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Beyond the plate: exploring next generation professionals' views on cell-based meat

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Abstract

Purpose – Cell-based meat is currently one of the most debated food sources of recent decades, as it involves cultivating animal-derived biological tissues in controlled environments. Opinions on this topic vary widely; some see this nutritional source as a strategy to address the sustainability challenges of the agri-food sector, while others perceive it as a potential negative impact on their culture and traditions. In this context, this study aimed to gather the opinions of Italian students engaged in animal production science studies to assess their viewpoints regarding socio-ethical, environmental, and economic dimensions since they represent the future generation of professionals and potential consumers.

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Design/methodology/approach – In this study, the hybrid qualitative-quantitative method of Q-methodology was used. By leveraging the strengths of both qualitative and quantitative approaches, Q-methodology provides a systematic method for examining interviewees' subjectivity by gathering individuals' points of view into clusters of opinions referred to as factors.

Findings – The analysis of the results revealed the existence of four distinct factors within the analyzed student population, highlighting the different viewpoints among a group of individuals pursuing the same course of study.

Originality/value – The results may provide additional insights into the debate on this topic and offer valuable information for policymakers regarding the discussion on novel foods, particularly cell-based meat, which still lacks a regulatory framework at the European Union level.

Keywords Cell-based meat, Cultured meat, Sustainability, Q-method, Policy

Paper type Viewpoint

1. Introduction

Humans, who initially gathered and hunted their food, had the intuition to confine plants and animals in the wild to a convenient and well-defined space, thus beginning the domestication process (Hartung, 2013). Since then, centuries of human societal development have brought us to the present day, where the enormous global population growth since the 1950s (Ritchie and Roser, 2023), coupled with an increase in per capita consumption of animal products (Ritchie *et al.*, 2023), have led to a significant impact on sustainability worldwide due to increased production in the agri-food sector (Van Zanten *et al.*, 2019).

This state of change is affecting our economic system and society as a whole. The drivers of this transformation, identified in the scientific discourse as the "Grand Challenges" (Bock *et al.*, 2020; FAO, 2022), include climate change, global demographic trends, the depletion of natural resources and ecosystems, changes in dietary patterns, public health, animal welfare and assure food security due to rising food demand. Specifically, the livestock sector has an important role because it is responsible for approximately 14.5% of total anthropogenic emissions (Gerber *et al.*, 2013) and 25% of global human digestible protein (HDP) (Mottet *et al.*, 2017). At the same time, today's consumers, who are increasingly developing environmental awareness and sensitivity, are generally unwilling to reduce their meat consumption, leading to what is now referred to in the literature as the "meat paradox" (Hansen and Lykke Syse, 2022). Recent developments and increased consumer awareness have led to the implementation of new strategies such as the UN's Sustainable Development Goals and the European Green Deal with the strategic "Farm to Fork" plan. As a result, the livestock sector today is not only called upon to increase the supply of animal-derived foods but also plays a much more important role since it has to provide products that meet high food safety standards, ensure traceability, maintain the welfare of farmed animals and continuously improve environmental sustainability. Indeed, while modern science has been combined with agricultural practices to meet the world's energy needs since the mid-eighteenth century (Hartung, 2013; Beltran-Peña *et al.*, 2020), in recent decades, the sector has shifted towards the implementation of innovative automated systems and digitalization, aimed to monitor as many parameters as possible to optimize production from the previously mentioned perspectives (Neethirajan and Kemp, 2021).

In parallel, new possibilities have been considered to achieve the proposed sustainability goals. Among these, the possibility of synthesizing food directly from cells, the basic unit of life (Wink, 2021), has been considered. Among these foods, cell-based meat (CBM), also known as cultured meat or cultivated meat, is a combination of biotechnologies and tissue engineering techniques representing an option which, according to its supporters, holds the promise and expectation of meeting global meat demand while mitigating the negative impacts currently attributed to the livestock sector and conventional meat (Langelaan *et al.*, 2010; Post, 2012; de Oliveira *et al.*, 2021; Nobre, 2022).

Highlighting the need for a sustainable agri-food system and the challenges it faces, CBM has been proposed as one of the potential solutions (Langelaan *et al.*, 2010; Post, 2012; de

Oliveira *et al.*, 2021). In this regard, the present study discusses the opportunities and challenges emerging from the current scientific literature on this topic. Based on these findings, a survey was developed to explore and analyze the diverse viewpoints of Italian university students directly involved in studies related to animal production regarding CBM, with a particular focus on its economic, socio-ethical and environmental dimensions (see Figure 1).

This research aims to fill a significant gap in the literature by focusing specifically on the perspectives of future professionals of the agri-food system and potential future consumers, a demographic that has been underrepresented in prior studies (Cain *et al.*, 2021). The findings contribute to the academic understanding of CBM and provide valuable insights for policymakers and industry stakeholders seeking to navigate the complexities of introducing innovative food technologies in a culturally rich environment. Overall, the originality of this paper lies in its innovative methodological framework and its focus on a previously overlooked demographic, setting a foundation for future research on CBM and its implications within the broader context of food systems.

Utilizing Q-methodology, this research aims to identify distinct patterns of thought and opinion within the student cohort, offering insights into how future agri-food professionals and potential consumers engage with the multifaceted implications of CBM. In an Italian context, where culinary traditions are deeply embedded, understanding these perspectives is crucial for anticipating future market trends and addressing the societal challenges posed by food innovation. Moreover, this paper presents a novel contribution to the discourse surrounding CBM by being the first to apply Q-methodology to this subject, to the best of our knowledge. While existing literature (Bryant *et al.*, 2019; Siddiqui *et al.*, 2022; Rehman *et al.*, 2024) on CBM has predominantly utilized quantitative surveys or qualitative interviews to explore consumer attitudes and perceptions, the approach of this study introduces a unique methodology that captures the complexity and diversity of opinions among participants.

2. An overview on cell-based meat

The history of CBM can be traced back to the late-nineteenth century when chemist Pierre Eugène Marcellin Berthelot predicted that future technologies could create foods resembling those consumed daily (Dam, 1894). Years later, in 1912, Nobel medicine laureate Alexis Carrel demonstrated the possibility of culturing and maintaining animal cells outside the organism, specifically embryonic chicken heart tissue (Carrel, 1912). In the 1930s, Frederick Smith, the British Secretary for India, and Winston Churchill, writer and lecturer at that time, both discussed the potential for producing food more efficiently, particularly animal products, by reducing animal suffering and minimizing the creation of food waste, such as inedible parts (Smith, 1930; Churchill, 1931). Toward the end of the twentieth century, specifically in 1995, the US Food and Drug Administration (FDA) approved using *in vitro* techniques for commercial meat production (Kirsch *et al.*, 2023). In 1999, the first patent for industrial-scale CBM production was registered (Van Eelen *et al.*, 1999), alongside NASA's early experiments to use this product for astronaut nutrition (Benjaminson *et al.*, 2002). With the onset of the new

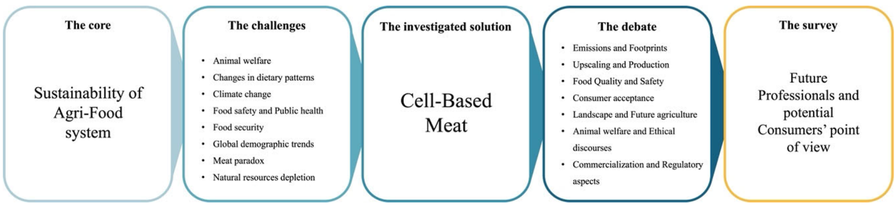

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Figure 1. Conceptual framework of the study

millennium, interest in CBM increased significantly. In 2010, Langelaan *et al.* highlighted in their article “Meet the new meat: tissue engineered skeletal muscle” how CBM could reduce environmental impact and limit the spread of zoonotic diseases associated with livestock farming by synthesizing lab-grown burgers. Three years later, in 2013, Professor Mark Post from Maastricht University, co-author of the research (Langelaan *et al.*, 2010), presented the first lab-grown burger, although production costs and required resources were unsustainable (Jha, 2013). This event marked the first tangible demonstration of the potential to grow animal cells *in vitro* as a food source, spurring further research and technological development. Today, with the rise of several companies dedicated to CBM production, some countries have already regulated the commercialization and production of these products for human consumption (Chodkowska *et al.*, 2022). Currently, the commercialized CBM is produced from muscle stem cells collected from donor animals and grown using substrates containing hormones, growth factors, and other nutrients obtained from animal and vegetable sources (FDA, 2022; FDA, 2023). Another way to synthesize animal proteins is through microbial biomass fermentation, which can convert raw materials into desired products (Burton, 2019), and under this production model, new cell-based products are under study (Knychala *et al.*, 2024). The process occurs in bioreactors monitored by several parameters (Martin *et al.*, 2004), allowing biologic tissues to grow outside the animal body and enabling the manipulation at different degrees of the final output (Bhat *et al.*, 2015; Lee *et al.*, 2024) (see Figure 2).

While early thinkers (Smith, 1930; Churchill, 1931) saw CBM as a potential solution for improving production efficiency and avoiding animal suffering, today, these technologies have a more significant impact on society and institutions since, according to CBM advocates (Langelaan *et al.*, 2010; Post, 2012; de Oliveira *et al.*, 2021), it can also provide a solution to the “Grand Challenges” primarily driven by global population growth. Whether CBM could represent or not an alternative to conventional meat is still uncertain. However, up to date, CBM still represents a theoretical debate because of the low availability of these products for human consumption (To *et al.*, 2024) and the scarcity of public data since almost the totality of the research is held by private companies (Ng *et al.*, 2021; Pajčin *et al.*, 2022), the evaluations are highly context-dependent, and current used methodologies (LCA) report considerable limitations in assessing if CBM would provide a more sustainable alternative than conventional meat (Lynch and Pierrehumbert, 2019).

Regarding what emerges from the available scientific literature, there is a contrasting landscape between those in favor and those against CBM, which is principally debated on the following topics.

2.1 Emissions and footprints

The potential benefits of CBM regarding greenhouse gasses (GHGs) compared to conventional meat production are still unclear (Lynch and Pierrehumbert, 2019). While

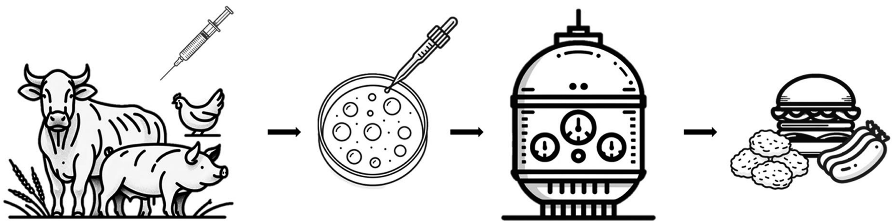

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Figure 2. Cell-based meat production

conventional meat, particularly from cattle, is responsible for emissions of methane (CH_4), nitrous oxide (N_2O) and carbon dioxide (CO_2) (Lynch and Pierrehumbert, 2019), CBM's greenhouse gas emissions are limited to CO_2. These emissions can be mitigated by utilizing renewable energy sources (Jiang *et al.*, 2020), representing a potential strategy for climate change mitigation (IPCC, 2022). At the same time, CH_4 seems to accumulate for a shorter period in the atmosphere than CO_2, so that cattle emissions could be less impacting than CBM production in the long run (Lynch and Pierrehumbert, 2019).

For what concerns energy consumption, the high amount requested represents a major production barrier (Mattick *et al.*, 2015; Rasmussen *et al.*, 2024), and up to date, the energy use for CBM production could be lower when compared to ruminants, while is much higher than pork and poultry (Mattick, 2018). Since these evaluations are made only of the most common production methods, further assessment should be dedicated to comparing CBM with different farming techniques (i.e. intensive/extensive methods, feeding practices, breeding selection programs, etc.).

Land use is expected to decrease as CBM production systems require less space than traditional farms, reduce the need for cropland for feed production and decrease animal-origin waste (Tuomisto and Teixeira de Mattos, 2011; Stephens *et al.*, 2018). However, eliminating livestock may not benefit humans, as herbivorous animals are crucial in converting non-edible plants into nutrients and maintaining soil fertility (Chriki *et al.*, 2022).

Regarding eutrophication potential, since CBM requires relatively lower agricultural requirements than conventional meat, it seems to have less impact than other livestock productions (Mattick, 2018).

The issue of water usage in beef production conceals a controversy regarding the metrics used for its measurement. If the measurement includes the water used to produce crops as feed, the total amount reaches 15,000 L/kg of fresh meat. However, when the measurement boundaries are set at the farm level, the quantity is reduced to a value between 550 and 700 L/kg of fresh meat (Doreau *et al.*, 2012), while pork and chicken water consumption accounts for 459 L/kg and 313 L/kg respectively (Chriki *et al.*, 2022). CBM's current consumption estimations are between 367 and 521 L/kg, which is not far from beef and higher than the other two meat sources (Chriki *et al.*, 2022).

The heterogeneity of the results emerging from the literature regarding emissions and footprints is the product of not enough precise methodologies and reflects a high variability of data as they are context-dependent (Lynch and Pierrehumbert, 2019), and measurements of CBM production should be performed on real production plants and not on hypothetical data to decrease potential estimation errors (Chriki *et al.*, 2022). Furthermore, comparing a primary product, which follows specific natural cycles in space and time, and a lab-grown one, resulting from an accelerated growth process in industrial plants – the so-called in the literature "breweries" (Jönsson, 2020) – is certainly not an easy challenge, calling for the development of more precise methodologies and full traceability of food production systems (Mariano *et al.*, 2023).

2.2 Upscaling and production

Regarding production and scalability, the high energy demand of production systems and the limited availability of renewable energy resources are the primary constraints to address (Mattick *et al.*, 2015). Furthermore, bioreactors, which show problems related to cellular damage due to turbulent flow while mixing, need constant redesign and updates based on the newly developed technologies and the need to increase production scales (Santos *et al.*, 2023).

Another factor is the high costs of cell culture media, which is estimated to be between 55 and 99% of the product's costs depending on utilized sources (Specht, 2020; Stout *et al.*, 2022) and currently strongly depends on fetal bovine serum (FBS) growing substrate (Chriki *et al.*, 2022). To overcome this barrier, the research focuses on developing cheap, easy-to-obtain, animal-free and safe culture media (Reiss *et al.*, 2021; Santos *et al.*, 2023).

To provide structure and support for the growing tissues, scaffolds have been developed to mimic a conventional meat cut and confer to CBM familiar sensory aspects, such as visual and texture properties, to the consumers. Scaffolds are classified as natural or synthetic origins (Santos *et al.*, 2023) and must be biodegradable and non-toxic for human consumption (Reiss *et al.*, 2021). To date, most CBM products do not possess prominent scaffold architecture and further research are needed to develop a structure that accomplishes the technological needs of CBM (Reiss *et al.*, 2021; Afonso *et al.*, 2024). For this reason, the expectations are that initially, CBM will be marketed as unstructured products like burgers, sausages or nuggets (Santos *et al.*, 2023).

These limitations, combined with the need for continuous research and development of new technologies, the complexity of the production systems from a structural point of view (see Post *et al.*, 2020), and the required specialized knowledge to manage the whole process, require significant capital investments. Also, for these reasons, almost all CBM research comes from private companies which patented the innovations they develop, often restricting access to research in general (Ng *et al.*, 2021; Pajčin *et al.*, 2022). This carries the risk of generating a natural monopoly in favor of those who hold the specific technologies (Treich, 2021), with the risk of generating market inefficiencies.

2.3 Food quality and safety

When discussing the consumption and commercialization of a food product, the crucial variables that come into play are its sensory and nutritional quality and the safety of the food in question. Conventional meat, unlike CBM, results from the complex interaction of numerous intrinsic and extrinsic variables related to the organism from which it is obtained (Munteanu *et al.*, 2021). Factors such as nerves, collagen, adipose tissue and myoglobin, combined with muscle tissue, characterize the meat that consumers are accustomed to, and CBM products are not able so far to perfectly replicate these characteristics (Hocquette, 2016). Moreover, elements like the enteric microbiome, which influences meat quality and is not currently present in CBM growing systems, are responsible for nutritional aspects such as vitamin B_{12} content in the meat (Munteanu *et al.*, 2021). The microbiome also plays various roles in many metabolic pathways that maintain the organism's homeostasis and are still the subject of ongoing research (Mizoguchi and Guan, 2024).

Additionally, important processes like aging, which impart many desirable characteristics to meat, are not considered by CBM producers (Hocquette, 2016). Moreover, myoglobin, which donates the typical color of red meat and represents the iron nutritional source (Suman and Joseph, 2013), is still not possible to be stimulated in CBM, giving these products an almost colorless appearance (Chriki *et al.*, 2022; Broucke *et al.*, 2023). Researchers are exploring various strategies to improve the appearance of CBM, focusing mainly on the addition of plant-derived heme proteins and other coloring molecules. One significant approach involves the incorporation of soybean leghemoglobin, a heme protein that gives CBM a color and flavor similar to conventional meat. These heme proteins not only improve color, imparting a brownish-red hue, but also enhance cultured muscle cells' growth, texture and overall quality (Simsa *et al.*, 2019). This also helps to provide bio-available iron, which is essential for human nutrition (Shaikh *et al.*, 2021).

Regarding public health implications, the absence of interaction between animals and humans decreases the likelihood of zoonotic diseases, and the controlled production environment of CBM can reduce the incidence of foodborne diseases as well (Datar and Betti, 2010). Furthermore, the reduction of farmed animals and livestock operations could decrease the use of antibiotics, to treat sick animals, which are often overused or misused (Hosain *et al.*, 2021), reducing the risk of disseminated antimicrobial resistance (Munteanu *et al.*, 2021). Even if CBM may promote public health, some doubts remain regarding using immortal cell lines for tissue growth since the proliferating cells may contain expressed oncogenes (Soice and Johnston, 2021), exposing consumers to related risks. Moreover, FBS may represent an additional problem in assuring food safety since it may represent a potential source of infection from viruses and prions (Park *et al.*, 2013). For these reasons, strict controls and further research are needed to prevent the occurrence of harmful consequences.

2.4 Consumer acceptance

From the consumer point of view, what emerges from a recent review study from Rasmussen *et al.* (2024) is that European and North American consumers showed some curiosity toward CBM since their willingness to try it arrange between 40 and 70%; but it also true that the “interest to try” may not be related to a willing to consume these products regularly, as reported by Wilks and Phillips (2017). To adopt CBM as an alternative meat source, consumer acceptance covers a key role and represents the most significant challenge (Hocquette, 2016; Bryant and Barnett, 2019; Franceković *et al.*, 2021).

This is why advances, such as adding plant-based heme proteins to replicate conventional meat’s flavor, color and texture are crucial to increasing consumer acceptance of CBM (Simsa *et al.*, 2019).

Concerning perception, acceptance and consumption patterns toward CBM, the literature reports as negative factors neophobia (Pakseresht *et al.*, 2021; Dupont *et al.*, 2022; Rombach *et al.*, 2022; Tsvakirai *et al.*, 2024), disgust (Pakseresht *et al.*, 2021; Rosenfeld and Tomiyama, 2022), personal concerns (Bryant and Barnett, 2018), unnaturalness (Bryant and Barnett, 2018; Pakseresht *et al.*, 2021), safety (Bryant and Barnett, 2018), healthiness (Bryant and Barnett, 2018); while the positive common factors are familiarity with the technology (Post *et al.*, 2020), curiosity (Rombach *et al.*, 2022) green consumption value (Bryant and Barnett, 2020; Dupont *et al.*, 2022) and food innovativeness (Engel *et al.*, 2024). Other variables such as lifestyle and pre-existing diets (Hocquette, 2016; Bryant and Dillard, 2019; Hansen *et al.*, 2021), familiarity with the product (Mancini and Antonioli, 2019; Hocquette *et al.*, 2022), social norms and dietary identity (Lewisch and Riefler, 2023) may vary based on the socio-cultural context. Focusing on pre-existing diets, vegetarians show a higher sense of disgust, unnaturalness and low perceived safety regarding CBM (Verbeke *et al.*, 2015b; Rosenfeld and Tomiyama, 2022). On the other hand, meat-eaters seem more prone to consuming these products (Pakseresht *et al.*, 2021; Rosenfeld and Tomiyama, 2022).

Socio-demographic variables suggest that young males, highly educated, meat eaters and left-wing/liberal political-oriented consumers are the most prone to accept CBM (Bryant and Barnett, 2020), while the role of income is still unclear (Bryant and Barnett, 2020). Regarding the place of residence, Shaw and Mac Con Iomaire’s study (2019) demonstrates how the degree of urbanization of a consumer’s living context influences willingness to try CBM. In that case, consumers from urban areas were more prone to consume CBM and believed it could be common food in the future, while rural counterpart consumers were more concerned about the topic.

Consumer acceptance is a complex topic because, in the decision-making process of food product consumption, several variables shape consumers’ choices (Chen and Antonelli, 2020), and sensory quality (Drake *et al.*, 2023) and cultural aspects (Fieldhouse, 1995) play a central role. Regarding sensory quality, so far, just a few studies have performed such analysis on actual CBM products, saying that CBM still has a long way to go and that in the future it may be a hybrid product of cultured animal cells and plant proteins vegetable proteins, but that it will almost certainly not be equivalent in terms of sensory characteristics to conventional meat (To *et al.*, 2024). At the same time, other research are based only on speculative cases since CBM are still not widely available for human consumption (To *et al.*, 2024).

2.5 Landscape and future agriculture

Regarding culture and traditions, the impact of CMB on human culture is an undervalued and understudied topic (Hansen *et al.*, 2021), and some authors suggest that it may endanger the connection between humans and nature (Dilworth and McGregor, 2014; Bhat *et al.*, 2015). It is obvious the role of modern agriculture goes beyond feeding the planet, but its primary function is to mitigate world inequality and political instability too (Noll and Murdock, 2019).

Food is not only essential for nourishing populations but also for gathering people and creating communities (Fieldhouse, 1995), and the production of meat, and food in general, is a process of matter transformation that requires energy and resources and is highly dependent on the surrounding environment. Conversely, CBM potentially requires only a container and water for production and is not bound by the environment like conventional livestock farming (Jönsson, 2020). The disappearance or replacement of agriculture and animal husbandry by CBM could lead to a new geographical characterization and arrangement of the territory favoring urban intensification at the expense of rural areas, given the different structural requirements of CBM compared to traditional farming (Jönsson, 2020; Helliwell and Burton, 2021), thereby endangering rural communities, which represent cultural heritage and the value of traditions, and maintaining the global agricultural landscape (Leah *et al.*, 2023).

2.6 Animal welfare and ethical discourses

Food doesn't only fulfil the mere biological need for nutrients but also plays a primary role in personal identity, the creation of social interactions and connections, is involved in religion and rituals and has a direct connection with nature (Fischler, 1988; Fieldhouse, 1995; Uhlmann *et al.*, 2018). That said, one of the initial ethical issues concerning the production of CBM focuses on the unnaturalness of these products compared to the conventional meat to which humans are accustomed. Some authors have emphasized how this practice increasingly embodies an anthropocentric view, where humans manipulate nature solely for their purposes, disrupting and detaching from the natural equilibrium (Bhat *et al.*, 2015; Laestadius, 2015; Alvaro, 2019). Furthermore, some more extreme viewpoints have highlighted how the unnaturalness of this practice could expand the boundaries of what can be synthesized in the laboratory, including human flesh, potentially facilitating access to "victimless cannibalism" practices (Hopkins and Dacey, 2008; Schaefer and Savulescu, 2014; Laestadius, 2015).

Another important debate on the ethics of CBM concerns farmed animals' welfare. As previously mentioned, the production of CBM does not involve the direct use of the whole animal but only a small part of it, which is then grown into a controlled environment outside the original organism. Given these circumstances, it may no longer be necessary to keep animals in captivity, transport them, make them suffer and slaughter them solely for human purposes (Hopkins and Dacey, 2008; Schaefer and Savulescu, 2014). Consequently, CBM is often associated with a cruelty-free practice that should satisfy ethical concerns such as animal welfare. Additionally, replacing conventional meat with CBM could promote biodiversity, which is continuously declining also due to livestock farming activities (Machovina *et al.*, 2015). At the same time, CBM still does not represent an animal-free production (Alvaro, 2019) since it utilizes stem cells (Treich, 2021) and FBS as growing substrate (Chriki and Hocquette, 2020), both obtained from donor animals, representing a contradiction to the CBM advocates' philosophy. While stem cells may be obtained from dead donors to not affect the welfare of live animals (Schaefer and Savulescu, 2014), for what concerns the substrates, many alternative serum-free media are under study, but up to date, they had scarcer results compared to FBS (Zhang *et al.*, 2020; Santos *et al.*, 2023; Yamanaka *et al.*, 2023).

2.7 Commercialization and regulatory aspects

To date, not many countries have specific regulations for CBM or even take into consideration its authorization. The first Country that regulated and legalized CBM was Singapore in 2020, followed by the USA in 2022 (Chodkowska *et al.*, 2022). However, not every member state of the US matches up with the federal decision. In Florida in May of 2024, CBM was banned, and manufacturing, distributing, holding or offering any CBM product was criminalized, and other states are considering this possibility. Still, the CS/CS/SB 1084 of the Florida State Senate "does not prohibit manufacturing or possessing cultivated meat for research purposes".

Regarding EU legislation, says Post *et al.* (2020, p. 410), "depending on the starting cell types used may either fall into Regulation (EU) 2015/2283 on novel foods or in the genetically modified organism (GMO) legislation (embodied by the GMO Directive 2001/18/EC and GMO Regulation (EC) No 1829/2003) will be applicable". Post and colleagues, also underscore that "the EU Novel Food Regulation excludes genetically modified foods and therefore the use of induced pluripotent stem cells for CBM production will most likely be covered by the EU GMO legislation". Given the lack of specific regulation in this area, some EU states are considering whether to ban the commercialization of CBM within their borders. The only Country that has forbidden CBM is Italy, which may conflict with potential European legislation favoring CBM (Battle *et al.*, 2023). This regulatory gap may allow CBM products to be commercialized as food. Still, it mostly depends on the degree to which the wider public agrees with the new food and is prone to adapting their dietary habits (Kurrer and Lawrie, 2018).

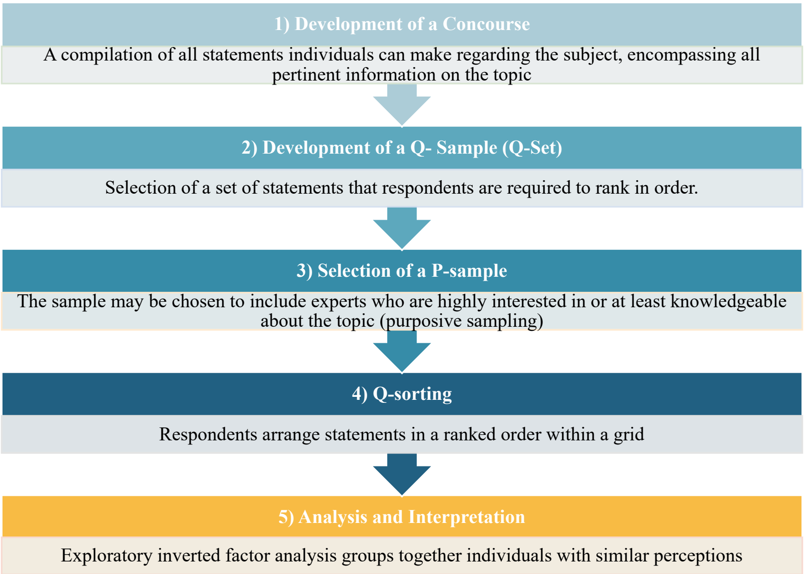
Summarizing what emerges from the literature study is a complex scenario of ideas, theories and speculations divided into the pro-CBM and the anti-CBM. The Q-methodology investigation is ideally suited to better observe the internal nuances of these two factions. Specifically, we used this tool to investigate the thoughts of students precisely where the points of debate on CBM arise from the scientific literature. Additionally, we explored their views on the responsibilities attributed to the production and commercialization of CBM.

3. Methodology

In examining human/consumer behavior, researchers frequently use quantitative and qualitative approaches to thoroughly understand their subjects. Qualitative methods can capture the nuances of specific behaviors and individual differences, enriching the collected data, but their less structured nature often limits the reproducibility of studies compared to quantitative methods (Vecchio *et al.*, 2024). Conversely, quantitative methods are esteemed for their capacity to furnish findings that can be applied broadly and to establish connections between variables using precise, impartial measurements. In this regard, hybrid approaches like the Q-methodology (QM) link qualitative and quantitative research, which can address the limitations mentioned (Brown, 1980). QM bridges two research traditions by providing a systematic method for examining subjectivity (Stenner *et al.*, 2008).

In the 1930s, British psychologist and physicist William Stephenson developed QM, presenting it as the scientific approach to investigating human subjectivity (Brown, 1980). The QM begins with the concept of constrained independent diversity (Keynes, 2013) or what Rogers (1995) refers to as "finite diversity", intending to gather and examine the array of connections individuals form (Kitzinger, 1987). This is achieved in QM-based studies by presenting participants with a diverse set of stimulus items, known as the "Q-set", which they are required to actively rank in order (Watts and Stenner, 2012). This task enables participants to concentrate on their subjective experiences, placing not only the participants' "builders" at the center of the method but also their individual "constructions" (Rogers, 1995). QM requires participants to rank a set of statements based on their personal viewpoints, usually on a scale from strong agreement to strong disagreement (Brown, 1980). The ranked data are then subjected to factor analysis to uncover patterns or clusters of similar perspectives, referred to as factors (Mckeown and Thomas, 1988).

Over the years, QM has been utilized in numerous fields such as psychology (Gao and Soranzo, 2020), political science (Kallis *et al.*, 2023), forest science (Misal *et al.*, 2023), sociology (Pike and Kinsey, 2024), education (Lundberg *et al.*, 2020), health studies (Mao *et al.*, 2020) and marketing (Hwang *et al.*, 2021). Its effectiveness in uncovering the underlying structure of subjective opinions has made it an essential tool for researchers aiming to understand complex human attitudes and behaviors. A QM study follows a five-step procedure, as seen in Figure 3 (Mckeown and Thomas, 1988).



Source(s): Adapted from Vecchio *et al.* (2024)

Figure 3. Steps in the Q-methodology

The first step in QM is the development of a concourse. This involves creating a comprehensive set of statements that reflect the full range of opinions and beliefs about the topic under study (Brown, 1993). At this stage, all aspects the subject has examined must be considered (Vecchio *et al.*, 2022). In this regard, the concourses for this study were developed by integrating insights from prior research on viewpoints toward CBM Verbeke *et al.* (2015b), Bryant *et al.* (2019), Van Loo *et al.* (2020), along with our understanding from earlier readings on the topic.

In the second step, once the concourse has been formed, researchers choose a subset of statements to create the Q-sample. This selection method entails refining and reducing the pool of assertions to a workable amount, usually ranging from 40 to 60 items (Brown, 1980). It is critical to ensure that the Q-sample includes diverse perspectives and covers all dimensions or features of the topic under consideration (Brown, 1993). In this sense, three key themes (environmental responsibility, social and ethical responsibility, and economic responsibility) on the students' viewpoints of CBM were used as a framework for developing a representative set of statements. Similar statements and statements expressing the same ideas were combined or deleted, yielding a final set of 29 statements.

The third step is the selection of participants or respondents involved in the study. Researchers purposefully select a diverse group of individuals, typically comprising 20 to 40 participants, who are knowledgeable or have a stake in the topic to ensure an adequate representation of viewpoints (Brouwer, 1999). The purpose is to capture diverse opinions rather than statistical representativeness (Mckeown and Thomas, 1988). Briefly, in QM, a small number of participants is considered sufficient because the primary focus is on understanding patterns of subjectivity – how people think or feel about a specific issue – rather than making statistical generalizations to a larger population (Watts and Stenner, 2012; Vecchio *et al.*, 2022).

After selecting the participants, the Q-sorting phase comes as the fourth step, where participants are given the Q-sample and asked to arrange or prioritize the statements based on their viewpoints or beliefs. Usually, this is done through a quasi-normal distribution grid, where participants place each statement along a spectrum from strongly disagree to strongly agree (Brown, 1980).

All gathered Q-sorts are analyzed and categorized based on similarity and, thereafter, summarized to derive a singular perspective (Brown, 1980). Multivariate data reduction techniques, such as principal component analysis (PCA) or factor analysis (FA), facilitate comparison, grouping and summarization. This reduction can transpire in two primary phases: extraction and rotation. The primary analytical decisions in Q include the number of groups, the factor extraction method (PCA or FA centroid) and the factor rotation method.

Factor extraction aims to condense all individual replies into a limited number of typical responses (Previte *et al.*, 2007). This phase encompasses traditional quantitative criteria, such as explained variance or eigenvalues exceeding one, and incorporates qualitative interpretation to ascertain the authenticity or similarity of one extracted “perspective” to existing ones. The researcher has the discretion to extract less information, sacrificing statistical detail to simplify interpretation (Vecchio *et al.*, 2022).

Factor rotation involves altering the perspective from which the findings are analyzed, akin to modifying the scale range or employing a logarithmic transformation. This is executed to get a more lucid and interpretable results framework. Whether is chosen factorial analysis or PCA, it always opts for an inverted solution (Stephenson, 1935; Burt, 1941; Fleiss, 1971) because a traditional one focuses on finding correlations between variables, whereas the QM approach correlates and factorizes individuals (Vecchio *et al.*, 2022). Two principal results characterize each identified perspective (factor). A set of coefficients, known as factor loadings, indicates the correlation between each respondent and the factor, similar to the interpretation of correlation coefficients. Another set of values represents the correlation between each item and the factor, expressed as z-scores or normalized scores. Z-scores are the weighted mean of the scores provided by respondents for a given item, while normalized scores offer a unified representation of z-scores. These scores reflect the ranking of items by a hypothetical individual representing a group of similar respondents (the factor). Factor interpretation relies on a synthesis of item scores and the researcher’s comprehension of the case and respondents’ perspectives. Both z-scores and normalized scores signify item categorization from a common viewpoint. Unique items with the highest or lowest scores are generally the most valuable for analysis. Upon identifying these objects, the interpreter assesses the rationale for their placement. Consensus items denote the shared agreement among all elements.

These five steps constitute the fundamental framework of QM, enabling researchers to systematically investigate subjective perspectives and identify patterns of beliefs or opinions within a specific population. In the present study, all methodology stages were imposed on the subject as proposed, and the results were analyzed.

In the study, the concourse (first step) was identified as previously stated, first by adding literature, particularly addressing consumer understanding of CBM (Verbeke *et al.*, 2015a), and secondly by employing a qualitative technique. A focus group discussion was conducted with four experts from academia, industry and institutions, each bringing a unique perspective on technological innovation in animal production (Zanoli *et al.*, 2018) to stimulate discussion on a series of statements compiled from the literature.

In a pilot study, the group of experts assisted in defining the dimensions to be investigated and selecting the appropriate statements for each dimension. Based on the literature review, focus group discussion and pilot test results, the statements were classified into three main categories: environmental, socio-ethical and economic responsibility. An interactive process among research group participants was employed to code the statements within these categories. The final Q-set was defined from the conversation after deleting items with equal significance, or that were difficult to connect back to one of the indicated dimensions. The Q-set consisted of 29 statements balanced across categories and accompanied by pros and cons viewpoints. The interviews were based on the respondents’ understanding of CBM, and they were conducted online to allow participants to complete surveys in their free time and in an environment free of pressure to provide answers, as the goal is to see subjectivity over the subject. The sample was defined by the filter question "*In my opinion, cell-based meat is . . .*", and the authors predetermined the number of participants based on Watts and Stenner's (2012) recommendation of fewer than 70 respondents, representing nearly half of the selected items.

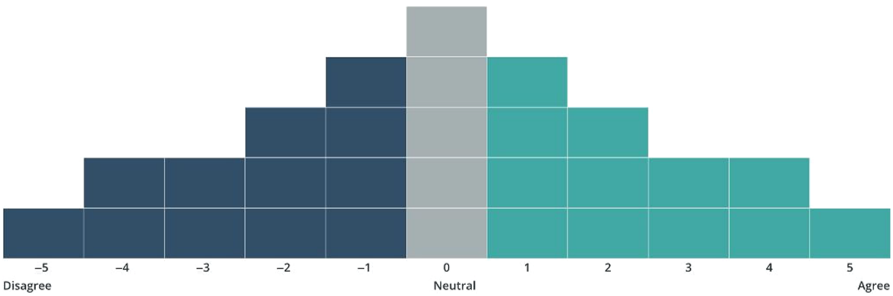
Respondents sorted the 29 statements into a distribution based on their level of agreement, neutrality or disagreement (values ranged from −5 to +5) (see Figure 4).

The P-set comprises 29 students from the Department of Veterinary Medical Sciences at the University of Bologna. Students were selected as the participant group due to their potential to represent future professionals and consumers. This study was conducted exclusively within the Department of Veterinary Medical Sciences for several key reasons. First, the department is renowned for its strong emphasis on food science and veterinary medicine, making it an ideal context for examining the complex interplay between animal health, food safety and innovative food technologies, such as CBM. Second, students within this department possess a foundational understanding of the biological and ethical considerations related to animal-based food production, which enhances the depth of insights gained from their opinions on CBM. By focusing on this specific cohort, the study aims to capture informed perspectives that reflect academic knowledge and potential professional attitudes toward emerging agri-food innovations. Third, opinions should come from a group of respondents with the same level of information (Brown, 1980) and interviewing students from a single department ensures that they have had the same teaching on the topics of interest (Vecchio *et al.*, 2020). Ultimately, the decision to limit the study to this department was driven by a desire to ensure that the insights gathered were rooted in a relevant academic context, providing a robust foundation for further research and discussion surrounding CBM in Italy.

Lastly, an inverted factor analysis was performed utilizing the centroid approach, followed by a Varimax rotation, the most commonly employed strategy for this study (Watts and Stenner, 2012), to improve result interpretation. Subsequently, based on the criteria of eigenvalues and data interpretability, the definitive number of factors to be retrieved was determined using the criterion of eigenvalues exceeding one (Raje, 2007; Vecchio *et al.*, 2024).

4. Results

After completing the iteration process, we determined that a 4-factor solution best represented the data, collectively accounting for 48% of the total variance. In that order, the eigenvalues for these four factors were 4.983, 3.525, 2.888 and 2.541. Table 1 identifies the respondents that define and share a specific perspective. Seven respondents were associated with factor 1, eight with factor 2, six with factor 3 and eight with factor 4, indicating that individuals can be categorized into four groups based on their insights on CBM.



Note(s): Ranking values range from −5, through "zero", to +5

Source(s): https://qmethodsoftware.com/

Figure 4. Example of fixed quasi-normal distribution

Table 1. Results of Q-factor analysis

	ID	Factor loading 1	2	3	4
Group 1 (n = 7)	2	*1.83697*	−1.35954	0.52906	0.10667
	7	*1.63419*	−0.53499	−0.44331	−0.55402
	8	*1.38553*	−1.20687	1.41664	0.2234
	1	*1.13274*	−1.03286	−0.09596	0.11384
	17	*0.64797*	−0.30801	0.41537	0.15685
	10	*0.61386*	−0.20863	−0.83144	−0.03807
	11	*0.24163*	−0.44562	−1.42856	−1.69543
Group 2 (n = 8)	3	1.07276	*2.16688*	1.05944	−0.93527
	21	0.56652	*1.85571*	−0.16608	−0.79327
	28	0.03025	*1.64013*	−0.66355	−0.0044
	13	0.42247	*1.39637*	−0.68544	0.08863
	29	−2.02527	*1.01501*	−0.47863	0.33961
	14	−0.70256	*0.50363*	−0.6785	0.75998
	27	−1.15128	*0.45821*	0.33713	−0.68201
	16	−0.88119	*0.09996*	−1.62357	−0.68277
Group 3 (n = 6)	5	−0.29146	0.40715	*1.87394*	0.47468
	25	−0.77082	−0.70289	*1.35857*	−1.42505
	12	1.44254	0.29612	*1.2135*	−1.1418
	9	−0.61041	−0.49269	*0.83141*	−1.17444
	24	−1.01603	−0.84227	*0.6421*	−0.2108
	4	0.32762	−1.5503	*0.55635*	−1.92335
Group 4 (n = 8)	15	−1.72358	0.80049	0.21223	*2.35561*
	22	−0.28755	0.1785	0.2522	*1.31298*
	23	0.31274	−0.11199	−0.35912	*1.20877*
	19	−1.08926	−0.27697	−1.6876	*1.19388*
	6	−0.94082	−1.03634	0.73914	*1.13856*
	18	0.00986	0.90574	0.75391	*1.00202*
	26	−0.22773	−0.23224	−1.60033	*0.64892*
	20	0.04029	−1.38168	−1.44889	*0.13627*
Eigenvalues		4.983	3.525	2.888	2.541
% Explained variance		17	12	10	9

Source(s): Authors work through QMethod Software (https://app.qmethodsoftware.com)

Table 2 presents the factor sort values for each statement. These values, which are Z scores converted back to their original scale, offer an overview of each group's perspective.

4.1 Factor description

4.1.1 Eco-optimists – "I am a friend of the planet!". Seven participants (Factor 1) expressed positive insights on CBM regarding its environmental impact. They were inclined to voluntarily accept this product since they found it safe and healthy (No. 17). Consequently, they were categorized as "Eco-Optimists". This group prioritizes characteristics such as environmental sustainability (No. 1), low emissions (No. 2) and energy efficiency (No. 7). Students in this group also give value to CBM since they think that it is associated with low water consumption per unit of product (No. 8) and high animal welfare (No. 10). In this regard, this group underscores the significance of employing sustainable production methods aimed at minimizing environmental impact. Nevertheless, they exhibit lesser concern towards processes that demand minimal or no input, such as antibiotics or hormones (Rank −2), and the replacement of farmed meat production (Rank −4). In conclusion, this group primarily emphasizes ensuring CBM production conforms to rigorous environmental standards without showing a marked opinion on social and economic responsibilities.

Table 2. Statements belonging to the Q-set

Dimensions	Q statements	Factor 1 rank	Factor 2 rank	Factor 3 rank	Factor 4 rank
Environmental	1. Environmentally sustainable	3	−2	0	0
	2. Characterized by low emissions	5	−4	1	0
	3. Far from nature	2	5	3	−2
	4. That will offer renewed rural area and landscape management	1	−5	1	−5
	5. Which can also be produced from Indigenous and limited breeds	−1	1	5	1
	6. Whose process requires little or no input (antibiotics, growth factors, hormones, etc.)	−2	−3	2	3
	7. Energy-efficient	4	−1	−1	−1
	8. Which requires low water consumption per unit of product	3	−3	4	1
	9. That does not produce waste, with a view to a circular economy	−1	−1	2	−3
Socio-ethical	10. Characterized by high animal welfare	2	0	−2	−1
	11. Socially sustainable	0	−1	−3	−4
	12. That can accommodate a broader group of consumers (vegans, vegetarians, different religions, etc.)	4	1	3	−3
	13. That will change people’s lifestyles	1	3	−2	0
	14. Ultra-processed, which encourages a chemically perfect diet	−1	2	−2	2
	15. That will replace the farmed productions	−4	2	0	5
	16. That will replace the plant-based productions	−2	0	−4	−2
	17. Safe and healthy	2	−1	1	1
	18. That is unlikely to be embraced by the European consumer	0	2	2	2
	19. That will make access to food more equitable	−3	0	−5	3
Economical	20. Economically sustainable	0	−4	−3	0
	21. Which will lead to food monopolies	1	4	0	−2
	22. That will solve the problems of food insecurity	−1	1	0	4
	23. That will encourage the development of urban farming	1	0	−1	4
	24. Of a supply chain that promotes a better redistribution of value between actors	−3	−2	1	−1
	25. That will steer towards safer and better-paid jobs	−2	−2	4	−4
	26. That will reduce the risk of health and, therefore, economic crises	0	0	−4	2
	27. That will only be well received by the non-European market	−4	1	0	−1
	28. Which will lead to an increase in per capita meat consumption in the future	0	4	−1	0
	29. Which will wipe out typical geographical indication productions (PDO, PGI, BIO, etc.)	−5	3	−1	1

Source(s): Authors work through QMethod Software (https://app.qmethodsoftware.com)

4.1.2 Pro-traditions – “Cell-based meat? No, Thanks!”. Factor 2, which consists of eight participants, identified as “Pro-traditions”, encapsulates the concerns of students who are critically apprehensive about the social and industrial facets of CBM. Students in this group perceive CBM as significantly different from nature (No. 3), that is, from conventional food sources, and this undoubtedly raises questions about the naturalness and authenticity of meat. Additionally, there is a palpable concern among participants that the widespread adoption of CBM will precipitate significant lifestyle changes (No. 13) and encourage overly processed and chemically treated diets (No. 14). Besides, they are concerned that CBM could displace existing plant-based alternatives (No. 16), thereby reducing dietary diversity. From an economic perspective, this group is worried about the potential for monopolistic practices (No. 21), fearing that large corporations could gain disproportionate control over the food supply chain through CBM production. On the other hand, interestingly, these students tend to think that CBM may become more accepted outside European markets (No. 27), pointing to doubts about its cultural and social fit within Europe. They also believe that the proliferation of CBM could lead to an increase in overall meat consumption (No. 28), and, as a result, potential health and environmental problems could worsen. Finally, there is a significant concern that the rise of CBM could erode the cultural and economic value of traditional, geographically indicated food products (No. 29), threatening the preservation of local culinary heritage and regional economies.

4.1.3 Inclusive innovators – "Cell-based meat: Brings a lot to the table for All". Factor 3, encompassing six participants known as "Inclusive Innovators", represents a group of students who are optimistic about the potential of CBM to drive positive change across various dimensions. These students believe CBM can provide significant advantages regarding environmental sustainability, social inclusion and economic equality. Here, CBM has the potential to reinvigorate rural areas and improve landscape management (No. 4), thus contributing to the long-term development of rural communities by lowering the environmental impact of traditional livestock farming. They value the potential of CBM to preserve genetic diversity by incorporating Indigenous and limited breeds (No. 5) while also emphasizing its role in waste reduction and promoting a circular economy through more sustainable resource use (No. 9). Inclusivity is a pillar of their philosophy since they consider CBM as a versatile choice that can accommodate a wide range of dietary preferences and constraints, including those of vegans, vegetarians and numerous religious groups (No. 12), without worrying about the removal of geographically indicated products from the marketplace. They believe that a more equitable food supply chain is achievable, with CBM serving as a means of redistributing value more equally among all actors, ensuring that producers, workers and consumers all benefit (No. 24). Furthermore, they highlight the potential for CBM to provide safer and higher-paying job possibilities by improving working conditions and increasing earnings (No. 25). Overall, this group's forward-thinking and opportunity-seeking attitude highlights the potential of CBM to build a more inclusive future for everyone.

4.1.4 Farming paradigm shifters – "Revolutionizing Food, Redefining Farming". The fourth-factor group, which consists of eight students, referred to as *Farming Paradigm Shifters*, considers a balanced mix of environmental, social and economic aspects. They place a high value on solutions to food insecurity (No. 22). By prioritizing minimal reliance on antibiotics, growth factors and hormones in the production process of CBM (No. 6), they believe this approach enhances food safety and reduces environmental impact. They also expect CBM will someday replace conventional farmed production, providing a more ecological and efficient alternative. Despite the probable opposition of European consumers (No. 18), they believe that CBM will eventually lead to more equitable food access (No. 19) and help economic sustainability (Ranked zero-neutral expression). In this factor group, students also view it as a stimulus for urban farming development (No. 23), increasing local production while lowering the carbon footprint associated with long-distance food transportation. Furthermore, they emphasize the health benefits of CBM, picturing a future in which it helps reduce health risks while also mitigating economic problems associated with food production (No. 26). In a nutshell, students emphasize the transformational potential of CBM for transforming agricultural methods and solving significant societal issues.

5. Discussion

Our study aimed to analyze the thoughts and viewpoints of Italian students involved in animal production science studies. Specifically, we were interested in understanding what they perceived to be the possible environmental, socio-ethical and economic responsibilities (Arnold *et al.*, 2022) attributable to CBM, considering their future roles as professionals in the agri-food sector and potential consumers due to their young age (Bryant and Barnett, 2020).

5.1 Environmental responsibility

Based on the findings from the literature, we aimed to evaluate the students' perspectives on the environmental responsibility attributed to CBM, starting with emissions and resource consumption as they are the main topics covered by the scholars (Lynch and Pierrehumbert, 2019; Chriki *et al.*, 2022; Rasmussen *et al.*, 2024). The eco-optimists (EOs) have an overall positive vision of CBM's potential environmental benefits. People in this group think this kind of production is environmentally sustainable, has low emissions, is energy efficient and requires low water inputs. In this sense, Tuomisto and Teixeira de Mattos (2011) found out that CBM uses around 7–45% less energy (only chicken uses less energy), 78–96% less GHG emissions, 99% less land and 82–96% less water, depending on the product. In contrast, the Pro-Traditions (PTs) counterpart showed the opposite thought. This viewpoint aligns with findings from other studies, which suggest that CBM may produce more negative externalities than certain meat alternatives, such as gluten, soybean meal or insect-based substitutes (Post *et al.*, 2020). Additionally, research indicates that the production of CBM requires high concentrations of components like glucose and amino acids, which notably impact its overall environmental footprint (Smetana *et al.*, 2015). The other two groups did not demonstrate polarizations, except for the Inclusive Innovators (INs), which have high expectations regarding the low water consumption and waste production of CBM.

The literature discusses the risks of endangering rural communities if agriculture is substituted by cell-based food production since industries could replace farms and be placed closer to metropolitan areas, leading to higher degrees of urbanization (Helliwell and Burton, 2021). From our results, it is possible to observe how this risk is shared from PTs and Farming Paradigm Shifters (FPs) point of view. Supporting this, other studies suggest that while alternative meat production could be localized to benefit rural areas, a more likely outcome involves bioreactor facilities being established near urban areas (Newton and Blaustein-Rejto, 2021). Companies might choose to position these facilities close to cities to reduce transportation costs or in economically distressed urban areas to promote job creation. Furthermore, the lack of necessary infrastructure in rural areas may hinder the establishment of alt-meat production facilities in these regions, potentially disconnecting meat production from rural communities and limiting their access to new economic opportunities (Stephens *et al.*, 2018; Santo *et al.*, 2020). In addition, interview findings from related studies reveal that even minor decreases in demand for animal agriculture, driven by competition from alternative meat, could have substantial financial repercussions (Newton and Blaustein-Rejto, 2021). Given the scale of the animal agriculture industry in countries like the United States, some stakeholders have expressed concerns that rural communities dependent on traditional animal agriculture may perceive alternative meat as a direct threat to their livelihoods, even if the industry as a whole remains viable (Broad, 2020).

As reported before, the idea of growing cells-based tissues outside the donor animal has a role in the naturalness perception of CBM products. At this purpose, three groups agreed at different degree levels that this practice is "far from nature", as Bryant and Barnett (2018) reported, while only FPs disagreed. They may have responded this way considering that CBM is not directly obtained from nature as we are used to; however, given their revolutionary vision for the future agri-food sector, CBM could represent a "natural" development of animal farming.

5.2 Socio-ethical responsibility

Regarding socio-ethical responsibilities, CBM is generally not perceived as socially sustainable by three groups, while only EOs did not express a positive or negative ranking. Furthermore, EOs are the only group that expects enhanced animal welfare thanks to this practice, and they are also sure that CBM will not replace farmed productions. Research by Liu *et al.* (2023) highlights that consumer in Southern Europe, specifically Italy, Portugal and Spain, express mixed feelings about CBM, often linking their acceptance to its perceived environmental benefits and animal welfare implications. This aligns with findings from Hibino *et al.* (2024), who emphasize that cultural perceptions significantly influence how CBM is viewed in terms of its social acceptability and sustainability. Various studies also support the perception of CBM's impact on animal welfare. For instance, Wilks and Phillips (2017) highlight that many consumers associate CBM with potential benefits for animal welfare alongside environmental advantages. However, they also identify ethical concerns and cost as significant barriers to acceptance (Valente *et al.*, 2019). This aligns with findings from Fuseini and Sulemana (2018), who note a negative correlation between attitudes toward animal welfare and meat consumption, suggesting that consumers who prioritize animal welfare may be more inclined to support alternatives like CBM. Furthermore, Heidemann *et al.* (2020) discuss the "meat paradox", where individuals desire to consume meat while simultaneously wishing to avoid harming animals, which could explain the mixed feelings toward CBM among different consumer groups. Moreover, the expectation that CBM will not replace farmed meat is echoed in the literature. For example, research by Post (2012) discusses the challenges and prospects of CBM, indicating that consumer acceptance will likely require overcoming entrenched beliefs about meat consumption and its associated ethical implications. This perspective is reinforced by the work of Bianchi *et al.* (2018), who emphasize that while there is a growing interest in plant-based and CBM alternatives, structural changes in the meat industry are necessary to facilitate a significant shift away from traditional meat consumption.

Three out of four groups agree that CBM could be consumed by individuals following vegan or vegetarian diets, as these dietary choices can be motivated by concerns for animal welfare or by the decision to avoid meat and animal products due to the environmental impact of the livestock sector (Cramer *et al.*, 2017); therefore, CBM could potentially meet the criteria to address these two factors.

Only PFs didn't agree with the statement since their point of view is in line with Verbeke *et al.* (2015b) and Rosenfeld and Tomiyama's (2022) findings, which reported that vegetarians and vegans may not represent the primary target of consumers since they are not convinced about healthiness and naturalness of CBM.

The four groups generally agree that CBM will not replace plant-based foods and did not take a firm stance on safety and health nor its impact on people's lifestyles. Only the PTs group is confident that CBM products will significantly affect the latter. The general view, except for the EOs, is that these products will obtain more success outside Europe.

5.3 Economic responsibility

None of the four groups has a positive idea about the economic sustainability of CBM. Still, the PTs and FPs groups disagree on whether CBM could lead to food monopolies due to patented technologies and high barrier costs for production, as Treich (2021) mentioned. As traditional meat producers adapt to changing consumer preferences, there is a risk that large corporations may monopolize the CBM sector, potentially stifling innovation and limiting market access for smaller producers (Wood *et al.*, 2021). The regulatory landscape surrounding CBM is also evolving, with agreements being established to ensure safety and quality standards (Sancar, 2019). These regulatory frameworks will be crucial in shaping the future of CBM and determining its role within the broader food system.

Furthermore, FPs are the only ones who strongly agree that CBM may be a good strategy to ensure food security, and they think it may encourage the development of urban farming, as suggested by Van Der Weele and Driessen (2013). Also, according to Bryant and Barnett (2018), adopting CBM could lead to the development of new business models and a reorganization of the agri-food supply chains.

The INs group is the only group with a positive outlook regarding the possibility of more equitably redistributing the value of production among stakeholders in the supply chain, and they are also confident that CBM will ensure safer and better-paid jobs. Additionally, they are the only ones strongly emphasizing that CBM do not decrease health risks from food consumption, unlike the FPs, who are more confident but less convinced, reflecting the uncertainties raised in the literature regarding the food safety of CBM, which highlight both the potential positive and negative effects (Datar and Betti, 2010; Park *et al.*, 2013; Hosain *et al.*, 2021; Soice and Johnston, 2021).

Concerning the possibility that CBM will increase per capita meat consumption, only PTs strongly agreed, while the others didn't deny or vehemently denied (INs).

6. Conclusion

Meat is a food product that we cannot give up consuming to get molecules that our body cannot produce on its own, to store energy, to acquire materials to fabricate our cells and to get vitamins, most of which are not found in any plant (Williams, 2007). The growing awareness of the difficulties in feeding an expanding global population, coupled with the need for more sustainable food production, is driving innovations in food systems that are transforming our future agri-food landscape. Having introduced a novel approach, this paper investigated Italian students' viewpoints on CBM since they represent the next generation of professionals and potential consumers, using Q methodology and analyzed numerous statements under the three dimensions mentioned above. In this sense, 29 Italian students ranked 29 statements about CBM into a normally distributed grid. The reason for choosing Q-methodology is to understand better how students, as future professionals and consumers, perceive CBM and their associated viewpoints. Through factor analysis, we then grouped the individual perspectives into common categories.

Drawing on the viewpoints of Italian students studying animal sciences, this study formed four groups reflecting real-world perspectives on CBM. The analysis results indicate that students in these factor groups demonstrated complex and diverse perspectives towards a product they have not yet tested or experienced based on their accumulated knowledge.

The results of the present study may also be helpful for policy implications since CBM still has not found a suitable place in European legislation (Post *et al.*, 2020). Students who fall in Factor 1 demonstrated a positive approach to the environmental benefits of CBM, believing that these products could effectively address current issues such as greenhouse gas emissions and the significant consumption of land, food and water. In contrast, participants in Factor 2 expressed skepticism about the potential of CBM, which they believe, despite possibly becoming more prominent and debated in the near future, does not offer a viable solution; they consider it unnatural and believe it could pose economic challenges and alter current consumption patterns.

On the other hand, students in Factor 3 approached CBM from different perspectives than the previous groups, focusing on environmental sustainability, social inclusion and economic equality. Lastly, students in Factor 4 expressed the belief that CBM could address one of the most significant food-related issues today: food security. Despite these differences, we also identify common ground among the factors. All factor groups tend towards the need to address the environmental, social and economic sustainability responsibilities of CBM. For example, in factor four, students identified that CBM can be produced from indigenous and limited breeds, which can be interpreted as new practices, while they also have concerns for animal welfare.

From a theoretical perspective, CBM may represent a game changer in facing the new sustainability challenges related to the agri-food system. Still, up to date, this topic is highly debated, and the available literature reveals many gaps between estimations and objective results (To *et al.*, 2024) and several remaining obstacles to overcome as well (Lynch and Pierrehumbert, 2019; Chriki *et al.*, 2022; Santos *et al.*, 2023).

On the other hand, from the political economy perspective, it is crucial to understand the broader implications of CBM, particularly concerning the roles of private companies and market dynamics that influence the sustainability of this emerging industry. The emergence of CBM is not merely a technological advancement but is deeply intertwined with economic structures and power relations within the food system. As noted by Bryant and Barnett (2018), the acceptance and integration of CBM into the market are influenced by various socio-political factors, including consumer perceptions, regulatory frameworks and the economic interests of stakeholders involved in meat production and distribution. This highlights the need to critically examine how private companies may shape the narrative around CBM, potentially prioritizing profit over genuine sustainability efforts. Furthermore, the economic implications of transitioning to CBM are significant. Heidemann *et al.* (2020) emphasize that the social and economic dimensions of CBM production should be considered to ensure equity among all stakeholders involved in this new supply chain. The potential for CBM to address environmental concerns is promising, yet it requires substantial investment and optimization of bioprocesses to become economically viable compared to traditional meat (Kurt *et al.*, 2022). This economic aspect is crucial, as it directly affects the accessibility and acceptance of CBM in various markets. Moreover, the political economy of CBM intersects with environmental sustainability. As Treich (2021) discusses, while CBM holds the potential to reduce the environmental footprint of meat production, it is essential to recognize that without addressing the underlying economic and political structures, the anticipated benefits may not be fully realized.

An interesting consideration by Chriki *et al.* (2022) highlights that, as of today, CBM does not constitute a sustainable diet food according to FAO (2010) parameters. This is because there are still doubts about the healthiness of the food (Soice and Johnston, 2021), more studies are needed on its environmental impact, and it is currently not economically viable. Regarding socio-ethical acceptance, if CBM is perceived as cruelty-free production (Hopkins and Dacey, 2008), at the same time, it is considered as far from nature (Bryant and Barnett, 2018) that we are accustomed to today.

Food doesn’t only cover the mere biological need for nutrient supply but has a primary role in self-identity, creating social interactions and connections, it is involved in religion and rituals and it has a straight connection with nature (Fischler, 1988; Fieldhouse, 1995; Uhlmann *et al.*, 2018). The impact of CMB on human culture is an undervalued and underestimated issue (Hansen *et al.*, 2021), and it should be taken into serious consideration for future studies. The worries are that the production and consumption of CBM, and cell-based food in general, could definitively mark the increasingly evident separation between humans and nature, reducing food to the sole purpose of sustenance (Welin, 2013; Bhat *et al.*, 2015). If CBM were adopted as a solution to today’s climate change problems, and consequently, livestock farming was discontinued, several areas would return to nature. However, at the same time, the detachment from animal farming could further alienate us from nature itself (Bhat *et al.*, 2015).

In conclusion, the solution to the negative externalities of animal husbandry production can only be found when the stakeholders and institutions employ a holistic and multidisciplinary approach. Still, only the future developments in the livestock sector and CBM industry will be able to outline the future of the agri-food system.

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