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Review

Cell-Based Meat and Firms' Environmental Strategies: New Rationales as per Available Literature

Germano Glufke Reis [1,*], Marina Sucha Heidemann [2], Katherine Helena Oliveira de Matos [3] and Carla Forte Maiolino Molento [2]

1 School of Business Administration, Federal University of Paraná, Av. Prefeito Lothário Meissner, 632, 80210-170 Curitiba, Brazil
2 Animal Welfare Laboratory, Federal University of Paraná, Rua dos Funcionários, 1540, 80035-050 Curitiba, Brazil; msuchah@gmail.com (M.S.H.); carlamolento@ufpr.br (C.F.M.M.)
3 The Good Food Institute Brazil, Avenida Paulista, 807, cj. 2315, 01311-100 São Paulo, Brazil; katherinem@gfi.org
* Correspondence: glufkereis@ufpr.br; Tel.: +55-41-988-394-278

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Abstract: Higher demand for meat production and limited inputs, as well as environmental and animal ethics issues, are bringing alternative protein sources to the market, such as cell-based meat (CBM), i.e., meat produced through cell culturing, without involving animal raising and killing. Although the potential social and environmental benefits of the technology have been recently addressed in the blossoming CBM literature, little has been discussed about the possible implications for the environmental strategies of firms that are entering the new cell-based production chain. Thus, drawing on the theoretical framework of competitive environmental strategies and a systematic review of the literature, we discuss prospects for cell-based meat regarding the possible adoption of environmental strategies by firms that are entering the CBM chain. The technology may be considered a potential means for mitigating most of the environmental impacts of large-scale meat production, e.g., extensive land use and greenhouse gas emissions. We discuss how such benefits and consumer attitudes towards cultivated meat could encourage the adoption of environmental strategies by firms, and the roles that value chain firms are likely to play in those strategies in the future.

Keywords: cell-based meat; environmental strategies; startup; value chain

1. Introduction

The world total and per capita meat consumption have significantly increased in the last decades [1–3]; they are also expected to keep rising, especially in the Southern Hemisphere [4]. In fact, the demand for livestock products is expected to grow around 70% from 2010 to 2050 [5]. Prices tend to increase as well, since opportunities for further optimizing of livestock production are currently limited and inputs such as water, lands, and energy are increasingly expensive. Hence, there is a need for finding and implementing alternative sources of protein [4,6].

Recently we have seen the development of alternative protein sources, such as the plant-based and cell-based meats. Cell-based meat (CBM)—also labeled cultivated, in vitro, clean, cultured, or lab-grown meat, amongst others [7]—is an animal-free form of real meat made from animal muscle cells, which is cultured from animal cells through specific processes [4,8]; it therefore does not depend on farm animal production and may potentially lead to significant transformations in the conventional meat chain. Major meat-processing multinationals from developed countries (e.g., Tyson Foods, Springdale, AR, USA; Cargill, Wayzata, MN, USA) have already invested in the technology, several startups have been created worldwide, and investments are increasing [9].

There are currently 82 publicly known CBM startups [10]; 41% of them are in North America, 27% in Europe, 17% in Asia, 7% in the Middle East, 4% in South America, 2% in Oceania, and 1% in Africa. Thus, although they are spread worldwide, there is a larger concentration of firms in the Northern Hemisphere. However, it is too early to predict whether this initial geographical configuration will remain when this industry matures, as this depends on an array of decisions by multiple players, which are not yet defined.

Furthermore, CBM innovation has been regarded as a highly promising innovation; see, for instance, the 2020 Technology Pioneer award given by the World Economic Forum to Aleph Farm CBM startup [11]. As the technology rapidly improves [12], CBM products are expected to gradually reach the markets in the next few years [4].

The process of CBM production is based on tissue engineering initially developed for biomedical purposes [13]. It starts from a small extraction of satellite cells from an animal, followed by cell proliferation and differentiation in appropriate equipment and nurturing environment, leading to in vitro development of animal tissue (e.g., muscle, fat). Cell-based meat products are expected to bring several environmental and animal welfare benefits [14]. These improvements involve severe issues associated with intensive industrial livestock production: environmental (e.g., land usage, deforestation, and methane emission), animal ethics and welfare, food safety, and the low efficiency of animal-based production. Furthermore, CBM offers virtually zero risks of zoonotic diseases, given that pathogens are intrinsically absent in the meat cultivation process. Thus, the innovation may in the future decrease the expanses and suffering related to preventing diseases that are associated with conventional meat production (e.g., Salmonella). In addition, dangerous virus mutations (e.g., H1N1 and the recent SARS-CoV-2) would be impossible to occur with cultivated meat consumption, which would be a major social benefit of the innovation [15].

Although the technology's potential benefits have been recently addressed in the blossoming CBM literature, little has been discussed and forecasted about the possible implications for firms' environmental strategies. Since organizations have been scrutinized and pressed by consumers and other stakeholders to adopt environmentally and socially responsible activities, it is relevant to examine the opportunities brought by CBM products in this regard. The growing number of cell-based firms [9] seems relevant—over 30 firms and startups of the emerging CBM value chain are publicly known [16]. Major meat processors (Tyson, Cargill), which are frequently required to adopt greener operations and products, have also joined the search for protein alternatives [9] and have invested in plant-based and cultured meat. All these firms may benefit from the adoption of sustainability strategies which, in turn, may be a source of competitive advantage [17]. Thus, drawing on the theoretical framework for competitive environmental strategies [18–20] and a systematic review of the CBM literature, our goal is to discuss the prospects for CBM production regarding the possible adoption of environmental strategies by firms entering the new chain.

The article is intended to make several contributions to the literature. By combining a systematic literature review on CBM with the environmental strategies' framework [19], we bridge the novel technology and environmental management debate and address whether CBM products could be a source of competitive advantage. Furthermore, we add to the original framework in two ways. First, CBM may be considered a "radical innovation" because it encompasses the three attributes that define radical innovations [21]: Uniqueness, novelty, and possible development of new technology in the meat value chain. This means that CBM innovation is dissimilar to prior and current inventions in conventional meat production chains, which are mostly incremental, "run-of-the-mill inventions" [21] (p. 717). Incremental innovations in the conventional meat chain can lead, for instance, to the reduction of unhealthy substances in meat products [22], to increase productivity [23], and decrease water consumption [5]. While incremental innovations promote only marginal changes, radical innovation, in turn, can promote significant transformation in all the business activities and interfirm activities within an industry [21,24]. This is the case with CBM, which is poised to cause major changes in the livestock value chain [7] through the introduction of new actors as, for instance, suppliers of culturing systems and novel production processes. Moreover, CBM is likely to stimulate the development of new technology along the chain (e.g., animal-free growth medium for cultivating cells, 3D meat bioprinting) [7], which is also a characteristic of radical innovation. Since previous research on environmental strategies of firms has mostly focused on mature industries and incremental innovations (see [20] for illustrative cases), we shed light on how the framework could be used in the context of radical innovation. Second, we also discuss the roles that value chain firms are likely to play in the development of environmental strategies in the future.

2. Theoretical Framework

2.1. Competitive Environmental Strategies

The literature has explored how organizations invest in environmental strategies as a means to gain competitive advantage. Companies develop green strategies to reduce the environmental impacts of their activities, respond to pressure from external stakeholders [25] and, at the same time, add value to products and increase their competitiveness [20]. Environmental strategies may entail improvements in several activities: Production processes, waste recycling, new product development [26], and reduction in greenhouse gas (GHG) emissions, i.e., gases with global warming potential (e.g., nitrous oxide and CO2) [14], amongst others. In this regard, firms often seek innovative solutions by adopting new processes, materials, and technologies. In parallel, CBM emerges as a promising alternative for adopting more environmentally friendly activities and products in the meat value chain [8,27]. This seems extremely relevant, as meat producing chains present important environmental issues, which may be mitigated by this new technology.

Orsato [18,19] proposes a theoretical framework that derives from Porter's generic competitive strategies [28] and addresses the competitive advantages companies intend to achieve through investments in environmental improvements. Environmental strategies of firms may prioritize the following: (a) low-cost strategies where organizations seek to reduce operating costs by implementing environmental investments, and (b) differentiation strategies where firms develop sustainability-driven value propositions. Environmental investments may also focus on: (c) organizational processes, activities, and routines; and (d) company products or services offered to consumers.

Based on these dimensions, four generic and interwoven strategies are defined: Eco-efficiency strategy, beyond compliance leadership strategy, eco-branding strategy, and environmental cost leadership strategy. The eco-efficiency strategy is process-oriented and focuses on competing by decreasing production costs while at the same time reducing environmental impacts in areas such as energy and water consumption, waste, emissions, etc. [17,29]. The beyond compliance leadership strategy is also process-oriented but, in this case, environmental improvements aim to promote value-adding by enhancing firms' positive image and reputation. This happens because greening investments are seen by consumers as differentiated, i.e., products are recognized as superior to those offered by other competitors, which leads to competitive advantage. Marketing and eco-labeling initiatives play a key role in this regard because they inform customers about firms' environmental improvements [20]. The eco-branding strategy, in turn, is product-oriented and focuses on differentiating the firm through the delivery and marketing of green products. Consumers are likely to pay for the costs of those differentiated green attributes [18], which are, in turn, difficult to imitate by competitors. Finally, the environmental cost leadership strategy is product-oriented and involves adopting innovations to substantially decrease costs. Significant changes in input raw materials and business models are expected in this strategy, which might lead to extensive changes in the industry and competitive environment.

In sum, the main components of the environmental strategies' framework are: (a) environmental improvements that may be achieved by changes in firm's processes, products, and chains [20]; (b) costs reduction associated with environment-oriented enhancements in processes, products, chains, or achieved through innovation; (c) differentiation and value-adding achieved through green products or environmental improvements in processes, products, and chains. It is worth noting that the four strategies are not mutually exclusive since the interplay between processes and products is expected [19].

2.2. Conventional Meat Chain, Environmental Implications, and the (Cell-Based) Meat of the Future

The conventional animal-based beef value chain consists of the following stages [30]: Inputs (feed, veterinary, other services), production (farming, feedlot, slaughtering), processing, and distribution and marketing/sales (supermarkets, restaurants, others). Other animal products (chicken, pork) may present specificities concerning chain components especially in the production stage, with additional important impact from high soy and corn use for feeding the animals. Thus, livestock chains occupy the land extensively through grazing areas and crop plantations for animal feeding, causing deforestation and soil degradation [31]. Animal feed production uses around 30% of terrestrial land [5,31], overtaking the other agricultural chains such as cereals and grains for human consumption. Conventional meat products are more demanding in terms of land and water use than plant-based products [32]. Emission of GHG in livestock production is a relevant issue as well [5,14]; these emissions mostly encompass methane, nitrous oxide, and CO_2, which are related to climate change. Conventional meat chains account for around 14.5% of global human-induced GHG emissions [5,31]. Another major issue with livestock chains refers to animal suffering, e.g., in slaughtering, stock density, painful procedures, extreme confinement conditions, etc. [33]; this is especially relevant for intensive industrial systems. Animal welfare has been recognized as an important corporate social and environmental responsibility issue [34,35]. Although animal welfare requirements have been imposed to meat producers and processors, this is a major problem in meat chains that still needs improvement [36].

Given that the consumption of conventional meat is expected to almost double by 2050, the impacts of those issues are likely to increase in the coming years [4,5]. Thus, alterative animal protein sources and improvements in meat production processes are necessary. In this regard, CBM is seen as a potential solution [14], given that it does not involve animal raising and slaughter. The overall process employs the same fundaments of tissue engineering technology: proliferation and differentiation of specific stem cells for each tissue required to match meat compounds, such as muscle and fat [27]. Since CBM employs unique and novel processes for producing meat, i.e., they are unlike previous and current processes, and may redefine the technology used in the meat chain, it meets the criteria to be considered a radical innovation [21]. In addition, the forecasted CBM value chain (Figure 1) may involve the following components: (a) Suppliers of culturing and processing systems (cell supplies, growth medium, scaffold and bioreactor suppliers, other input suppliers), (b) meat culturing and processing (meat growth factories, starter tissue suppliers, cell-growth farms), (c) CBM further processing, (d) distribution, marketing and sales (supermarkets, retailers, fast food chains, smaller retailers, importers, etc.) [4,7,13,37].

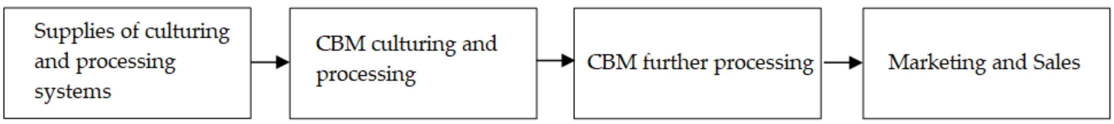

Figure 1. Overall structure of the cell-based meat (CBM) value chain.

3. Method

A systematic literature review focusing on CBM was conducted following the general guidelines adopted in previous work [38]. Thus, in order to identify relevant publications, we screened all scientific articles that addressed one or more of the following terms: clean meat, cell-based meat, cellular meat, cultured meat, lab-grown meat, animal free meat, in vitro meat (see, for instance, [39]). A set of international literature databases and search engines were used with no temporal restrictions: Emerald Insight, Google Scholar, ScienceDirect, and Web of Science. From this initial screening, 141 articles were identified, from 2005 to 2019.

Nonetheless, a set of exclusion criteria was imposed to the identified publications. Thus, the following articles were dropped: Technical articles that discuss topics that are not in the scope of this work (e.g., tissue growth, scaffolds for 3D-cell culture), studies that focus only on social aspects of CBM (e.g., ethical and philosophical issues), papers that were not in English language, and non-peer reviewed.

After the exclusions, 43 articles remained in the final set of analyzed articles. They were published in journals of several fields (based on Scimago Journal and Country Rank), such as agricultural and biological sciences (53%); biochemistry, genetics, and molecular biology (35%); environmental science (28%); medicine (19%); veterinary (12%); social sciences (9%); engineering (9%); food systems (9%); food security (9%); chemistry (9%); nursing (9%), among others (one or more subject areas may apply to each journal). The more frequent journals were: *Meat Science* (six articles; 14%), *Journal of Integrative Agriculture* (five; 12%), *Frontiers in Sustainable Food Systems* (four; 9%), *Trends in Food Science and Technology* (three; 7%), *Appetite* (two; 2.5%), *Environmental Science and Technology* (two; 5%) and *PloS ONE* (two; 5%).

A set of papers comprised reviews about CBM (42%). Different methodological approaches were employed in the remaining articles: Surveys (20%), experiments (with consumers) (12%), systematic literature reviews (about consumers' attitudes) (7%), life cycle analysis (7%), qualitative methods (content analysis/focus groups) (9%), and others (e.g., climate modeling/simulation) (5%). Since our objective was to address the extent to which CBM production may benefit the environmental strategies of firms, the chosen publications and subsequent analysis were categorized according to the main components of the environmental strategies framework as discussed above: environmental improvements (18 articles; 42%), costs reduction (13; 30%), and differentiation (17; 40%).

4. Results

4.1. Expected Environmental Improvements

According to the analyzed publications, CBM may be considered a potential means for mitigating the aforementioned negative environmental impacts of conventional large-scale meat production. It has been associated with significant reductions in land use, water and energy usage, GHG emissions, and ocean sustainability [8,40–48]. Tuomisto and de Mattos [14], for instance, used a life cycle analysis to estimate the environmental consequences of CBM in relation to conventional meat production in Europe if non-animal inputs are used in the culture medium. They found that 99% less land would be needed to produce CBM while GHG emissions might be 78–96% lower depending on the product (beef, poultry, etc.). Moreover, energy and water use would be reduced, respectively, by 7–45% and 82–96%. The greatest positive impacts would be for beef and sheep production [14]. Mattick et al. [48] also conducted a life cycle assessment assuming another culture medium and similarly found that CBM would demand less land. Alexander et al. [49] in turn, point out that CBM would decrease cattle land use to the levels of poultry production, which is over 50% less. In addition, Sun, Han, and Lin [50] forecasted the environmental impacts of several types of products, such as crops, livestock products, and CBM, in China. They found that CBM production may be beneficial to the Chinese environment, due to its lower use of land and less GHG emissions, as well as an energy demand similar to conventional pig production.

Lynch and Pierrehumbert [51], in turn, estimated the climate impact, in relation to temperature, of beef from cattle and CBM production, forecasting over different time frames the variations on CO_2, methane, and nitrous oxide related to cattle production, in comparison with CO_2 emissions from CBM. The authors observed that CBM may lead to less global warming than cattle for the initial 100 years due to its single emissions of CO_2, in a scenario of intense meat production and consumption. However, they emphasized that after this period CBM production may provoke increased global warming, given it requires energy consumption which generates accumulation of CO_2 emissions. They concluded that energy generation with less CO_2 is needed for the environmental benefits of

CBM production to be increased. Furthermore, energy inputs are higher in CBM production than in conventional animal production, due to the greater demand for electricity by the laboratories in all phases of the CBM production process [14,48]. Similarly, Smetana et al. [52]—based on a "cradle-to-plate" life cycle comparative analysis—emphasized that CBM has currently more environmental impact than other protein alternatives, e.g., insects, due to its energy consumption. Hence, improvements in energy use, such as clean and renewable alternative sources of energy, remain an important environmental requirement when considering the insertion of CBM in the market, as environmental gains in terms of energy efficiency seem less clear than the evident environmental gains related to other resources such as land and water.

Since CBM production is mostly an animal-free system [36,53,54], it can improve animal welfare management, which is also recognized as a relevant sustainability issue related to food producing chains [35]. According to the Food and Agriculture Organization [55], animal welfare is a component of sustainability, which then means that sustainability of a system is intrinsically bound to animal welfare. Thus, the low welfare intensive animal production systems cannot be considered sustainable, even if they were efficient in the use of natural resources such as land and water. Cell supply is the only stage of the CBM chain that involves animal handling and still may be significantly reduced.

Thus, this new meat industry may substantially decrease the world-wide enormous numbers of animals, in a scale of billions of individuals, involved in intensive raising practices, their suffering in intensive industrial systems and the slaughter of such high numbers of individual animals per year.

4.2. Cell-Based Meat and Possible Cost Reductions in the Meat Value Chain

Since CBM is virtually animal-free [53], costs related to conventional meat production tend to be reduced [8,13,43]; this applies to activities such as animal feed production, veterinary services, breeding, farming, feedlots, animal transportation, slaughtering, amongst others. Moreover, production lead time and losses are significantly decreased. CBM has a faster growth process in comparison to conventional meat production, which demands animal raising [56]. Production may also focus on the desired meat only, as opposed to the full animal body in the conventional chain, which greatly increases efficiency of the whole process.

Furthermore, CBM is less exposed to pathogen contamination, for instance, Salmonella [54,55]; such pathogens require stringent surveillance, standardization processes, and costly food inspection systems due to food safety and public health concerns. Moreover, CBM also offers increased financial security, allows for some avoidance of carbon-related taxes if decarbonized energy generation availability increases, offers enhanced product consistency and is less dependent on climate conditions, thus related to improvements in food security.

On the other hand, entering the cell-based arena requires investments in biomaterials and bioprocesses equipment and facilities which are currently costly; total costs involved in implementing cell-based facilities are not informed in the literature so far. Nonetheless, it is already known that 55–95% of meat culturing expenses are related to culture medium costs [58]; thus, research has been conducted and remains important in order to reduce those costs within the next few years [32]. Another major challenge regarding CBM is scaling the production up [8,13,59], to make production less costly and more competitive. To improve the efficiency of CBM production systems, bioreactors should reach bioconversion indexes comparable to those of conventional meat production systems [27]. Bioreactors must be developed and improved as well in order to reach increased efficiency of media use, support larger amounts of culturing meat, and to spend less energy [8,13,40,48]. Furthermore, alternatives are necessary to the components of cell culture media and scaffoldings, in both cases commonly of animal origin and high cost [13,42,60].

Some issues with relevant impacts in terms of production costs are difficult to consider at this point in time, as, for instance, the time and facilities required per batch of a given amount of CBM. The amount of CBM that can be produced in a time unit depends on the type and size of the bioreactor, mode of production, amongst other factors [61]. Weele and Tramper [46], for instance, calculated that a 20 m^3 bioreactor can supply the meat demand of 2560 people, considering 10 kg per person per year. In turn, a 300 m^3 bioreactor conceptually conceived by Li et al. [62] can supply the meat demand of a population of 75,000. Comparatively, one average Dutch farm produces 35 tons per year of cattle meat, which, according to Post [63], is analogous to the production of cell-based beef on a growth farm with four bioreactors of 1000 L capacity each—i.e., a total farm capacity of 4 m^3. As for the time required, according to the estimations from Aleph Farms, CBM production has considerable advantages over conventional beef, since their cell-based meat is claimed to take three to four weeks to be produced, while the same amount of beef is expected to take two years to be produced by conventional animal farming [64]. The total timescale estimation depends on the specific product, because of post-production procedures such as how much maturation time is needed. For instance, minced meat for hamburgers is likely to require less time than a complex steak cut. In addition, faster-developing animals may have faster timescales in vitro as well. The equipment available may also have an impact because timescale is dependent on the size and type of bioreactors used [61]. Overall, the production length is not expected to be significantly different amongst cell-based beef, pork, chicken, and seafood.

Finally, since CBM is a developing technology, knowledge is currently built based on estimations rather than exact numbers. Keeping this background in mind, it is worth considering that Tubb and Seba have recently developed a forecast on the future of protein alternatives. They estimate, for the year 2024, the cost of cell-based beef to be around 10 U$/kg, while conventional beef is expected to be 4.5 U$/kg in the same year. However, in 2030, cell-based beef is estimated to cost 2 U$/kg and conventional beef 6 U$/kg. The changes in products and production processes will depend on the outcomes of the ongoing adaptation and on the development of technologies regarding different production phases. A crucial phase requiring significant research and development today is that of culturing systems. To develop enhanced bioreactors and less costly, animal-free growth medium are amongst the top priorities [61,62,65], which reinforce CBM's role in putting forward eco-efficiency strategies.

4.3. Consumer Acceptance and Differentiation Potential

In recent years, some studies have assessed consumer attitudes towards CBM and other meat substitutes [38,66–68]. Those studies assess people's acceptance of CBM products and willingness to buy and eat them. Results are mostly positive, suggesting that those products will find interested buyers once they are launched. The research outcomes present, however, some degree of variability.

On the one hand, Wilks and Phillips [69] found that 65.3% of US consumers would try CBM while 33% would consume it regularly or replace it for conventional animal meat. However, acceptance rates seem to be higher in India and China, 48.7%, and 59.3% (consumers that are very or extremely likely to purchase), respectively, than in the USA [86]. Valente et al. [70], in turn, identified that 63.6% of Brazilian respondents would eat CBM while 54% of Italian consumers would do the same [71]. Among Belgian consumers around half would try CBM after being informed about its positive environmental impacts [72]. Similarly, 57% German consumers would try CBM. Respondents seem mostly motivated by environmental and animal welfare concerns [70,73].

In addition, Hocquette et al. [74] found that a smaller proportion of 5–11% respondents of a cross-national sample would choose to eat CBM instead of conventional meat, while Slade [75] found that 11% of Canadian respondents would prefer a cell-based burger against other meat options; in contrast, 65% would choose beef burger. According to Bryant and Barnett [66], those inconsistencies may be attributed to methodological issues involving the adoption of biased and non-representative samples (e.g., [74]) or the use of unclear CBM definitions and stimuli in experiments. Other issues, such as the impact of time on the degree of perceived novelty and artificiality attached to CBM, may help explain the variance in published results. Accordingly, research has identified whether and how consumer attitude changes once further information about CBM is provided. Verbeke, Marcu et al. [76], for instance, identified in focus groups with consumers from Belgium, Portugal, and the United Kingdom initial reactions of disgust and perception of unnaturalness; however, consumers recognized CBM as having environmental and animal welfare benefits. Consequently, resistance towards CBM decreased as interviews progressed. The fact that acceptance improves as more information is provided was also noted by Marcu et al. [77] and Bekker et al. [78], in their studies on consumer attitudes. Thus, despite the potential benefits of the technology, consumers are yet under informed about it and marketing efforts are needed in order to garner their full potential for acceptance of CBM products. This may additionally apply to managing the negative characteristics that may be attributed to CBM by consumers, such as unnaturalness and artificiality, limited taste, lack of safety, and price [69,70,72,76,79,80].

Of particular interest in the context of environmental differentiation strategies are the findings that demonstrate that as consumers perceive the environmental and animal welfare benefits of CBM, their willingness to consume it increases [38,73,78]. The intention to buy cell-based products among Italian consumers, for instance, is mostly influenced by extrinsic product attributes, including sustainability, animal welfare, and health benefits [71]. Gómez-Luciano et al. [81] conducted a cross-cultural study in the United Kingdom, Spain, Brazil, and the Dominican Republic addressing consumer willingness to purchase alternatives to conventional meat encompassing CBM, plant-based meat, and insect protein; the authors concluded that one of the attributes that deserves to be emphasized to consumers is the sustainability of those alternative protein sources, among other characteristics (e.g., healthiness, safety, taste). Similarly, Bekker et al. [78] found that positive attitudes towards CBM are improved when the product is associated with sustainability-related information. Verbeke et al. [72], in turn, identified that the motivation to buy and pay more for CBM increases when further information regarding environmental and public health benefits are provided to consumers, in comparison to offering just basic information.

5. Discussion

Although CBM is still in its infancy and faces several challenges ahead, the increasing number of startups, investments, and the fast-developing technology [9] suggest it will rapidly reach the markets [82,83]. However, research is still needed to forecast its market, economic, environmental, and social impacts. To the best of our knowledge, this article is the first to forecast competitive environmental strategies that could be adopted as soon as cell-based products are offered to consumers. Furthermore, our systematic review indicated that this subject has been overlooked in the business management literature as a whole. However, the extant literature on CBM reinforces its potential to decrease some of the major environmental issues caused by the conventional meat chain, while simultaneously responding to the growing demand for animal protein for human consumption. Thus, in the mid- or long-term it has the potential to be explored in environmental strategies in order to increase firms' competitiveness.

The technology may significantly redefine the meat value chain, introducing new production processes, required inputs, and supply schemes. As seen in our review, some important process-related cost reductions are expected to be achieved with CBM, since animal production and slaughter will not be necessary, accompanied by environmental (e.g., decrease in water, land usage, and waste) and animal welfare improvements. Conventional food safety processes and surveillance systems are expected to be less demanded given that cells are developed in laboratories that have highly controlled environments [54,57]. Furthermore, in the case of conventional meat production, between 30% to 50% of the body of an animal is not edible, which is not the case in CBM production. Hence, since there is potential for production costs to be reduced while environmental benefits increase, it is likely that eco-efficiency strategies will be encouraged. Eco-efficiency is a source of competitive advantage in the market because it is strongly linked to sustainable development and to reduction in production costs [17,29]. It also enables a firm to respond to pressure for sustainability improvements in the value chain from stakeholders such as customers, non-government organizations (NGOs), and governments, and may increase firms' reputation and performance [84].

However, to allow for eco-efficiency initiatives, the CBM technology has to overcome multiple challenges. Bioreactors must be improved in order to increase scalability and to decrease energy-related waste and costs [42,45]; more effort is needed in improving the efficiency of cell culture media as well [60]. Those improvements will likely drop production costs and product price in the future [85]. Environmental cost leadership strategies, in turn, will be conditioned to those improvements because they involve not only innovations but also reductions in production costs [18]. Furthermore, research is still needed on specific gaps, for instance costs in all value chain stages should be forecasted, comparing cell-based and conventional meat; costs involved in adopting the new technology, such as those related to facilities, inputs, etc., should be assessed; and measurement indicators for eco-efficiency [17] for CBM production are yet to be developed.

In addition, studies on consumer attitudes have mostly shown positive acceptance towards CBM, although research outcomes have varied depending on methodological issues. Besides, emerging markets such as Brazil, China, and India have shown more extensive interest in consuming CBM [70,86] and are important markets to be targeted in the future. Environmental and animal welfare attributes seem to increase the willingness to consume CBM, which may encourage differentiation approaches: eco-branding, e.g., labeling the eco-friendly appeal of CBM products, and beyond compliance leadership strategies, e.g., enhancing firms' reputation due to more sustainable production processes. This result is consistent with the increasing will of consumers to pay for products that are labeled and certified as eco-friendly [87], as causing less animal suffering [33], or as animal-free [38,88]. Thus, slaughter-free meat products may be valued by those markets, which is likely to stimulate the adoption of eco-branding strategies [19]. Moreover, such sustainability-related attributes cannot be imitated by conventional meat producers which is desirable for differentiating green products [18].

However, given that providing information about environmental benefits increases the motivation to consuming CBM, consumers must be communicated and educated about those attributes [71,72,78]. Moreover, consumers are mostly underinformed about the environmental impacts of conventional meat production, which may hamper the adoption of meat alternatives. Providing further information to consumers, in turn, increases the purchase intention of eco-friendly and green products [89,90]. Thus, framing green labels and communication strategies will be required to differentiate CBM products as superior to those offered by conventional meat producers. Nonetheless, product quality and taste should also be reinforced to consumers [71], while perceptions of unnaturalness and of "high tech" identity should be carefully handled [79,80]. Additionally, more research is needed to investigate whether consumers would be willing to pay premium prices due to those environmental and animal welfare benefits, and whether this intention would persist over time.

As for the CBM value chain previously shown (Figure 1), although CBM producers and processors may be concerned with eco-efficiency strategies, their suppliers (e.g., growth medium, scaffold and bioreactors suppliers) are likely to have a greater role in developing the technology to achieve more economically and environmentally efficient production. They will be responsible, for instance, for the sourcing of animal-free medium alternatives to cell culturing farms; will also supply bioreactors that are less energy-consuming and generate less CO2 emissions. Moreover, they may be pressed by lead consumer-facing firms (e.g., major meat processors and supermarket chains) to improve quality, efficiency, and green initiatives [20,91]. It is noteworthy that major players (e.g., Cargill, Tyson) are currently investing in cell-based and plant-based alternatives and may therefore enter the chain in production and marketing activities, exerting pressure over their suppliers 'green initiatives. Summing up, upstream firms are likely to have a major role in developing and enabling competitive environmental strategies such as eco-efficiency and environmental cost leadership (Figure 2) and may be pressed to do so. Those strategies will depend to a large extent on the substantive technological advancements those upstream firms are capable of achieving. This aspect represents a major difference from the conventional meat chain, where most upstream activities and firms are not technologically intensive, with some exceptions such as genetics and breeding research, and are focused on incremental efficiency improvements, as further exemplified by water waste management in cattle husbandry, for instance.

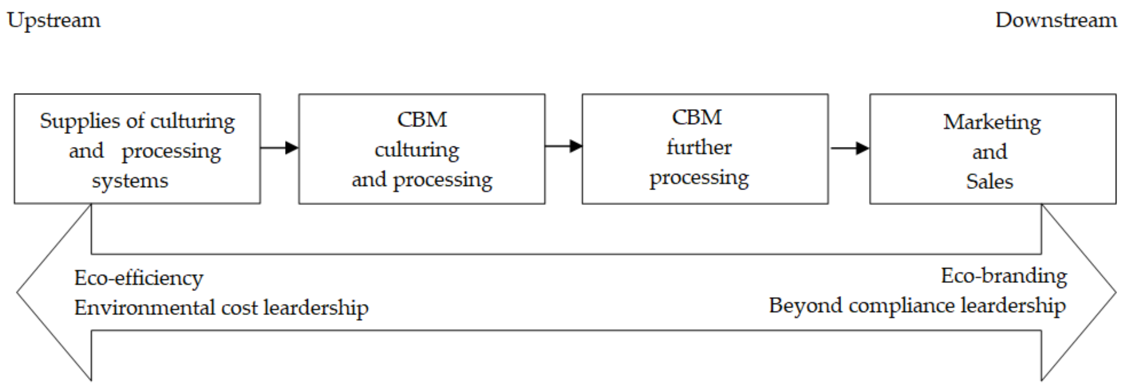

Figure 2. CBM value chain: Roles of upstream and downstream firms in environmental strategies.

On the other hand, downstream firms—which are consumer-facing and more demanded for valuing their reputation—are more prone to adopt environmentally and socially responsible initiatives [92]; their environmental strategies are often more visible and may have greater impacts on their markets. Thus, differentiation strategies such as eco-branding and beyond compliance leadership are likely to be emphasized by those firms (Figure 2). However, major downstream companies may also exert pressure on firms along the chain to bring them into alignment with their strategic efforts, e.g., enforcing sustainability standards or improving efficiency throughout the global value chain.

Finally, since CBM is a radical innovation [21]. This case provides insights that may add to the original environmental strategies' framework [19], which may in turn be further explored in future research. The original framework discusses the implications of innovations mostly with regard to product-related cost decreases, which can lead to the adoption of environmental cost leadership strategies, and incremental efficiency improvements that report to eco-efficiency environmental strategies. Such improvements do not reflect, however, major changes in the whole meat chain. The CBM case, on the other hand, involves the adoption of new production processes (meat cultivation) and types of supplies (cell lines, growth medium, etc.), novel actors (growth farmers, culturing systems suppliers), and technological development along the chain (scaffolds, animal-free growth medium, etc.). Thus, as a radical innovation, CBM production can ignite major changes in the meat industry as a whole and may impact all four environmental strategies by significantly changing products and processes; it may lead to cost reduction and also to significant differentiation. For instance, unique green products along with unique eco-friendly and low-cost production processes may be adopted by firms. Furthermore, as discussed above, value chain participants may have several roles to play in putting these strategies forward, which also adds to the framework. Upward firms may have a key role in technology development and efficiency improvement, allowing the adoption of eco-efficiency and environmental cost leadership. Downward firms, in turn, may be more sensitive to market and stakeholder pressure and therefore be pushed to emphasize eco-branding and beyond compliance leadership strategies. In addition, major downward firms may press chain participants, aiming at advancing technology development and improve efficiency and greening efforts along the chain.

Suggestions for Future Research and Contributions

A major limitation for studies on CBM is that products are not actually available thus far. Consequently, most of the research on environmental impacts and consumer attitudes involve forecasting and speculations about possible impacts, which are certainly useful. The extent to which environmental benefits, eco-efficiency, and differentiation opportunities can actually materialize will become clearer overtime, as the technology develops and as products reach the markets. Moreover, other factors may influence the acceptance and implications of CBM, such as regulation, major animal-based meat processors, NGOs, media coverage, governments, among others. Thus, continuous and longitudinal studies—considering those factors and actors—are desirable, in order to acknowledge how environmental strategies will evolve in the future. In addition, as aforementioned, more research is needed to improve our knowledge on the financial costs and efficiency benefits of CBM production over conventional meat.

Even though cell-based products are not available yet, there is a growing number of publications on the subject, probably due to the obvious impacts of this innovation. Surprisingly, there is a lack of publications on CBM in the business and management literature. Thus, several management-related subjects could be addressed in order to contribute to the development of our knowledge on the CBM business. Some of these subjects are (1) how the novel CBM value chain is going to be coordinated and governed by its players; and (2) which capabilities are needed to enter the new chain; and (3) how corporate social responsibility (CSR) and environmental issues are managed in CBM firms.

This article brings several contributions to the literature. First, it is amongst the few in the business and management literature that address CBM. Thus, the case adds to the literature on innovation by illustrating how a new technology can transform such a mature and traditional industry as the meat sector. In this regard, it shows how CBM innovation may bring new actors to the fore as well as novel value chain structure. It also contributes to the corporate social responsibility and sustainability management literature by shedding light on how investing in this innovation could relieve environmental and animal welfare issues associated with large-scale industrial livestock production. In addition, our analysis is contextualized with careful consideration of the marketing and consumer behavior literature by exploring issues regarding product acceptance which was initially considered as a potential bottleneck. Most importantly, by addressing the potential environmental benefits of CBM, the article also shows how those advantages adhere to environmental strategies that, in turn, may improve firms' competitiveness. Thus, we bridge the knowledge on CBM and on firms' environmental strategies, which may be of value not only to inspire future studies but also to inform practitioners and entrepreneurs. Second, through the adopted theoretical framework and its components, we could integrate a large amount of fragmented information from several fields, obtained through our systematic literature review. In addition, we also address the roles that key participants of an emerging value chain, currently represented by startups and major companies, are likely to play in those environmental strategies in the future. As for CBM startups working as suppliers of culturing and processing systems or culturing and processing firms, they seem to be key players for further developing CBM technology in order to decrease production costs and increase the environmental efficiency of culturing systems. This higher environmental efficiency may be achieved by reducing energy consumption and CO_2 emissions from bioreactors, as well as developing animal-free growth medium. Consequently, those startups are likely to have a key role in putting forward eco-efficiency and environmental cost leadership strategies in the CBM value chain (Figure 2). Aleph Farms startup, for instance, is a CBM culturing firm that claims to "(...) provide an eco-efficient solution to feed and nurture a clean and thriving planet" [93]; thus, they emphasize the environmental advantages of the production process they have developed. Major conventional meat-processing companies, in turn, are likely to partner with CBM culturing startups [7] and supply end consumers; their green initiatives may lead to increased reputation, as well as to product differentiation and value-adding. Thus, differentiation strategies like eco-branding and beyond compliance leadership may be adopted by those companies while they press upstream chain firms (e.g., CBM cultivating startups) to reduce costs and improve efficiency and positive environmental impact.

Finally, we show the challenges and inconsistencies that the new technology faces to achieve its potential benefits and to bring products to market and discuss the use of the original framework in the context of radical innovation.

6. Conclusions

In conclusion, the radical innovation brought by the use of cell-based technology to produce meat and other animal products may be considered a potential means for mitigating most of the environmental impacts of large-scale meat production, e.g., extensive land use and greenhouse gas emissions. Cell-based meat also efficiently addresses animal ethics and welfare problems intrinsically related to conventional meat production systems. Such benefits and consumer attitudes towards cultivated meat may encourage the adoption of environmental strategies by firms and the roles that value chain firms are likely to play in those strategies in the future.

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