3, EVC4, EVC5). This reinforces the finding that policy uncertainties negatively affect VC activity (*see Chapter 2.4.2*). ES3 strongly believed that numerous VC funds are monitoring regulatory situations closely and will commit

[42] WEIRD, introduced by Henrich, Heine, and Norenzayan (2010), stands for Western, educated, industrialized, rich and democratic. The notion will be picked up again in *Chapter 5.2.1*.

significant capital once governments greenlight the technology. On the other hand, ES1 argued that EPU should not deter VC investments since CBM ventures could initially focus on countries that permit commercialization and then expand into other key markets in tandem with regulatory approvals. Several experts stated that intense lobbying is critical for educating policymakers and regulators on CBM to expedite approval processes (ES1, ES3, EVC2). EVC4 stated that larger geographical markets would facilitate commercialization. Additionally, most experts concurred that institutions and governments are facilitators and catalysts of awareness and acceptance. For instance, transparent, consistent, and pragmatic labeling regulations across markets would help consumers differentiate between different types of meat, fostering feelings of trust and safety. This may lead to greater willingness among consumers not only to try CBM, but regularly consume it CBM (ES1, ES2, ES3, EVC2, EVC3). Additionally, non-equity funding, for instance risk-free governmental grants or equipment leasing, was perceived as necessary (ES1, EVC2). EVC3 adds that regulators' leniency toward meat incumbents, concerning environmental quotas that must be fulfilled, are keeping the industry's "pressures to change" at bay.

4.2.1.4 Fund structures, investment horizons, and risk tolerances

Venture capital fund structures, investment horizons, and risk tolerance pose significant barriers to investment in the alt-protein sector, and for CBM in particular. The DCF trap and notion of the capitalist's dilemma prioritize short-term ROIs over longer-term prospects achieved through DI (*see Chapter 2.1.1*). This was reinforced unanimously by the experts. The conventional "Silicon Valley VC model", characterized by pushing for expeditious exits does not align with the resource-intensive and time-truncated nature of CBM where investors seek quick, double-digit returns, which CBM does not offer (ES1, ES2, ES3, ES5, EVC2, EVC3, EVC4, EVC5). Although ESG-oriented funds may have adjusted time horizons and ROI expectations, capital still concentrates on shorter-term opportunities. Several experts reported that the investment community perceives CBM as highly risky. Experience-based customer feedback is scarce, leaving room for ample speculation about future demand – a critical factor for VCs evaluating investments in consumer-facing food ventures (ES3, EVC4). The experts unanimously agreed that current investor risk tolerance and impatience hinder capital flows. ES1 highlighted that European VCs, in particular, are too risk-averse to invest in CBM ventures. However, EVC4 remarked that investment horizons will likely change as the more capital-intensive "deep tech era" commences.

4.2.1.5 Inefficient capital markets

Cox et al. (2022) noted that although the public and private sectors are committing substantial capital to achieve net-zero goals, capital markets remain inefficient when it comes to investing for climate outcomes (*see Chapter 2.4.2*). The flow of capital into climate technologies does not align with the climate change impact of particular sectors benefitting from substantial capital inflows. Most experts attribute this to fund structures, investment horizons, and risk tolerances, as previously discussed.

Investors deploy funds to climate technologies that promise quicker ROIs at the expense of higher emissions savings (EVC2, ES3, ES4, ES6). EVC2 suggested that mass media contributes to this since capital flows tend to follow public opinion. Capital market inefficiency may be perceived as another barrier to more substantial investments into CBM.

4.1.2.6 Lack of alternative protein success stories

According to ES2, ES3 and EVC4, the lack of success stories within the greater alt-protein domain presents another notable impediment. Despite significant attention and funding that Beyond Meat, Impossible Foods Inc., and other plant-based protein players attracted, there are increasing concerns about alt-proteins' long-term growth and profitability (ES2, EVC3). After Beyond Meat's IPO in 2019, investors betting on plant-based meat alternatives caused shares to skyrocket. Four years later, Beyond Meat's stock has plummeted nearly 83% as sales slumped across all channels (Shanker, 2023). Decreasing net revenues, negative gross margins, and net losses in excess of $360 million have shaken investor confidence (Beyond Meat, 2023). From EVC3's corporate perspective, PBM's short-term limitations[43] have compromised attractiveness of the sector. Overall, after years of cheap capital and burgeoning valuations, the current correction triggered by rising interest rates and inflation makes investors more risk averse (EVC1). The cyclical downturn and absence of "big wins" in more mature segments of alt-proteins has spilled over into CBM (ES2).

4.2.1.7 Business model uncertainty and societies' long-term needs

EVC3 even questioned CBM's raison d'être. He hypothesized that society's future needs, in terms of healthy and balanced nutrition, are more appropriately addressed by ensuring access to safe protein rather than replicating meat. The expert acknowledged bio-technological

[43] Referring to the width of plant-based companies' product portfolios and ability to replicate conventional meats.

progress within the field but raised doubts about whether current end-consumer product-focused business models satisfy long-term market needs. Although alt-meat's environmental and ethical benefits are clear, reducing per capita meat consumption would yield a more significant impact, according to the expert. Both, EVC3 and EVC4 stressed that gradually reducing meat consumption would yield far greater societal benefits.

Chapter 5: Conclusions

The final chapter summarizes results and discusses limitations and areas for future research.

5.1 Main findings

Findings in the previous chapter inform our assessment of CBM's disruptive potential.

5.1.1 Current levels of consumer acceptance

Overall, our survey indicated substantial levels of consumer CBM acceptance. Although aware of the effects of meat on the environment and cognizant of ethical concerns, the influence of these was lower than expected. CBM is accepted as a viable alternative to conventional meat (*see 4.1.7.1*). Health, rather than the environment and ethics, are primary motivators for considering CBM a substitute. This contrasts with the extant literature (*see Appendix I*). Nonetheless, awareness of the consequences of meat consumption for climate change and animal welfare emerged as strong predictors of acceptance. Similarly, prior familiarity with the concept of CBM, its technology, and benefits are also positively associated with acceptance. Contrary to the literature, self-reported familiarity with CBM was high in the cohort surveyed.

Rogers (1983) and Davis (1989) highlighted psychological and cognitive factors for acceptance and diffusion of innovations (*see Chapter 2.1.3*). Consumers perceived CBM as safe, healthy, and natural, though feelings of disgust and fear about the technology were reported. Notions of food neophobia and technophobia concerning CBM raised in the literature were confirmed (*see Appendix I*). Consumers who reported positive feelings along the dimensions tested were significantly more willing to accept CBM. The product attributes that shape meat purchasing decisions are affordability, taste, visual appearance, texture, and smell. Conventional meat is perceived as marginally superior compared to PBM or CBM. Among the three, CBM was the least favorable option. Differences between conventional meat and the two alternatives reinforced that parity in price and sensory characteristics is essential for adoption.

5.1.2 Barriers to investments in cell-based meat ventures

Alt-proteins are expected to make up approximately 11% of the global protein market by 2035 (*see Chapter 1*). This is premised on alt-proteins' ability to gain parity with animal proteins in taste, texture, and price. CBM's potential to replicate conventional meats sets it apart from other emerging alternatives. However, this quality comes with costs and risks that private and

corporate investors seem reluctant to assume. Several barriers to investment were identified. Technological challenges revolving around tissue engineering and the scalability of production are a major issue. The investment community views the enormous capex requirement as highly risky. Short and mid-term production economics favor low-volume, high-value specialty products. This precludes reaching price-sensitive mainstream customers, which, in turn, is critical for investments in the field. Assuming that key challenges can be resolved, the minimum price for a kilogram of cell-based beef may be reduced to merely $2 (Risner et al., 2021).

At present, there is limited awareness of alt-proteins, and in particular, CBM. Although experts reported trends toward greater awareness of meat consumption's negative externalities, this remains a peripheral phenomenon in developed countries. Building awareness, fostering understanding, and gaining acceptance among mainstream consumers will take time. The regulatory environment remains uncertain across highly fragmented geographies, which stymies investment. Governmental inconsistencies, for instance, concerning labeling practices[44], provokes consumer distrust.

CBM's resource-intensiveness further does not match capital allocators' short-term investment horizons and ROI expectations. There is a limited universe of ESG funds investing with longer-term ROI expectations. Investment into climate tech is also not rationally related to a sector's ability to impact greenhouse gas emissions. The overall attractiveness of the alternative meat domain has decreased since COVID-19. The pullback within more mature segments of alt-proteins has given investors pause. Finally, current end-product-oriented business models deployed by most CBM ventures provide limited societal impact.

5.1.3 Disruptive potential of cell-based meat

Peter Drucker famously said that "[...] no human being can possibly predict the future, let alone control it" (2011). This statement applies to the complex problem of assessing CBM's potential to become a disruptor in the billion-dollar meat industry. Our analysis shed light on determinants and inhibitors of consumer acceptance, and investment flows into CBM. These insights are the basis for our scenario analysis. Shoemaker's (1995) scenario planning approach involves creating multiple plausible future scenarios based on relevant dynamic factors. In

[44] Untransparent labelling practices are perceived as a major barrier across the overall alternative protein industry.

contrast with other planning methods[45], this seeks to transform "data [turned] into a limited number of possible states" (p. 26).

As visualized in *Figure* 18, building blocks depict drivers of change, which are divided into basic trends and key uncertainties. Cause-and-effect relationships between drivers that contour scenarios are considered.

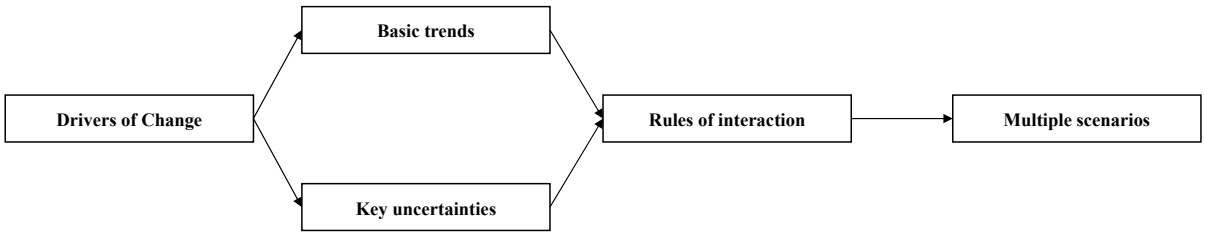

Figure 18: Shoemakers' building blocks of scenario planning (1995)

A simplified version of Shoemaker's scenario planning approach was used as a management tool to assess CBM's disruption potential, focusing on consumer and investment dimensions. Limitations of this simplification are discussed in *Chapter 5.3.2*.

5.1.3.1 Possible scenarios

Basic trends and key uncertainties presented in *Table 11* in *Appendix IX*, were identified. The correlations in *Table 12* in *Appendix IX* indicated relationships between identified uncertainties. According to Shoemaker (1995), although more sophisticated procedures exist, the correlation matrix "is a practical way for assessing a scenario's consistency" (p. 32). Three scenarios positing CBM's disruptive potential for the meat industry are shown in *Figure 19*. The weights applied to a "Yes" answer for each of the eleven uncertainties resulted in two extreme and one median scenario (Shoemaker, 1995). Weightings per uncertainty were determined based on our analyses.

Three scenarios lay out different disruption trajectories with the "piece-of-the-puzzle" scenario emerging as the most probable. It proposes that although consumer awareness of meat's negative environmental and ethical consequences is rising and individuals seek to mitigate these factors, mainstream adoption of CBM is unlikely in the short or mid-term. For the average consumer, price remains critical. CBM's production economics, however, preclude commercialization for price-sensitive mainstream consumers.

[45] Among others, contingency planning, sensitivity analysis and computer analysis are emphasized by Shoemaker (1995).

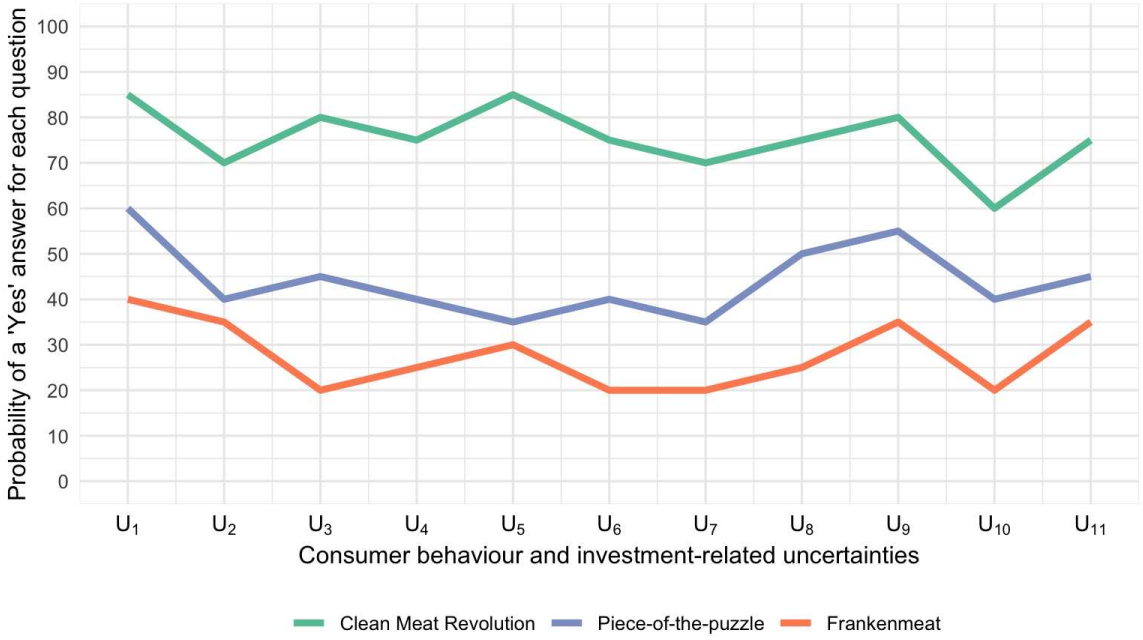

Figure 19: Scenarios of CBM's disruption potential

Furthermore, complex technology challenges detract from consumer acceptance. Amidst rising demand for alt-proteins, no "winner-takes-all" scenario on a company or product-level can be anticipated. In the light of a more capital-intensive "deep tech" century, VCs are expected to lengthen investment horizons. Yet, investor tendencies to prioritize quick ROIs continue to prevail. This tendency reinforces notions of the capitalist's dilemma and the DCF trap, which, in turn, sustains capital market inefficiencies in climate tech investing. Although investments in alt-proteins are increasing, flows into CBM remain weak. Meanwhile, governments and institutions continue pursuing climate objectives. The environmental footprint of global food systems is increasingly scrutinized. However, regulatory hurdles and lack of public funding prevent CBM from gaining momentum among consumers and the investment community.

5.1.3.2 Disruptiveness of cell-based meat

CBM's potential to become a disruptive force in the global meat industry in the short or mid-term may be considered relatively low. Following Roger's classification, CBM appeals primarily to the innovator segment. This suggests it will remain a niche product for the foreseeable future. As technology progresses, higher perceived usefulness (PU) and perceived ease of use (PEOU) can be expected. According to Davis, increased PU and PEOU may stimulate greater consumer acceptance and help CBM move toward mainstream markets. Nonetheless, CBM will continue being technology rather than demand-driven. High levels of uncertainty and experimentation on both the product and process levels suggest that CBM will remain in what Abernathy and Utterback (1978) termed the fluid phase. In sum, given

technological challenges, CBM gaining significant traction is not envisaged in the short or medium term.

To conclude, framing CBM as hype does an injustice to this promising technology. However, its potential to disrupt the billion-dollar meat industry is relatively low. CBM becoming a minor "piece-of-the-puzzle" in the transition towards more sustainable food systems is more likely. While technological advancements determine how CBM can be viably produced, manufacturers, investors, governments, and ultimately consumers will decide whether it emerges as a greater success story.

5.1.4 Theoretical and practical implications

Our research contributes to a growing body of literature that, to date, has focused primarily on the technology and consumer behavior. Drawing upon prominent management literature and frameworks, CBM's disruption potential was assessed based on technology disruption, diffusion, and acceptance.

Overall, our findings differed from Christensen's perspective on typical disruptive trajectories[46] whilst confirming the importance of consumer acceptance for innovation diffusion. Furthermore, this research stressed the importance of capital markets for the maturation of deep-tech ventures. We highlighted investment inefficiencies that hinder progress in sectors that provide high decarbonization levers.

The consumer behavioral component highlighted that a lack of awareness concerning meat consumption's environmental and ethical consequences and a knowledge lacuna concerning CBM have adverse effects on individuals' willingness to engage. The finding that consumers are generally open to CBM also provided valuable insights for startup fundraising or investor evaluation criteria. The investment component contributes to understanding commercial challenges faced by the sector. Our overall findings concerning CBM's disruptive trajectory are potentially valuable for startups, investors, and policymakers.

[46] CBM enters the meat industry via the higher-end rather than lower-end footholds of the market by overshooting performance expectations of the mainstream consumer.

5.2 Limitations

This thesis has limitations that affect the generalizability of findings.

5.2.1 Survey

Data collected via a self-reported online survey have inevitable inaccuracies (Bryman, 2016). One issue was use of service providers, such as Amazon MTurk. Two data quality measures were included to identify invalid responses. The resulting sample size (n = 293) was representative when compared to peer-reviewed studies in the field. The study was conducted internationally, however roughly 95% of respondents were in the US. Also, the population was rather homogenous across several demographic variables. Thus, it was not possible to assess properly how demographics influenced consumer acceptance. Henrich, Heine and Norenzayan (2010) concluded that this is a common problem for research with human subjects. WEIRD[47] populations, who "are some of the most psychologically unusual people on earth" (p.29), further skewed findings.

5.2.2 Expert interviews

Semi-structured interviews only cover a limited scope and depend on researcher discretion. The interview guide created through an inductive process and informed by the literature review may have introduced biases. Time and resource constraints in sampling experts and privileging those who were easily accessible and willing to speak potentially inhibited collecting more diverse and contrasting views. However, the overall quality of experts was high. Two experts provided insights via e-mail, foreclosing detailed insights gained from live discussion. Of the remaining ten interviews, four declined to be recorded requiring memory-based recollection. Although open-coding and thematic analysis provide a standardized approach to qualitative analysis, interpretation biases may not have been fully avoided.

5.2.3 Implications on findings

As discussed, various limitations reduce the reliability and generalizability of our findings. Shoemaker's scenario planning approach also had implications for our conclusions. Scenarios were created from survey outcomes and expert interviews, but the probabilities of each scenario were based on hypothetical situations. Clearly, CBM is still in its infancy and developments are dynamic and uncertain. Hence, scenarios may not be comprehensive enough to capture all

[47] WEIRD stands for Western, educated, industrialized, rich and democratic study subjects.

relevant factors and potential outcomes. Finally, our research scope excluded meat industry incumbents facing a potentially disruptive threat of substitution. Incumbents' behavior influences a disruptor's trajectory and is relevant for assessing CBM's potential future (Schuelke-Leech, 2018; Klenner, Hüsig, & Dowling, 2013).

5.3 Future research

Future researchers could investigate larger and more demographically diverse consumer populations to find determinants of consumer acceptance. Also, contrasting countries that allow CBM commercialization (i.e., Singapore or Israel) with those that do not (i.e., Italy) would yield insights. Moreover, longitudinal studies to monitor changes in consumer attitudes and behaviors over time, alongside technological, regulatory, and overall industry progress, might result in alternative evaluations of CBM's disruptive potential. Experts from additional stakeholder groups, such as governments, policymakers, governmental and non-governmental organizations, and institutions, should also be interviewed.

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Appendices

Appendix I: In-depth review of determinants of consumer acceptance

Although in its infancy, cell-based meat (CBM) alternatives continue to attract consumer attention (Onwezen et al., 2021; Pakseresht, Ahmadi Kaliji & Canavari 2022). Research shows that consumer attitudes and beliefs play a vital role in accepting novel food technologies (Mancini & Antoniolo, 2020; Pakseresht, Ahmadi Kaliji, & Canavari, 2022). Numerous studies suggest that consumers have ambivalent attitudes about accepting cultured meat (Verbeke, Sans & Van Loo, 2015; Wilks & Phillips, 2017). There is a growing body of literature devoted to consumer perception, attitudes, and tendencies to accept this novel food technology (Bryant & Barnett, 2020).

A complex range of factors influence consumer food perception, attitudes, and acceptance. These can be broadly categorized into (a) product-related factors, (b) individual-related factors, and (c) contextual factors (Chen & Antonelli, 2020). Research shows that product-related factors and personal factors are strongly associated with the acceptance and consumption of CBM and other meat substitutes (Bryant et al., 2019; Siegrist & Hartmann, 2020; Verbeke, Sans & Van Loo, 2015). Hence, contextual factors, such as the environment in which food is consumed, will be excluded from our literature analysis. Pakseresht, Ahmadi Kaliji and Canavari (2022) extend Chen and Antonelli's categorization by introducing seven key themes that elaborate bibliographic analysis of existing literature (n = 43). These include (1) public awareness and knowledge, (2) risk-benefit perceptions, (3) ethical and environmental concerns, (4) emotions, (5) personal factors, (6) product properties, and (7) alternatives and availability. Additionally, Rombach et al. (2020) differentiate between factors that either drive or inhibit perception and consumption. Most qualitative reviews and quantitative studies deploy a comparable approach with negligible semantic deviations so themes identified guide the subsequent analysis (de Oliveira Padilha, Malek & Umberger, 2022; Rombach et al., 2022; Bryant and Barnett, 2020).

Public awareness and knowledge

Consumer awareness and knowledge are critical for acceptance of meat alternatives (Verbeke, Sans, & Van Loo, 2015). Even though these terms are often used interchangeably there are distinctions. In the context of innovation diffusion, Rogers (2003) considers awareness as the first criterion and knowledge acquisition as the second stage in the consumer technology

acceptance process. Past research has shown that consumer skepticism towards novel food technologies is often attributed to *lack of awareness of respective technologies* and their inherent advantages (Pakseresht, Ahmadi Kaliji, & Canavari, 2022). Rolland, Markus and Post (2020) investigated the effect of information on acceptance of cultured meat among Dutch consumers (n = 193). They argued that "previous awareness of cultured meat was the best predictor of its acceptance" (p.1). Mancini and Antonioli (2019) reinforce these findings as "participants familiar with cultured meat showed a more positive attitude towards cultured meat […] compared to those lacking any familiarity with the topic" (p. 105). The link between (*knowledge regarding new food production technologies* and attitudes has been extensively elaborated (Pakseresht, Ahmadi Kaliji, & Canavari, 2022). Prominent literature on CBM has pointed to consumer knowledge deficiencies. Siegrist, Sütterlin and Hartmann (2018) show that additional *information* about the production process reduced perceived unnaturalness, increasing consumer acceptance. A study among Belgian consumers (n = 180), by Verbeke, Sans and Van Loo (2015), showed that additional information about benefits of cultured meat over traditional meat resulted in 43% of participants indicating willingness to try CBM.

Risk-benefit perceptions

The literature also highlights the role of the risk-benefit trade-off on consumer attitudes towards food technology innovations, though most research focusses on inherent benefits rather than risks (Pakseresht, Ahmadi Kaliji, & Canavari, 2022). The *safety* and nutritional qualities, ergo *healthiness*, of CBM are perceived as risky by some consumers. Furthermore, notions of *unnaturalness* prevail (Bryant & Barnett, 2020). A study among Belgian, Portuguese and British consumers (n = 179) found that CBM is perceived to have no desirable attributes. Instead, "a number of concerns were expressed about the potential negative long-term effects on human health" (Verbeke et al., 2015, p. 54). Bryant and Barnett (2020) support this claim stating that a "common concern reported by consumers […] was that cultured meat could be generally unhealthy or nutritionally inferior to conventional meat" (p. 16). Experiments conducted by Siegrist and Sütterlin (2017) even revealed that health risks associated with meat consumption were much more accepted for conventional meat compared with cultivated meat. Furthermore, Verbeke et al. (2015) noted that when thinking about long-term consequences, consumers stated that genetically modified foods and animal cloning invoked notions of unnaturalness. Numerous studies have shown that "perceived unnaturalness […] was often at the root of disgust and health and safety concerns" (Bryant & Barnett, 2020, p.15). Naturalness is a key food attribute among consumers, strongly associated with authenticity, to create

feelings of trust, transparency, and control (Quevedo-Silva & Pereira, 2022). Hence, consumers may be inclined to question *food safety* as "cultivated meat can evoke notions of the 'adulteration of nature' compared with other food technologies" (Quevedo-Silva & Pereira, 2022, p. 4). Gómez-Luciano et al. (2019) concluded that although cultured meat was considered tastier than other alternative proteins, it was generally perceived as the least healthy, nutritious, and safe option.

Bryant and Dillard (2019) and Bekker et al. (2017) placed these findings into perspective. The researchers demonstrated that *framing effects*, coined by Tversky and Kahneman (1989), have a statistically significant impact on explicit and implicit attitudes towards CBM. Hence, the information provided, being either positively or negatively connotated, determines consumer acceptance. Terminology used (I.e., usage of "cultured meat" rather than "artificial" and "lab-grown" meat) seems to have an impact (Asioli, Bazzani & Nayga, 2022). Since consumer perceptions and attitudes to date are information rather than experience-based absent large-scale commercialization of alt-proteins, framing is especially relevant.

Environmental and ethical concerns

As previously discussed, meat demand is on the rise globally. This implicates *animal welfare* and *environmental concerns*. Previous research shows that "avoiding animal suffering and slaughter was one of the major perceived benefits of cultured meat" (Bryant and Barnett, 2020, p.13). Moreover, Weinreich, Strack und Neugebauer (2020) found that animal welfare and ecological concerns were the strongest positive driver of consumer acceptance towards CBM. Mancini and Antonioli (2019) further stipulated that these concerns not only increase acceptance and adoption of CBM, but also influence willingness-to-pay a premium. Some consumer studies find that environmental benefits of CBM, particularly concerning reducing greenhouse gas emissions, even outweigh animal welfare benefits (Pakseresht, Ahmadi Kaliji, & Canavari, 2022; Bryant and Barnett, 2020). Yet, despite acknowledging animal welfare and environmental benefits of CBM, some consumers remain reluctant (Circus and Robison, 2019). Verbeke et al. (2015) found that although consumers encouraged CBM to address global food security issues, they exhibited personal disgust. This paradox of global advocacy yet personal aversion "could be interpreted as a type of contradictory 'Not In My Backyard' or NIMBY attitude" (Circus & Robison, 2019, p. 535). Generally, these findings indicate that consumer acceptance does not imply intent to consume.

Personal factors and emotions

Past research has shown that demographic factors, such as *age*, *gender*, *education*, *culture*, *dietary preferences*, *meat consumption patterns*, *socioeconomic status,* and *political orientation* are associated with CBM acceptance (Bryant & Dillard, 2019; Bryant & Barnett, 2020; Zhang, Li, & Bai, 2020). CBM appeals more to younger than older people (Bryant & Dillard, 2019; Mancini & Antonioli, 2019; Weinreich, Strack, & Neugebauer, 2020; Zhang, Li, & Bai, 2020). Wilks and Phillips (2019) reported that based on a consumer study conducted in the United States (n = 673), men were generally more receptive to CBM than women. Additionally, Bryant and Barnett (2020) identified "higher education as a predictor of CBM acceptance" (p. 12). Van Loo, Caputo & Lusk (2020) show that young, well-educated male subjects tend to show a relatively strong preference for CBM compared to females. However, Wilks and Phillips (2019) indicated that age and gender are stronger predictors of acceptance than education. Siegrist and Hartmann (2020) conducted a survey (n = 6,128) across ten countries[48]. Their findings suggest large cultural differences with regard to accepting CBM. For instance, "consumers in France showed significantly lower levels of acceptance compared with those in the other nine countries" (p. 5) Various studies confirm that consumers from Belgium, the UK, Spain and Italy appear more amenable to CBM, whilst German and especially French consumers are less enthusiastic (Bryant & Barnett, 2020; Gómez-Luciano et al., 2019; Mancini & Antonioli, 2019; Siegrist & Hartmann, 2020). Furthermore, shifting dietary preferences and overall (meat) consumption patterns impact CBM acceptance. Bryant and Barnett (2020) found that CBM "tends to be more appealing to meat-eaters compared to vegetarians" (p. 12). Wilks and Phillips (2017) demonstrated an evident paradox as meat restrictive consumers (vegetarians or vegans) appear less willing to engage with CBM. Circus and Robison (2019) findings, Bryant and Barnett (2020) found that "cultured meat seems to be more appealing to those who are higher in meat attachment, indicating that it may be the future protein of choice for most committed carnivores" (p.12). However, Wilks and Phillips (2017) remarked that participants who had a higher reported percentage of meat in their current diet tended to express fewer favorable views on CBM. Additionally, Gómez-Luciano et al. (2019) stated that higher socio-economic status, measured by consumer household income, correlated with a higher willingness to consume CBM. However, Bryant and Barnett (2020) pointed out that existing studies present contradictory results, hence the balance of data is unclear. Furthermore, Wilks and Phillips (2017) discussed political orientation as an influence on CBM acceptance. Their study

[48] Australia, China, England, France, Germany, Mexico South Africa, Spain, Sweden and the United States

illustrated that those "who identify on the political left were more willing to try CBM than those on the political right" (p. 10).

Emotions also play an important role in attitude and belief formation towards novel technologies (Pakseresht, Ahmadi Kaliji, & Canavari, 2022). *Food neophobia*, rooted in culture and risk perceptions, contribute to reluctance to consume novel foods (Quevedo-Silva & Pereira, 2022). In the case of CBM, Verbeke, Sans and Van Loo (2015) show that food neophobia includes fear of unfamiliar technology and unknown risks. Besides, general suspicions of food science technologies and their unknown long-term effects negatively impacted attitudes towards CBM (Wilks et al., 2019). Additionally, the notion of unnaturalness previously mentioned provokes feelings of *disgust* towards CBM (Siegrist & Hartmann, 2020). Verbeke et al. (2015) concluded that *disgust sensitivity* is a principal barrier to acceptance. Egolf, Hartmann and Siegrist (2019) further argued that consumers who described CBM as "disgusting" also perceived it as riskier and demonstrated overall lower willingness to engage with meat alternatives.

Product properties, availability and alternatives

Product properties such as *price*, *sensory appeal* and *nutritional content* are the most important factors that influence food choice (Pakseresht, Ahmadi Kaliji, & Canavari, 2022). Studies suggest that the availability of novel foods at reasonably low prices leads to greater consumer acceptance (Bekker, Tobi, & Fischer, 2017; Verbeke, Sans, & Van Loo, 2015). Wilks and Phillips (2017) reported that consumers were unlikely to pay a premium for CBM. Zhang and Bai (2020) affirmed price sensitivity from a study among Chinese consumers (n = 1,004) where willingness-to-pay (WTP) was just 2.2% above the price of conventional meat. Verbeke, Sans and Van Loo (2015) reinforced that price, in light of current production costs, remains a major obstacle. Additionally, Bryant and Barnett (2020) argued that *sensory appeal* remains a key determinant of consumer acceptance. The researchers suggested that "consumers tended to expect cultured meat to be worse tasting than conventional meat, and to have inferior texture and appearance" (p. 19). Mancini and Antonioli (2019) added that taste strongly predicted acceptance and subsequent purchase intent. Overall, research agreed that rather than environmental and health concerns, sensory characteristics such as taste, texture, appearance and aroma were more important determinants of consumer acceptance and purchase intent (Verbeke et al., 2015; Wilks and Phillips, 2017; Gomez-Luciano et al., 2019).

Across developed countries, a growing tendency to substitute meat with alternative protein sources is prevalent (Grasso et al., 2019). In general, adoption of alternative proteins depends on the *availability* of the product in the market (Gómez-Luciano et al., 2019; Mancini & Antonioli, 2019). Grasso et al. (2019) examined consumer acceptance of alternative proteins in the European Union and concluded that "plant-based protein was the most accepted alternative, more sustainable protein source (58%), followed by single-cell protein (20%), insect-based protein (9%), and in vitro meat-based protein (6%)" (p. 1). Overall, researchers noted that availability and acceptance related to successful commercialization of alternative protein sources had a significant impact (Grasso et al., 2019; Mancini & Antonioli et al., 2019).

Appendix II: Investments in climate tech-, alt-protein- and cell-based meat ventures

Climate technology	**Total investments raised** (in $b)	**Total number of investments** (since 2013)	**Impact on capital employed** (in $billions per $1 trillion invested)	**CO_2 – savings** (in gigatons) **per $1 trillion invested**
Light-duty battery electric vehicles	50 (in 2020 alone)	n.a.	22 – 35	0.4
Low-GHG heavy duty vehicles[49]	90 (in 2020 alone)	n.a	3-6	0.1
Power	750 (in 2020 alone)	n.a	13-21	0.3
Alternative protein(s)	11,10 (since 2013)	939 (since 2013)	221 – 345	4.4
Spread across:				
Plant-based protein(s)[50]	6,36	590		
Mirco-organism based protein(s)	2,81	161		
Cell-based protein(s)	1,93	188		

Table 6: Investments in climate technology, alt-protein and CBM ventures

These estimates are based on findings of Morach et al. (2022) and Kozloski et al. (2022).

[49] Including aviation
[50] Investment details include dairy segment

Appendix III: Conceptual model

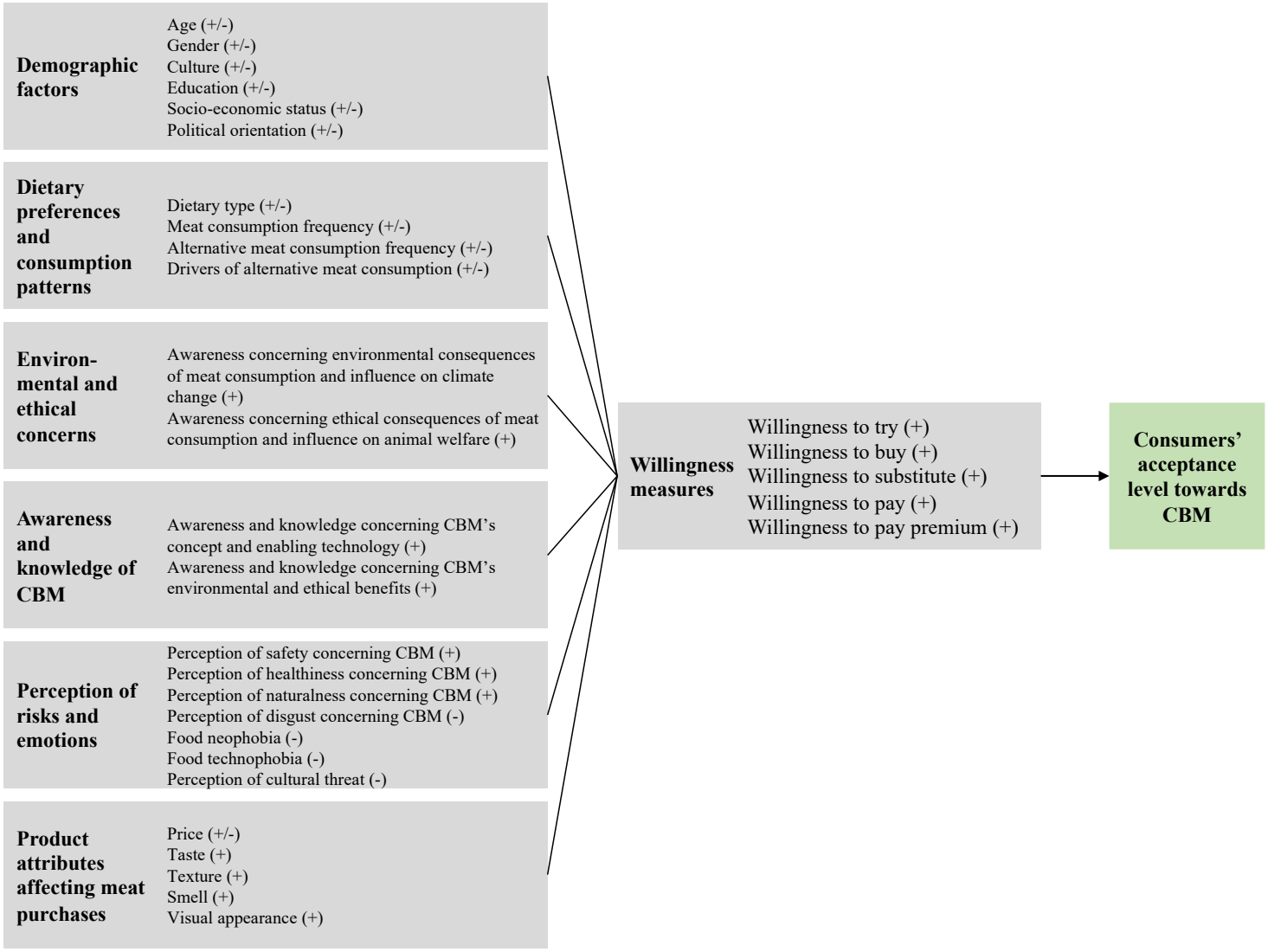

Figure 20: Conceptual model

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Appendix IV: Outline of survey questions

#	Question	Question Type	Answer options
1	How old are you?	Multiple choice	18 - 24 years old; 25 - 34 years old ;35 - 44 years old; 45 - 54 years old; 55 - 64 years old; 65 years and older
2	What gender do you identify with?	Multiple choice	Male; Female; Non-binary / Third gender; Prefer not to say
3	In which country do you currently reside?	Multiple choice	United States; Germany; Italy; Israel; Singapore
4	Please indicate the highest level of education you have completed or the highest degree you have achieved.	Multiple choice	Less than high school degree; High school graduate; Vocational training; Bachelor's degree (or equivalent); Master's degree (or equivalent); Doctoral degree
5	What was your total household income (in USD) before taxes in the past year?	Multiple choice	Less than $25,000; Between $25,000 and $49,999; Between $50,000 and $99,999; Between $100,000 and $199,999; More than $200,000; Prefer not to say
6	Please indicate your political affiliation or orientation.	Multiple choice	Extremely liberal; Somewhat liberal; Neutral; Somewhat conservative; Extremely conservative
7	What best describes your ethnic origin	Multiple choice	White / Caucasian; Asian – Eastern; Asian – Indian; Hispanic; African-American; Native-American; Mixed race; Other
8	Please indicate your religious affiliation, if any.	Multiple choice	Christian; Muslim; Jewish; Buddhist; Hindu; Agnostic; Atheist; Other; Prefer not to say
9	Which of the following categories (and corresponding statements) best describes your typical consumption habit?	Multiple choice	Carnivore; Omnivore; Flexitarian; Pescatarian; Vegetarian; Vegan
10	How often do you consume meat?	Multiple choice	Daily; Less than daily but more than once per week; Once per week; Once per month I do not consume meat
11	How often do you consume meat alternatives?	Multiple choice	Daily; Less than daily but more than once per week; Once per week; Once per month I do not consume meat alternatives

12	Why are you consuming meat alternatives?	Multiple choice (multiple selection possible)	Health reasons; Environmental reasons; Ethical reasons; Religious/cultural reasons; Taste; Other, please specify
13	Please indicate your level of agreement with the following statements: "Meat consumption has many consequences for the environment" "Meat consumption is a principal driver of climate change" "Meat consumption has ethical consequences" "Meat consumption leads to animal suffering"	5-point Likert scale	Strongly disagree (1) – Strongly agree (5)
14	Please indicate your level of familiarity with the concept and the enabling technology of cell-based meat: How familiar are you with the concept of cell-based meat? How familiar are you with the technology that enables the production of cell-based meat?	5-point Likert scale	Strongly disagree (1) – Strongly agree (5)
Basic information concerning the concept and enabling technology of cell-based meat was provided.			
15	Please indicate your level of familiarity with the environmental and ethical benefits of cell-based meat: How familiar are you with the environmental benefits of cell-based meat? How familiar are you with the ethical benefits of cell-based meat?	5-point Likert scale	Strongly disagree (1) – Strongly agree (5)
Basic information concerning the environmental and ethical benefits of cell-based meat was provided.			
16	Would you agree that cell-based meat is a viable alternative to conventional meat? Please select "Somewhat disagree" from the options underneath.	Quality Control Question	Strongly agree; Somewhat agree; Neither agree nor disagree; Somewhat disagree; Strongly disagree
17	Please indicate your level of agreement with the following statements: "I perceive cell-based meat as safe" "I perceive cell-based meat as healthy" "I perceive cell-based meat as natural" "I perceive cell-based meat as dangerous" "I perceive cell-based meat's enabling technology as dangerous" "I perceive cell-based meat as a threat to my cultural heritage"	5-point Likert scale	Strongly disagree (1) – Strongly agree (5)
18	Please rate the importance that you attach to each one of the five product attributes when you purchase meat (or meat alternatives).	Rating scale question	Score between 0 and 100 per attribute

	Allocate 100 points to reflect the relative weights of the attributes. The more points you assign to an attribute, the greater is its weight in your opinion: (1) Price, (2) Taste, (3) Texture, (4) Smell, (5) Visual appearance		
19	Please evaluate the three options (conventional meat, plant-based meat, and cell-based meat) on the following attributes. The more you believe an option possesses an attribute, the higher the score you should give the option.	Matrix question	Low on this attribute (1) – High on this attribute (5)
20	Please imagine the following scenario: You have the opportunity to try cell-based meat in your local supermarket or restaurant. Would you be willing to try it?	Likert scale	Not willing at all (1) – Extremely willing (5)
21	Now, please imagine the following scenario: Cell-based meat has become widely available in your local supermarkets or restaurants. Would you be willing to buy and consume it on a frequent (at least once per week) basis?	Likert scale	Not willing at all (1) – Extremely willing (5)
22	Would you be willing to substitute conventional meat with cell-based meat if parity in taste, texture, smell, and visual appearance is guaranteed? This would imply that cell-based meats are indistinguishable from conventional meat.	Likert scale	Not willing at all (1) – Extremely willing (5)
23	Why would you consume cell-based meat instead of conventional meat?	Multiple choice (multiple selection possible)	Health reasons; Environmental reasons; Ethical reasons; Religious/cultural reasons; Taste; Other, please specify
24	Imagine that a kilogram of conventional meat costs $6. Would you be willing to pay the same amount for the same quantity of cell-based meat?	Likert scale	Not willing at all (1) – Extremely willing (5)
25	Imagine that a kilogram of conventional meat costs $6. Would you be willing to pay more for the same quantity of cell-based meat?	Likert scale	Not willing at all (1) – Extremely willing (5)
26	Assuming that conventional meat costs $6per kilogram. How much more would you be willing to pay for cell-based meat?	Multiple choice	Up to 10% more (= $6.60 per kilogram); Up to 20% more (= $7.20 per kilogram); Up to 30% more (= $7.80 per kilogram); I am not sure

Table 7: Outline of survey questions

Appendix V: Interview guides

The semi-structured interview guides were utilized to gain further insights into the investment landscape in the cell-based meat industry. Two versions, one for the investors- and one for the venture-perspective, were developed. Depending on whether investors committed, and startups raised, capital, the interview guides were slightly adapted[51]. Also, introductions to the conversation varied[52]. Where applicable, clarifying questions were asked.

The core of the guides, however, remained the same for the sake of comparability.

Interview guide – Venture Capitalists and Corporate Venture Capitalists

Question 1 [both]: Could you please introduce yourself, your background, and your role at [COMPANY]?

Question 2a [if invested]: Your company has previously invested in the alt-protein / cell-based meat alternative ventures. What are the principal drivers / reasons to invest in these areas?

Question 2b [if not invested]: Your company has not yet invested in the alt-protein / cell-based meat alternative ventures. What are the principal drivers / reasons not to invest in these areas?

Question 3 [both]: Although alternative protein investments have grown at a steady pace in recent years, they remain a miniscule fraction of the trillions of dollars that have been invested globally in climate technologies as a whole. In 2021 alone, private capital in earlier stage technology companies amounted to $47 billion. Cell-based meat has thus far raised *only* $2 billion since 2016. In your opinion, what are the principal barriers to investments in (a) the alt-protein, and more specifically, the (b) cell-based meat industry?

Question 4 [both]: Stepping away from the challenges we have just discussed. Recently, several reports surfaced that emphasized that private capital markets are inefficient for investing in climate outcomes. For instance, according to a PwC-study, only 25% of total funding raised in climate tech is being channeled into technologies that have an 81% share of the

[51] Square brackets after question numbers indicate which questions were asked per type of VC, CVC
[52] For instance, if Company X recently announced to have invested/raised capital, guides were adapted to facilitate the discussion or embed the questions in the present situation

emissions reduction potential. Do you (a) think that current VC structures are hindering growth in the industry, and/or (b) do you believe that a "new class of investors" is required to stimulate more efficient climate investing?

Question 5 [both]: McKinsey, the Boston Consulting Group, Blue Horizon, the Good Food Institute and other reputable sources predict that cell-based meat will make up approximately 11% of the global protein market by 2030. Given those blooming forecasts, and our discussion today, how do you think the industry is going to evolve in the next five to ten years. Do you believe that cell-based meat has the potential to "disrupt" the conventional meat industry in the years to come?

Interview guide – Startups[53]

Question 1 [both]: Could you please introduce yourself, your background, and your role at [COMPANY]?

Question 2a [funded]: Your company has raised [amount] in [round XY]. Looking back from a fundraising perspective, what challenges did you encounter? In hindsight of future investment rounds, what challenges are you currently facing?

Question 2b: [unfunded] Thus far, you have not raised funding. What are the principal challenges that you have encountered in fundraising? Do you believe that alternative protein / cell-based meat ventures are overlooked by investors?

[53] Only Question 2a/2b differed from the VC/CVC guide. Question 3 until Question 6 were identical, hence are not included in the interview guide for startups.

Appendix VI: Output tables of linear regression models

Demographics[54]

	Dependent variable:				
	Try	Buy	Substitute	Pay same	Pay more
	(1)	(2)	(3)	(4)	(5)
25 - 34 years old	-0.087	-0.031	0.122	-0.063	-0.131
	(0.274)	(0.300)	(0.267)	(0.278)	(0.308)
35 - 44 years old	0.545**	0.590**	0.751***	0.610**	0.591*
	(0.275)	(0.301)	(0.268)	(0.279)	(0.309)
45 to 54 years old	-0.060	0.070	0.003	0.029	0.165
	(0.335)	(0.367)	(0.326)	(0.341)	(0.377)
55 to 64 years old	-0.223	0.060	-0.060	-0.199	-0.240
	(0.482)	(0.527)	(0.469)	(0.490)	(0.541)
65 years and older	0.344	0.201	1.351	-0.770	0.462
	(0.859)	(0.939)	(0.836)	(0.872)	(0.965)
Female	0.529	0.743	0.700*	0.825*	0.687
	(0.415)	(0.453)	(0.403)	(0.421)	(0.466)
Extremely conservative	-0.627***	-0.735***	-0.502***	-0.724***	-0.855***
	(0.162)	(0.177)	(0.157)	(0.164)	(0.182)
Extremely liberal	0.697***	0.682***	0.535***	0.606***	0.743***
	(0.185)	(0.202)	(0.180)	(0.187)	(0.207)
Somewhat conservative	0.062	0.089	0.049	0.081	0.323*
	(0.151)	(0.165)	(0.147)	(0.153)	(0.170)
Somewhat liberal	0.128	0.356*	0.100	0.251	0.568***
	(0.166)	(0.182)	(0.162)	(0.169)	(0.187)
High school graduate	0.130*	0.325*	0.168*	0.103*	-0.057*
	(0.155)	(0.170)	(0.151)	(0.158)	(0.174)
Less than high school degree	-1.428**	-1.214**	-0.989**	-1.313**	-1.301**
	(0.573)	(0.626)	(0.558)	(0.582)	(0.644)
Master's degree	0.098	0.163	0.055	0.067	0.064
	(0.121)	(0.132)	(0.118)	(0.123)	(0.136)
Vocational training	-0.504*	-0.138*	-0.320*	0.259*	0.330*
	(0.367)	(0.402)	(0.358)	(0.373)	(0.413)
Lower-Middle Income	0.117*	-0.175*	-0.078*	-0.004*	0.173*
	(0.199)	(0.217)	(0.193)	(0.202)	(0.223)
Upper-Middle Income	0.465**	0.145**	0.306*	0.304*	0.537**
	(0.194)	(0.212)	(0.189)	(0.197)	(0.218)
High Income	0.374*	0.200*	0.189*	0.232*	0.369*
	(0.213)	(0.233)	(0.207)	(0.216)	(0.239)
25 - 34 years old*Female	-0.667*	-0.856*	-0.823*	-0.912**	-0.670
	(0.437)	(0.477)	(0.425)	(0.443)	(0.490)
35 - 44 years old*Female	-1.126**	-1.273***	-1.198***	-1.447***	-1.242**
	(0.445)	(0.487)	(0.434)	(0.452)	(0.500)
45 - 54 years old*Female	-0.771	-0.574	-0.444	-0.954*	-0.625
	(0.498)	(0.545)	(0.485)	(0.506)	(0.560)
55 - 64 years old*Female	1.421	-0.048	0.191	0.081	0.128
	(0.989)	(1.081)	(0.962)	(1.004)	(1.110)
Constant	3.029***	3.064***	3.147***	3.046***	2.683***
	(0.340)	(0.371)	(0.331)	(0.345)	(0.382)
Observations	293	293	293	293	293
R2	0.263	0.229	0.226	0.243	0.214
Adjusted R2	0.206	0.170	0.166	0.185	0.153
Note:			*p<0.1; **p<0.05; ***p<0.01		

Table 8: Relationship between gender, age and political affiliation on willingness measures

[54] Where applicable, variables were "squared" or "logged" to account for skewness and heteroscedasticity. No further analysis was conducted unless these measures resulted in statistically significant coefficients or considerably higher (adjusted) R_2 values.

Meat consumption frequency

	Dependent variable:				
	Try	Buy	Substitute	Pay same	Pay more
	(1)	(2)	(3)	(4)	(5)
No meat consumption	-0.672**	-0.796**	-0.290*	-0.263	0.140
	(0.367)	(0.394)	(0.354)	(0.365)	(0.407)
Once per month.	0.108*	0.276**	0.240*	0.149*	0.041*
	(0.130)	(0.139)	(0.125)	(0.129)	(0.144)
More than once per week	0.995***	0.704*	0.710**	1.237***	0.473
	(0.367)	(0.394)	(0.354)	(0.365)	(0.407)
Once per week	0.315**	0.348**	0.236**	0.430***	0.283**
	(0.126)	(0.135)	(0.121)	(0.125)	(0.139)
Constant	3.505***	3.462***	3.624***	3.430***	3.527***
	(0.090)	(0.097)	(0.087)	(0.090)	(0.100)
Observations	293	293	293	293	293
R2	0.057	0.052	0.031	0.073	0.019
Adjusted R2	0.044	0.039	0.018	0.060	0.006
Note:					*p<0.1; **p<0.05; ***p<0.01

Table 9: Relationship between meat consumption frequency and willingness measures

Dietary type

	Dependent variable:				
	Try	Buy	Substitute	Pay same	Pay more
	(1)	(2)	(3)	(4)	(5)
Flexitarian	0.026	0.051	-0.037	0.081	-0.123
	(0.142)	(0.152)	(0.136)	(0.142)	(0.153)
Omnivore	-0.270**	-0.130	-0.137	-0.281**	-0.459***
	(0.129)	(0.139)	(0.123)	(0.129)	(0.139)
Pescatarian	0.143	-0.222	-0.075	-0.222	-0.335
	(0.327)	(0.351)	(0.313)	(0.327)	(0.352)
Vegan	-0.065	-0.722	0.175	-0.055	0.165
	(0.522)	(0.560)	(0.498)	(0.521)	(0.562)
Vegetarian	-0.040	-0.183	0.137	-0.029	-0.066
	(0.197)	(0.211)	(0.188)	(0.196)	(0.212)
Constant	3.732***	3.722***	3.825***	3.722***	3.835***
	(0.090)	(0.097)	(0.086)	(0.090)	(0.097)
Observations	293	293	293	293	293
R2	0.022	0.013	0.009	0.027	0.042
Adjusted R2	0.005	-0.004	-0.008	0.010	0.025
Note:					*p<0.1; **p<0.05; ***p<0.01

Table 10: Relationship between dietary type and willingness measures

Appendix VII: Summarized answers of expert interviews

The summarized answers per expert are shown within the following pages. The first question, dedicated to the expert's background, company, and role at the company has been excluded for the sake of anonymity and conciseness. The profiles of the interviewees may be retrieved from *Table 2*. Minor differences within the questions asked, largely dependent on the type of expert and company, were explained in Appendix V. Each table contains the expert's code, the date and duration, and the type of interview (e-mail or video conference).

Expert Startup 1 (ES1)

Code: ES1	**Date**: 05.04.2023	**Time**: 10:00 AM	**Duration**: Not applicable	**Type**: E-Mail
Question 2				
We have raised approximately 700.000€ in a pre-seed round. There were – and still are – three major challenges that we've faced from a fundraising perspective. First, explaining the concept, the technology, and our value proposition to investors, who sometimes had not really been in touch with cultivated meat or other food-related deep tech topics, was extremely challenging. Secondly, the cultivated meat industry is still at a very early stage – specifically when compared to other meat alternatives, such as plant-based meats. Although we are not end-consumer focused – seeing that we develop end-to-end bio-processing systems that enable the production of cultivated meat – investors remained skeptical in hindsight of cultivated meat's potential as no real, experience-based consumer feedback is available to date. Third, investors are still hunting quick ROIs instead of long-term impact.				
Question 3				
I think the key barriers to more investments, and I can only refer to the challenges faced by players in the cultivated meat domain, evolve around the things I have mentioned before. The industry is still very immature, the infrastrucuture required to produce cultivated meat at scale will take years to develop. Also, the regulatory environment is still very uncertain. Not being able to commercialize cultivated meat and collect real customer feedback, makes it challenging to develop a convincing "case" when speaking to investors. However, using the regulatory uncertainty as an argument to not make investments in this field is, from my perspective, a simple excuse. Investors could simply back companies that				
Question 4				
As mentioned before, current VC structures and short- and mid-term investment horizons are hindering investments in the field. Also, investor's risk profiles mismatch the nature of the cultivated meat industry – especially European investors are simply too risk averse. Cultivated meat requires significant upfront investments and time to establish critical infrastructures. Hence, investors must delay their expected returns. To date, they are too impatient for the long-term nature of the industry. In general, deep-tech may have a significant and positive impact on the society. Israel, for instance, is supporting the development of the cultivated meat infrastructure with significant investments. I believe that governmental stakeholders must become more active in promoting the industry.				
Question 5				
I am convinced that cultivated meat may have a positive impact on our society. The forecasts that you have mentioned are of course promising, however it is practically impossible to predict how the industry will develop in the mid- or long-term future. The technological challenges and numerous uncertainties must be addressed before more reliable predictions can be made.				

Table 11: Summarized responses of ES1

Expert Startup 2 (ES2)

Code: ES2	**Date**: 11.04.2023	**Time**: 07:00 PM	**Duration**: 23 minutes	**Type**: Cellphone
Question 2:				
I have joined the company at a fairly mature stage. Hence, I cannot really provide my perspective on the "very early days" of the company. Regardless, I believe that the challenges faced back then are not so different from those that we – or the industry as a whole – are facing now.				
Question 3:				
There are several risk factors that need to be considered. First, from R&D to mass production - the ability to produce at small quantities in the lab (with high costs) vs. being able to mass produce in huge quantities in the production environment is very different, from a technological standpoint. Secondly, cost elements - In order to sell to mass markets, the cultivated meat needs to be cost competitive with regular meat. Just being environmentally friendly is not enough to persuade mass consumers to adopt the product. Third, huge investment to scale - in order to mass produce and lower costs, it takes a massive amount of investment in equipment, infrastructure and manufacturing facilities to build the scale. It's just like the EV industry. Fourth, consumer Acceptance - even if mass production at reasonable cost can be achieved, it will still take time for consumers to understand cultivated meat, any health risks involved, tastes/texture, maybe even overcoming cultural or religious differences, etc. And lastly, regulatory Factors - since this is food, it will require various regulatory reviews and approval by each country or market authorities. It can take years before a product is approved to go to market.				
Question 4:				
This industry will need substantial and sustained investment over a long period of time to develop. That means that investors will need to be more risk tolerant and more patient. In a robust economy with lower interest rates, such investment maybe a bit easier to get. But the nature of investment may be difficult to take such long-term view on this industry. I think each investment fund has its own risk tolerance and timeline that it has to manage to. Usually, the shorter the timeline, the risk tolerance might be higher. To me, it's just the nature of investment. It would be great if investors focusing on ESG have more allocation of capital on longer term investments. More importantly, we need some big wins from ESG, and cultivated meat, ventures to prove that it's not just about ideas but those ideas can be turned into real businesses that can be sustained.				
Question 5:				
I also strongly believe in the cultivated meat industry, which has great potential in the long run. However, the investment community still views this industry with very high risks, which I think is justified. If the challenges explained before can be overcome, cultivated meat hast the potential to disrupt the conventional meat industry. However, it is still too early to tell.				

Table 12: Summarized responses of ES2

Expert Startup 3 (ES3)

Code: ES3	**Date**: 17.04.2023	**Time**: 10:00 AM	**Duration**: 24 minutes	**Type**: Zoom
Question 2:				
As mentioned before, I am working in the cellular agriculture industry since 2018. I have experiences as a founder, independent consultant and angel investor at different B2B- and B2C-oriented cell-agriculture ventures. For the purpose of the interview, I will consolidate my insights across the whole spectrum.				
Question 3:				
First of all, I agree that investments are miniscule to date. Although UPSIDE Foods and Memphis Meat have raised millions, in the grand scheme of things, investments are not significant. Though, I believe that the investments will increase in the future. The cultivated meat industry is a pretty nascent industry – most companies have been established around 2016 or 2017, though the industry is still in an R&D phase. I am quite certain that once established players are ready to move from R&D towards industrial scale production, and commercialization starts, investments will likely go into the billions. As long as players remain at "lab-scale", there's no justification to pour in trillions of investments. Secondly, the regulatory environment is another notable barrier from my perspective. So far, only Singapore, Israel and soon the US will have established a regulatory framework that allows the commercialization of the cultivated meat. Overall, approvals will take time and a lot of effort – especially within the EU. Proposed bans, such as the one Italy recently proposed, will likely not manifest. Regardless, if I would be selling cultivated meat already – even at smaller scales – and show some revenues and a potential path to profitability, investors would be likely more attracted to commit capital. I am convinced that some investors are in the "starting blocks" and will invest as soon as a consumer uptake materializes. Thirdly, several studies attest that consumer awareness is picking up, however, acceptance requires knowledge and understanding. Communicating and educating the abstract nature of cultivated meat, emphasizing differences to conventional meat, explaining benefits and risks of cultivated meat, and so forth, will take considerable time and effort. The industry is required to engage in consumer awareness and information campaigns to demystify the industry to create acceptance. Therein, regulatory bodies should facilitate the consumer awareness and acceptance process. Finding the right balance is essential there.				
Question 4:				
The typical Silicon Valley VC does not fit capital-intensive industries. Cultivated meat is extremely R&D and science-heavy, hence it attracts a different kind of investors. Not being able to quantify potential pay-offs "scares off" traditional investors. So far, primarily family offices, and angel investors, and some very few more long-term oriented VCs have committed capital. Few CVC-arms of meat production companies have also invested in cultivated meat ventures; however, it seems like they are simply increasing their exposure to the industry to hedge risks.				
Question 5:				
I think that it will take substantial time before cultivated meat will obtain substantial market share numbers and emerge as a "disruptor" in the meat industry. The "lag-time" of the infrastructure built-out alone is a bottleneck in itself. Even if significant consumers uptake upon approval and commercialization manifests, actual production quantities required to obtain major market shares in key markets will take at least 10 years.				

Table 13: Summarized responses of ES3

Expert Startup 4 (ES4)

Code: ES4	**Date**: 28.04.2023	**Time**: 12:00 AM	**Duration**: 23 minutes	**Type**: Cellphone
Question 2:				
As previously mentioned, we're still in the pre-seed phase and have not yet raised capital. We're currently in the process of identifying suitable, strategic investors that are willing to engage in longer-term commitments. We're not solely interested in raising capital but gaining access to industry players. We are among few startups that specialize in hybrid products – leveraging the characteristics and advantages of plant- as well as cell-culture technology – to create several meat alternatives ranging from burger patties and ground beef to (one day) whole meat cuts and steaks. We anticipate that the hybrid approach gives us an edge compared to other players who are squarely focused on either plant- or cell-technology. However, there are many fundraising challenges that we have encountered so far. However, these pertain to the industry as a whole.				
Question 3:				
Overall, the alternative protein industry has registered enormous growth between 2010 and 2020 – primarily driven by developments of plant-based players such as Impossible Foods, Beyond Meat, Garden Gourmet. This growth, however, is stagnating or even declining in some geographies. Seeing the "powerhouses" of the industry struggle to turn profitable worries investors. Although I am convinced that consumer preferences, especially among younger generations, will continue to shift, I feel like there's a lot of skepticism whether meat alternatives reach mainstream acceptance in the short-term future. Secondly, the technology – specifically concerning scaling – is still in a very early stage. Well-funded players, such as UPSIDE Foods, JUST or Aleph Farms – who started commercialising their products in Singapore and in select restaurants across Israel – may have attracted significant investments for scaling, however, are still years away from reaching industrial scale production figures and economics. More specifically, cell-culture productivity and media development costs and bio-reactor capacities are hindering the growth. Thirdly, regulatory inertia plagues the alt-protein industry – especially in Europe. Its rather unsurprising and, from my perspective, justified that regulators are somewhat overwhelmed by the complexity of cultivated foods and remain cautious with approving novel foods that originate from laboratory processes. Stronger collaboration between industry players and regulators is required to transparentize risks, avoid labeling differences and overall streamline approval processes. I have to admit that the regulatory environment, also in hindsight of the strong meat lobby across the globe, concerns us the most at the moment. The alt-protein industry as a whole requires legislators as allies.				
Question 4:				
Yes, current VC or PE structures certainly restrain the progress of the industry. However, I am certain that the future of food will emerge as one of the top investable themes in the short-term future. From my perspective, investors are already starting to adjust their ROI expectations and investment horizons – some are driven by own ESG-objectives, others are driven by contributing to a "greater cause". Also, governmental support is required, not only from a legislative, but also from a monetary perspective – for instance in form of tax breaks or the like.				
Question 5:				
I strongly believe that cultivated meat, both in hybrid and pure form, will obtain a share of the overall alternative protein industry in the mid-term future. However, seeing the challenges ahead, I don't suspect that it will fully "disrupt" the conventional meat industry in the years to come.				

Table 14: Summarized responses of ES4

Expert Startup 5 (ES5)

Code: ES5	**Date**: 03.05.2023	**Time**: 10:00 AM	**Duration**: 25 minutes	**Type**: Cellphone
Question 2:				
My previous venture in the US was not really concerned with cell-culture technology, but more with precision farming. Although similarities exist, the (nature of the) challenges that we encountered in fundraising were quite different from the once I am currently facing in my daily business within the accelerator programs. Therefore, I will focus on the challenges I have encountered advising early-stage alt-protein ventures.				
Question 3:				
I think first and foremost, investors are worried about consumer adoption. Food always was and always will remain a consumer-facing business, hence consumer demand – and not only initial but repeat consumption – largely determines success or failure. Novel foods generally face the problem of initial consumer skepticism – the more abstract the product, the less likely consumers are to understand, engage with, and fully accept it. This effect is pronounced in the cultivated meat industry. The bio-technological processes are simply too "complex" to grasp for the average consumer. Although first studies attest some sort of consumer interest and acceptance, investors will remain somewhat hesitant until large-scale commercialization and field studies provide more evidence of cultivated meats commercial viability. Second, the technology is still at a nascent stage. Reaching cost parity, or even undercutting the costs of animal proteins, is essential to reach mainstream consumers – although some consumers may be ready to pay a premium for clean meat, affordability will determine adoption. Current industrial scale production economics are singling out consumers who are not willing to pay substantially more, hence it will exclude the average price sensitive mainstream consumer. Third, the regulatory environment remains highly ambiguous and unpredictable. The US is currently on the verge of approving the commercialization – I believe that right now the Agricultural Department is in the final review. This will for sure have an immediate and positive impact on the global cultivated meat industry. Nonetheless, it remains to be seen how and when consensus on food and safety standards are reached. Approvals and regulations are sometimes rigid and based on the current state of the industry's technology standard – the highly dynamic nature of the cultivated meat industry – seeing that no dominant approaches have been formulated – will thus constantly challenge or clash with the boundaries established by the regulators. This will certainly present challenges to ventures looking to commercialize their products.				
Question 4:				
Certainly, current VC structures are hindering more intense investments. Overcoming the technological challenges, establishing the production infrastructure, marketing and educational campaigns to foster consumer awareness and acceptance require substantial upfront investments that the traditional "Silicon Valley VC" is reluctant to take. Investment horizons are simply too short, therefore mismatch the long-term nature of the industry. However, I suspect that this will change as we approach the more capital intensive "deep tech" era that I have mentioned before.				
Question 5:				
I'm quite optimistic that the challenges can be overcome in the next seven to ten years. Alternative proteins are here to stay and will gradually move closer toward parity. As mentioned, affordability is key and will determine success. Cultivated meat will certainly emerge as piece of the future protein market. Though, I have my doubts that it will fully "disrupt" the conventional meat industry.				

Table 15: Summarized responses of ES5

Expert Startup 6 (ES6)

Code: ES6	**Date**: 11.05.23	**Time**: 08:00 AM	**Duration**: 25 minutes	**Type**: Cellphone
Question 2:				
In 2021, we raised roughly 1.300.000€ in a pre-seed round. There are numerous challenges that we face(d) when raising funds. It took us more than two years two identify, reach, and convince investors of our vision. Although major players such as UPSIDE Foods or Aleph Farms had already received funding from investors, most VCs were hesitant to evaluate our investments opportunity. In comparison, we were considered pioneers within Europe around the same time. Back then, select European investors, who had already committed some capital to more mature players in the market, were rather uninterested as they already "made their bet". Also, we did not just want to "give away" a piece of our business for the sake of raising capital – our intention was, and still is, to get partners on board that are willing, and may provide, long-term value post investment. We are producing cultivated meat for the end consumer, hence require access to distribution channels once our product is ready and commercialization permitted. Identifying investors who were not only committed to provide funding, but also networks and access to industry players, such as wholesalers, supermarket chains, or even meat producers, was extremely challenging. However, eventually we found a match.				
Question 3:				
As mentioned before, there are numerous challenges that cultivated meat players face, when raising capital. First, consumer awareness and adoption, although I suspect that the coming generations are more open to try novel foods, is still at an early stage. People are somewhat aware that intensive livestock production is harmful to the environment and animals, however, a behavioral change in terms of meat consumption among mainstream consumer will take more time to develop. Other alt-protein players, such as Beyond Meat, are struggling right now to show customer growth albeit raising billions. This has investor's questioning whether less mature segments of the market can deliver substantial revenues. Secondly, the technology is still at a nascent stage. To be honest, there's still a fairly noticeable difference between our and conventional ground beef burger patties. However, to reach mainstream consumers – and we primarily target carnivores or flexitarians – parity must be achieved. Also, the scalability, and reaching cost parity, is a major obstacle. Finally, the regulatory environment, specifically within Europe, presents challenges. When raising fresh capital, players within the US will soon profit from the FDA's tentative approval. Meanwhile, progress in Europe has been moderate. I suspect that it will take at least three or four years until the EU has established consensus – and even then, differences per country will pose challenges. The "lag-time" favors players in the US, and other geographies, immensely when raising capital.				
Question 4:				
VCs are primarily interested in short-term ROIs and have short investment horizons. The complexity of the industry mismatches investors' expectations, hence they steer capital towards alternative climate technologies. However, the future of food will surely emerge as one of the most investible themes in the future. We'll approach 10 billion people by 2050, hence alternatives to current protein production are deeply required.				
Question 5:				
I strongly believe in the future of cultivated meat. However, we must stay realistic – conventional meat will remain an essential part of mainstream consumers' diet. Nonetheless, I believe that some sort of "disruption" will take place once cultivated meat has been commercialized.				

Table 16: Summarized responses of ES6

Expert Venture Capital 1 (EVC1)

Code: EVC1	**Date**:04.04.2023	**Time**: 4:00 PM	**Duration**: Not applicable	**Type**: E-Mail(s)
Question 2:				
We have made two investments across two rounds within a later-stage cultivated meat venture. Hence, we were not on board from the pre-seed stage onwards. Seeing that I'm still in an official capacity at the company, I am not at liberty to discuss any specifics pertaining to the current status or challenges faced by the company without the explicit authorization of the CEO. However, I am happy to briefly elaborate on my perspective concerning the challenges faced by cultivated meat players in general.				
Question 3:				
In general, the science or technology, which enables the production of cultivated meat, are still at a very early stage. Also, the infrastructures required to facilitate the maturation of the industry as a whole are simply non-existent to date. Thus far, most ventures remain in R&D- and pilot-scale production quantities. The upfront investments required to advance the industry may be perceived as barrier themselves – it simply does not fit most VCs. Further, in the absence of commercialization – consciously excluding fairly smaller markets in Singapore and Israel here – predicting future consumer demand is challenging. VCs interested in consumer-facing startups in the domain remain hesitant. Lastly, regulatory inertia, not so much in the US but more in other key markets such as the European Union, are hindering more intense investments in the space.				
Question 4:				
As mentioned, the capital-intensive nature of the cultivated meat industry does not fit most VCs models time frame to exit. Most fund structures have shorter- or mid-term investment horizons which mismatches cultivated meat. Also, in today's down-market conditions, characterized by high interest rates, capital becomes more expensive. Allocating this capital on longer-termed investment opportunities is thus discouraged. Investor's tendency to seek short-term ROIs will most likely continue for the foreseeable future.				
Question 5:				
The global protein markets is a trillion-dollar opportunity. Hence, alternative protein players will continue to emerge. The question whether cultivated meat may emerge as a disruptor for the conventional meat industry remains to be seen. Given that the technological challenges – especially concerning scalability and reaching cost parity – are overcome, I do not see why cultivated meat should fail. Its ability to identically replicate conventional meat cuts, without the burdens of traditional livestock farming, sets it apart from other alternatives in the market. Nonetheless, within the alternative protein, or more specifically the alternative meat industry, no "winner-takes-it-all" scenario will ever manifest. It is more likely that a combination of multiple alternatives will emerge and form a "puzzle" of alternatives.				

Table 17: Summarized responses of EVC1

Expert Venture Capital 2 (EVC2)

Code: EVC2	**Date**:11.04.2023	**Time**: 05:00 PM	**Duration**: 23 minutes	**Type**: Zoom
Question 2:				
As mentioned in the introduction, we're early-stage investors – pre-seed is our sweet spot – and we usually target 5 to 15 percent ownership in the startups we back. We mainly apply four criteria when evaluating potential investments in the alternative protein, and in particular the cultivated meat, sector. First, we're looking for a balanced team – founders that combine scientific training with business acumen are preferred. Secondly, the technology plays an important role – we are focused on hedging our bets by investing in different approaches towards producing cultivated meat. Third, we are looking for ventures with proprietary IP. Overall, our family office is mission-driven, therefore we continue to invest in competitors within the cultivated meat market. Our investment philosophy is philanthropy- rather than ROI-driven.				
Question 3:				
First, the alternative protein, and in particular cultivated meat industry, is still a bubble. Although consumers trend towards more sustainable and conscious consumption, awareness of what's happening on our plates is practically non-existent among mainstream consumers. Public discussions are very much focused on carbon emissions produced by light and heavy transportation. Even at the COP, food was on the agenda for the first time – which is crazy when considering the enormous environmental impact of animal agriculture. Secondly, acceptance among consumers is still in question – although first studies indicate that consumers are generally open to try, no robust data on actual future demand exists. To establish and understanding of the benefits and risks associated with the technology, intense lobbying and governmental and regulatory support are required. Thirdly, the regulatory environment is still uncertain. Singapore, Israel and the US have approved the sale, however, other key geographies such as the EU are lagging behind. Fourthly, the typical "Silicon Valley VC model" does not fit the long-term nature of the cultivated meat industry – moving from R&D to bio-processing, to commercialization and positive EBITDAs requires at least 10 to 15 years. Traditional fund structures are simply not accommodative to these time horizons. Family offices present an exception to the rule as they often have mission-driven evergreen capital at their disposal. Lastly, the tech itself presents a barrier. The current enabling technology is not suited to cater to the high-volume, low-margin meat market. We are still years off from reaching price parity which is critical in the food sector.				
Question 4:				
I have already addressed the mismatch between traditional fund structures and the nature of the cultivated meat industry in the previous question. I am convinced that VCs will adapt their horizons to a certain extent, however, the momentum will likely be driven by family offices, VC-arms of established meat or FMCG-corporates and philanthropic or angel investors. I do not anticipate that the inefficiencies will dissolve in the foreseeable future. The "10x mentality" of traditional VCs will remain – but they simply do not fit with the deep tech era that we are approaching.				
Question 5:				
The cultivated meat market industry – or the alt-protein industry as a whole – will never be a "winner-takes-it-all" market. Hence, a single "disruptor" will likely never exist. We have committed to eight ventures in the cultivated meat space. Although no further investments are in the pipeline, we are convinced that if parity on product characteristics and price are achieved, and regulation permits, cultivated meat will succeed.				

Table 18: Summarized responses of EVC2

Expert Venture Capital 3 (EVC3)

Code: EVC3	**Date**: 25.04.2023	**Time**: 08:00 AM	**Duration**: 24 minutes	**Type**: Zoom
Question 2:				
I am aware that we have invested in a cultivated dairy startup via our VC-arm, however, I am not fully aware of the details nor the drivers of this investment. However, I am very familiar with our VC-arm, current portfolio companies and the overall investment philosophy or scope. First of all, I believe that our company, due to the clear focus on dairy products, is not interested in pursuing a future in the meat industry. I suspect that we are particularly interested in getting exposure to the cell-based infant milk domain. The underlying technology of the startup, used to artificially produce proteins, will have driven this investment. Our portfolio companies are actively pursuing creating proteins "out of thin air" – hence, jumpstarting technological advancements by investing in or even acquiring startups in that domain seems logical.				
Question 3:				
Looking at the alt-protein industry as a whole, plant-based alternatives were booming, recording double-digit growth between 2015 and 2020. Since COVID-19, dairy proteins have rebounded. In step with the downturn of the "hype", major plant-based players stagnated in terms of revenue growth. The field simply does not feel as promising as it used to. This surely has negative implications on investors' sentiment towards alt-proteins as a whole. Also, when looking at the product portfolio of most plant-based meat players, primarily burgers and ground beef were sold – this somewhat showed the short-term limits concerning the replicability of conventional meats. Also, the technology itself is still immature, hence, risk averse investors might delay their investments until consensus on specific technological challenges are reached.				
Question 4:				
I personally believe that there are simply less abstract, more mature and straight-forward investment opportunities in the market that are still unexploited. Overall, investors are surely focused on quick ROIs. I believe that this tendency will persist as long as enough shorter-term opportunities exist. Also, tackling the negative externalities and inefficiencies of the traditional agricultural industry, including intensive livestock production, will depend on regulatory intervention. The lenient regulatory environment on a global scale, for instance with regards to environmental quotas that must be fulfilled by meat incumbents in the market, are keeping "pressures to change" at bay. Without serious consequences, incumbents will proceed without major changes. This, in turn, will also discourage investors to allocate capital on technologies that might provide promising decarbonization levers in the future.				
Question 5:				
From a societal perspective, I am not convinced that cultivated meat will be our future. Instead, I would bet that protein creation will be a monumental topic in the future. But, even in this broader domain, other alternatives may "outplay" cell-cultivation. Overall, ensuring safe protein access will become more important than replicating whole meat cuts. Also, a more conscious protein- or meat consumption among consumers would provide a greater lever to reduce the negative environmental externalities of global food production and supply systems than any alternative in the market. Keeping meat consumption exceptional, for instance by introducing carbon taxes on traditional meat cuts, would lower the environmental impact instantly. Overall, I do not believe that cultivated meat will emerge as a disruptor in the short-, mid- or long-term future.				

Table 19: Summarized responses of EVC3

Expert Venture Capital 4 (EVC4)

Code: EVC4	**Date**:28.04.2023	**Time**: 10:00 AM	**Duration**: 36 minutes	**Type**: Zoom
Question 2:				
As mentioned before, we have invested in early-stage sustainability- or circular economy ventures in recent years. In general, I perceive the agri- or food-tech domain as incredibly complex and hard to grasp. When looking at consumer-facing, early-stage ventures, regardless of the exact segment of the market, it's very difficult to predict which technology or products may "take off". Locating the USP of a potential "winner" in this jungle of opportunities is overwhelming. Even established VCs are starting to realize that they are "out of their depth" when evaluating potential investments in the bio-technology sector. Nonetheless, we are continuously evaluating opportunities in the food tech sector, however, technologies such as cultivated meat and seafood are "moonshots" that might savor relevancy in our investment considerations in five or ten years. In a nutshell, these are the primary drivers for not having invested in these areas.				
Question 3:				
Pertaining to the alt-protein industry as a whole, product characteristics such as taste, smell and texture still have to reach parity. Also, the nutritional values of alternatives, for instance of plant-based milk, are not comparable to their conventional counterpart. Furthermore, reaching price parity, specifically when targeting the mainstream market, is essential. Concerning cultivated meat, I strongly believe that the technologies immaturity is a major inhibitor to more intense investments. Furthermore, the uncertain regulatory environment and the absence of a clear path-to-market, especially in the EU, are hindering industry maturation and investments. Although Singapore and Israel have approved the sale of cultivated meat, investors will remain hesitant until larger geographic markets, such as the US, EU, India or China, have established regulatory precedents. Even then, the question remains whether startups will be able to adhere to the regulatory boundaries set by the legislators. Additionally, VCs are simply too short-term oriented. The time frame to exit mismatches the nature of the industry. Lastly, it remains to be seen whether a consumer uptake will manifest as soon as cultivated meat becomes commercially available – at the end of the day, cultivated meat originates from the lab, hence consumer will have doubts, perceive risks and therefore respond emotionally and sometimes even irrationally.				
Question 4:				
I genuinely believe that the "traditional" VC industry will soon be transformed. Throughout the past few years, VCs have funded the transformation or disruption of sectors that were easy to digitalize. We are approaching a VC-era that will be dominated by longer-term deep-tech-investments – focused on sectors, such as mobility, decarbonization, and food, which cannot be digitalized, transformed or disrupted without significant upfront capex. I am very excited to see how this asset class will evolve. For sure, fund structures and investment horizons must be adapted to accommodate longer-term investments.				
Question 5:				
Honestly, I still believe that cultivated meat will remain a "moonshot", despite its promising technology. I am convinced that meat will remain the dominant source of protein among the mainstream consumer, simply because it's the most affordable. I suspect that cultivated meat will, even if challenges pertaining to the technology and scalability are solved, remain a niche market product for the foreseeable future.				

Table 20: Summarized responses of EVC4

Expert Venture Capital 5 (EVC5)

Code: EVC5	**Date**: 03.05.2023	**Time**: 04:00 PM	**Duration**: 27 minutes	**Type**: Cellphone
Question 2:				
We are committed to support ambitious founders from the Seed-stages until Series A and, in special cases, Series B. As mentioned before, we have invested in 16 food- and beverage-tech ventures in the past 5 years. Thus far, we have not invested in cultivate meat ventures, however, we are closely monitoring the developments in this sector. We leverage the elaborate network and expertise of our parent company to create sustainable business that have a positive impact on the environment and society. In general, we're focusing on mission-driven B2B and B2C that drive responsible consumption or revolutionize the way food and beverages are produced. We not only offer monetary support bur provide access to our network, knowledge and experience in the domain. The criteria we apply are highly dynamic given the diverse nature of the ventures we evaluate.				
Question 3:				
In general, alternative proteins are an important investment theme for us. As mentioned, the cultivated meat industry has certainly gained our attention in recent years. From my perspective, the barriers that hinder more intense investments in the cultivated meat industry, may be broken down into three categories; First, the technology is still quite immature – especially when compared to other alternatives in the market. Challenges pertaining to the scalability of production, required for a profitable commercialization, seem insurmountable in the next five to ten years. The infrastructure required to scale to even one percent of the global protein market will cost trillions in upfront investments, which, in turn, discourages many investors from even considering this sector. Secondly, it's still highly uncertain how consumers' perception towards "lab-grown" meat will develop. Some studies indicate that consumers are generally open to try cultivated meats, however, real customer feedback is practically non-existent – specifically outside of Singapore and Israel. In the end of the day, food remains a consumer-facing industry. Without real feedback, investors will question whether consumers are even remotely interested in engaging in repeat purchases. Also, plant-based meats have gained a lot of popularity in recent years, registering considerable growth in the US and the EU. However, major players struggle to reach profitability. Finally, the regulatory environment remains unpredictable – specifically in the EU. The fragmented nature of the markets will hinder rollouts. Also, retailers will be hesitant to "just" shelf cultivated meat products, even if uncertainties surrounding regulation are solved.				
Question 4:				
Yes, I fully agree. Most VCs, and even those who are committed to ESG investing, have investment horizons that simply do not fit the nature of food tech. The enormous monetary and time invest required to move the cultivated meat industry from lab-scales to industrial production are incompatible with investors' demand of quick payoffs. I think that CVCs, angel investors and family offices are generally more open to engage in longer-term investments, however, even among those, cultivated meat remains relatively unattractive due to the reasons outlined before.				
Question 5:				
I believe that cultivated meat is a promising technology that will – in some shape or form – contribute to the transformation of the global protein market. However, I am not convinced that it will "disrupt" the conventional meat market in the next 10 to 15 years.				

Table 21: Summarized responses of EVC5

Expert Venture Capital 6 (EVC6)

Code: EVC6	**Date**: 08.05.2023	**Time**: 10:00 AM	**Duration**: 22 minutes	**Type**: Zoom
Question 2:				
Our mission is to accelerate the transition towards more sustainable food systems. Every investment must fulfill two central criteria; First, any investment must be able to generate positive, above market returns. Secondly, any investment must generate a positive impact on people, planet and/or animals .Our end-to-end approach entails supporting ventures from pre-seed until exit. We leverage our network to provide promising ventures not only with capital, but with access to industry connections and expertise across the globe. Unlike traditional VCs or PE, some of our investments have longer-than-usual time-horizons. We have exposure to several cell-technology ventures – these focus on dairy products, meats and bio-processing capabilities. In general, we seek founders with a strong scientific background and a track record in the food domain.				
Question 3:				
We gained exposure to the cell-tech industry – so not speaking exclusively about the cultivated meat industry – early on. Although I am not focused on this specific segment of the alternative protein industry in my daily business, I can provide my perspective. First, the technology itself, although already successfully applied in the context of the pharma industry, is still at a very nascent stage. Challenges surrounding cell-culture productivity, tissue engineering and extensive media costs hinder scaling, which, in turn, would be required to attract more significant capital from investors. Secondly, the regulatory environment is challenging. Food safety regulations differ between, and sometimes even within, countries. So far, only Singapore and Israel have allowed commercialization of cultivated products. The FDA has approved it in the beginning of the year; hence I suspect that more regions will follow suit. Nonetheless, it will take years until consensus concerning lab-grown food standards have been established – especially in the EU, this process will be onerous. Thirdly, consumer awareness and acceptance are still ambiguous. Not being commercially available across key meat consuming regions makes predictions about real consumer demand extremely difficult. Across more developed regions, trends concerning more environmentally and ethically conscious lifestyles emerge, however, in the grand scheme of things – and especially in less developed but heavily populated regions – this remains a niche phenomenon. Developing an understanding among consumers, educating them about benefits and risks will take a lot of time and patience – which investors usually do not have.				
Question 4:				
Yes, current capital markets are inefficient in allocating capital according to emissions savings potential. Other climate technologies, specifically in the mobility or power sector, simply offer quicker ROIs, higher multiples and the impact generated is more easily quantified. Also, the environmental impact of foods has simply not been scrutinized as much as other sectors. However, I believe that investments will pick up soon.				
Question 5:				
I am not quite sure whether the concept or term “disruption” is suitable for this kind of technology or sector. Conventional meat will always remain an integral part of humanity’s diet. However, I strongly believe that a considerable market share of the global protein industry will be occupied by alternative protein players. As mentioned before, a “winner-takes-it-all” scenario will never manifest in the protein or meat industry. Hence, I believe that cell-tech foods, and in particular meat, will emerge as a part of the greater protein mix, given that challenges are overcome.				

Table 22: Summarized responses of EVC6

Appendix VIII: Coded categories based on expert interviews

#	Coded category	Trigger key words and phrases
1	**Technology and infrastructure immaturity**	• "Technology has not reached maturity" • "Technological challenges persist" • "Scalability is a major obstacle" • "Infrastructure built out requires years" • "Lack of bio-processing capacities" • "Moving from R&D to mass production will take time" • "Food is a high volume, low margin business" • "Ability to achieve price parity is still in question"
2	**Lack of consumer awareness, knowledge and acceptance**	• "Alternative proteins is still a bubble" • "Public climate change and carbon emission discourses focuses on individual mobility and transportation – so far, little attention has been given to what's happening on our plates" • "Even at the COP, food was on the agenda for the first time in 2023" • "Among alternative proteins, CBM is the most abstract and controversial due to its technology" • "Risks associated with CBM consumption must be educated to and understood by consumers" • "Consumers' awareness, understanding and acceptance of CBM will take time"
3	**Uncertain regulatory environment and lack of institutional funding**	• "Regulatory reviews and approvals per country and market require years before go-to-market is achieved" • "Investments will accelerate significantly as soon as approval rates increase" • "Approvals in larger geographic markets, such as the US, will be a game change and accelerate investments" • "Fragmented European regulation inhibits progress" • "Intense lobbying to educate policymakers and regulators to expedite approval processes is critical" • "Institutions and governments' public policy should facilitate consumer awareness and acceptance" • "Non-equity funding through governmental grants, equipment leasing, R&D project financing is key"

4	**VC fund structures, investment horizons, and risk tolerances**	• "VCs are short-term oriented – investors want quick ROIs" • "CBM does not align with most VCs model of time frame to exit" • "The typical Silicon Valley VC model will not work for CBM" • "From R&D and bio-processing to commercialization and profitability, you need at least 10 years - many VCs have that '10x mentality' which biotechnology does not offer" • "Would be great if investors focusing on ESG have more allocation of capital on longer-term investments" • "The investment community views this industry with very high risks" • "Investors must be more risk tolerant and more patient" • "European VCs are too risk averse for CBM" • "VC structures will change in the near-term future as more capital intensive deep-tech investing gain momentum"
5	**Inefficient capital markets**	• "Investors desire quick and easy returns, which CBM does not offer, therefore they shift it to other climate technologies" • "Public discourses and opinions steer capital flows"
6	**Lack of alternative protein success stories**	• "We need some big wins from alternative protein, and in particular cell-based meat ventures, to prove that it's not just about ideas but those ideas can be turned into real businesses that can be sustained" • "Since 2015, plant-based products gained enormous traction, recording double digit growth in the US and Europe. After COVID-19, however, dairy products rebounded and plant-based growth has diminished to single digits. The field does not feel as promising as it used to" • "Product portfolios of plant-based companies were very much centered around burger patties and ground meat. Virtually no company accomplished whole cuts. This showed the short-term limits of the industry"
7	**Limited societal impact and business model uncertainties**	• "I believe that societies' future needs, in terms of health and nutrition, are more about ensuring safe protein access rather than replicating different kinds of meats" • "If we ever invested in a CBM venture, we would prioritize the technology used to produce protein rather than the meat itself" • "I believe that reducing meat consumption will have a larger impact on the planet, then commercializing CBM"

Table 23: Allocation of keywords – Reasons for lack of investments in CBM ventures

Appendix IX: Consumer and investment trends and uncertainties in the protein industry

	Perceived trends in the meat industry		**Key uncertainties in the meat industry**
T_1	The global population continues to grow for the foreseeable future.	**U_1**	Select consumers are becoming increasingly conscious of the negative externalities of meat consumption, will mainstream consumers follow?
T_2	Global meat demand, specifically in emerging economies, rises.	**U_2**	Although consumers become increasingly conscious of the negative externalities of meat consumption, will they adjust and reduce their (meat) consumption?
T_3	Consumers become increasingly conscious of climate change.	**U_3**	Will the importance attached to product attributes in consumers' meat purchase decisions change in the future?
T_4	Consumer become increasingly conscious of meat consumptions' contribution to climate change.	**U_4**	Will mainstream consumers (frequently) substitute conventional meat with CBM?
T_5	Consumers become increasingly conscious of meat consumptions' implications for animal welfare.	**U_5**	Among available meat alternatives, will one specific option emerge as the most accepted and popular among mainstream consumers?
T_6	Consumers' demand for alternative proteins accelerates, continuing the rise of flexitarian, vegetarian and vegan lifestyles.	**U_6**	Will consumers' willingness to try novel and exotic alt-meat products, such as CBM, translate into repeat purchases?
T_7	Consumers' willingness to try novel and exotic alt-meat products[55] increases.	**U_7**	Will consumer pay a premium for alternative meats?
T_8	Investments in climate technologies (and other ESG-themes) accelerate.	**U_8**	Will investors sacrifice quick ROIs for long-term prosperity and impact?
T_9	Investments in agri and food-technologies accelerate.	**U_9**	Will investors commit to the sustainable transformation of global meat production systems?
T_{10}	Investments into the alternative protein industry continue.	**U_{10}**	Will markets become more efficient in allocating capital to climate

[55] Novel and exotic alt-meat products are, for instance, CBM, micro-organism or insects-based meats.

			technologies in proportion to a sector's capacity to mitigate GHGs?
T_{11}	Governments and institutions are becoming increasingly invested in the green transformation of food systems.	**U_{11}**	Will governments accelerate approval processes and investments in the alternative protein industry?

Table 24: Consumer and investment trends and key uncertainties in the meat industry

	U_1	**U_2**	**U_3**	**U_4**	**U_5**	**U_6**	**U_7**	**U_8**	**U_9**	**U_{10}**	**U_{11}**
U1	X	+	?	+	?	+	?	0	+	0	+
U2	X	X	?	+	?	+	?	+	+	0	+
U3	X	X	X	+	?	?	+	+	+	0	?
U4	X	X	X	X	0	+	+	?	+	0	+
U5	X	X	X	X	X	-	?	+	0	0	?
U6	X	X	X	X	X	X	?	+	+	0	+
U7	X	X	X	X	X	X	X	+	+	0	+
U8	X	X	X	X	X	X	X	X	+	+	+
U9	X	X	X	X	X	X	X	X	X	+	+
U10	X	X	X	X	X	X	X	X	X	X	+
U11	X	X	X	X	X	X	X	X	X	X	X

Table 25: Correlations among uncertainties