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Carlos Ricardo Soccol
Carla Forte Maiolino Molento
Germano Glufke Reis
Susan Grace Karp *Editors*

Cultivated Meat

Technologies,
Commercialization
and Challenges



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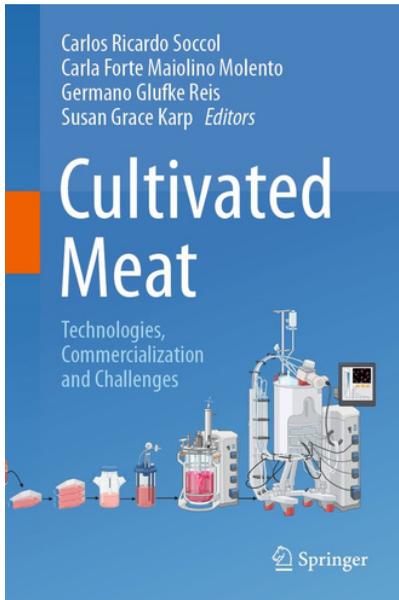
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2024. VII, 441 p. 87 illus., 51 illus. in color.

Printed book

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C. R. Soccol, C. F. M. Molento, G. G. Reis, S. G. Karp

Cultivated Meat

Technologies, Commercialization and Challenges

• Presents relevant technological information on cultivated meat

production, from the laboratory to the industrial scale

• Discusses waste management, life-cycle assessment and bioeconomic parameters of cultivated meat production

• Shows regulatory aspects, policies, patented technologies, market perspectives and challenges for this new food system

Cultivated meat is an emerging substitute for conventional meat that is not associated with animal farming and slaughtering. Instead, animal cells are cultivated in bioreactors and post-processed into “artificial” meat products. Although this new technology solves several ethical and environmental problems, there are techno-economic challenges that need to be addressed to make the commercial-scale production of cultivated meat a real perspective. This book addresses fundamental aspects of new food systems, animal cell culture and cultivated meat production, including cell lines, culture media, microcarriers and scaffolds, bioreactors, downstream processes, formulation, packaging, quality control, scale-up, and waste management. Also, aspects related to commercialization, market, patents, legislation, global and regional policies, and sustainability metrics such as life-cycle assessment, together with a bioeconomy perspective analysis, are reviewed. Finally, case studies are presented and the challenges and future prospects for cultivated meat production are proposed. This book is a collection of 21 chapters written by specialists in the field.

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RESEARCH ARTICLE

How much do opinions regarding cultivated meat vary within the same country? The cases of São Paulo and Salvador, Brazil

Gabriel Mendes¹*, Jennifer Cristina Biscarra-Bellio¹*, Marina Sucha Heidemann², Cesar Augusto Taconeli³, Carla Forte Maiolino Molento^{1,2}

1 Cellular Animal Science Laboratory, Federal University of Paraná, Curitiba, Paraná, Brazil, **2** Animal Welfare Laboratory, Federal University of Paraná, Curitiba, Paraná, Brazil, **3** Department of Statistics, Federal University of Paraná, Curitiba, Paraná, Brazil

✉ These authors contributed equally to this work.

* gabriel_mds17@hotmail.com (GM); jenniferbiscarra@gmail.com (JCB-B)



OPEN ACCESS

Citation: Mendes G, Biscarra-Bellio JC, Heidemann MS, Taconeli CA, Molento CFM (2025) How much do opinions regarding cultivated meat vary within the same country? The cases of São Paulo and Salvador, Brazil. PLoS ONE 20(2): e0317956. <https://doi.org/10.1371/journal.pone.0317956>

Editor: Giuseppina Rizzo, University of Palermo: Universita degli Studi di Palermo, ITALY

Received: September 30, 2024

Accepted: January 7, 2025

Published: February 19, 2025

Peer Review History: PLOS recognizes the benefits of transparency in the peer review process; therefore, we enable the publication of all of the content of peer review and author responses alongside final, published articles. The editorial history of this article is available here: <https://doi.org/10.1371/journal.pone.0317956>

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Abstract

The problems related to conventional meat production have been widely discussed globally and alternative proteins emerge as more sustainable and ethical options. Thus, understanding the intention to consume cultivated meat is key. This work aimed to study the intention to consume cultivated meat by residents of São Paulo and Salvador, Brazil, studying demographic differences. An online questionnaire comprising 17 multiple-choice and open-ended questions about opinions on conventional and cultivated meat was administered. The results were analyzed using quantitative methods, including binary logistic regression and ordinal regression models, as well as the qualitative Collective Subject Discourse methodology. With 809 participants, 419 (51.8%) from São Paulo and 390 (48.2%) from Salvador, 265 (32.8%, of which 170 (64.2%) from São Paulo and 95 (35.8%) from Salvador) respondents stated they would eat cultivated meat. Residents of São Paulo demonstrated higher familiarity with cultivated meat (187 (44.6%) had heard of it compared to 123 (31.5%) in Salvador). Such disparity in awareness seems coherent with differences in access to information and educational levels. Our results suggest that the acceptance of cultivated meat varies significantly across different regions of Brazil, likely related to the country's continental size, uneven economic and educational status and rich cultural diversity. We conclude that the acceptance of cultivated meat correlates with knowledge about it and that efforts to raise such knowledge require the consideration of cultural and socioeconomic aspects on a regional rather than national level, especially for geographically big and culturally diverse countries. Continued research is essential due to dynamics of acceptance and its entanglement with familiarity and knowledge regarding cultivated meat.

Introduction

The projections by the United Nations, in 2022, suggest that the global population is likely to grow to around 8.5 billion in 2030, 9.7 billion in 2050 and 10.4 billion in 2100 [1]. The effect



Innovations and challenges in collagen and gelatin production through precision fermentation

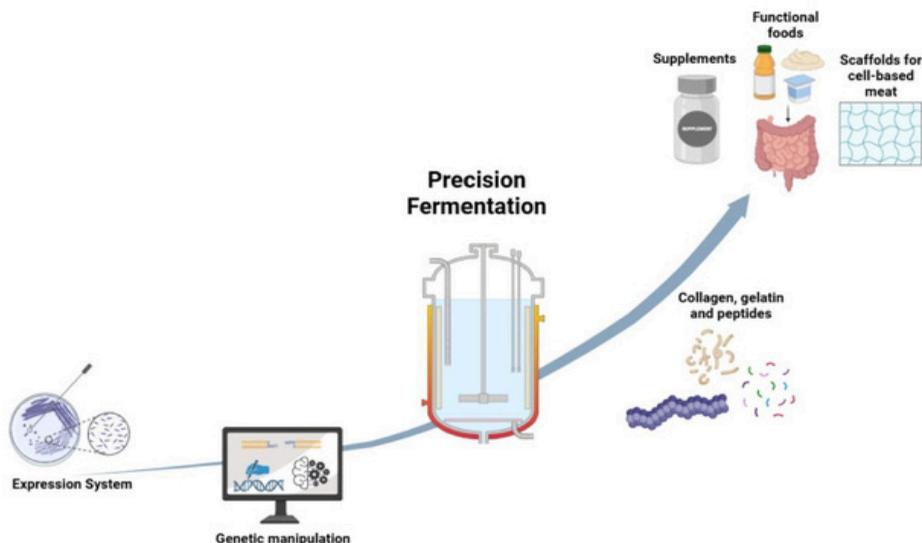
Sofia de Moura Campos¹ · Gabriela dos Santos Costa¹ · Susan Grace Karp¹ · Vanete Thomaz-Soccol¹ · Carlos Ricardo Soccol¹

Received: 27 November 2024 / Accepted: 24 January 2025
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Abstract

Collagen and gelatin are essential biomaterials widely used in industries such as food, cosmetics, healthcare, and pharmaceuticals. Traditionally derived from animal tissues, these proteins are facing growing demand for more sustainable and ethical production methods. Precision fermentation (PF) offers a promising alternative by using genetically engineered microorganisms to produce recombinant collagen and gelatin. This technology not only reduces environmental impact but also ensures consistent quality and higher yields. In this review, we provide a comprehensive overview of collagen and gelatin production through PF destined for the food sector, exploring key advances in recombinant technologies, synthetic biology, and bio-process optimization. Challenges such as scaling production, cost-efficiency, and market integration are addressed, alongside emerging solutions for enhancing industrial competitiveness. We also highlight leading companies leveraging PF to drive innovation in the food industry. As PF continues to evolve, future developments are expected to improve efficiency, reduce costs, and expand the applications of recombinant collagen and gelatin, particularly in the food and supplement sectors.

Graphical Abstract



Keywords Precision fermentation · Collagen · Gelatin · Alternative protein · Recombinant technology

✉ Carlos Ricardo Soccol
soccol@ufpr.br

¹ Department of Bioprocess and Biotechnology Engineering,
Federal University of Paraná, Curitiba, Brazil



Promises and uncertainties in the cultivated proteins market: Perspectives from Germany and Brazil

Germano Glufke Reis^a, Beatrice de Freitas Martins da Silva^b, Anna Loraine Hartmann^c,
Terese E. Venus^{d,*}

^a Business Management School UFPR, SfoodLab - Sustainable Food Value Chains Laboratory, Federal University of Parana, Av. Lothário Meissner, 632, Jd Botânico Curitiba, PR 80210-170 Brazil

^b Department of Bioprocess Engineering and Biotechnology, Coronel Francisco Hieraclito dos Santos Street, 100, Centro Politecnico, Curitiba, PR 82590-300 Brazil

^c Food Cluster, KERN- Competence Center for Nutrition, Hofer Straße 20, 95326 Kulmbach, Germany

^d Bioeconomy Economics Research Group, Universität Passau, School of Business, Economics and Information Systems, Dr.-Hans-Kapfing-Str. 30, 94032 Passau, Germany

ARTICLE INFO

Keywords:

Food Policy
Innovation
Alternative Proteins
Cultivated Meat
Stakeholders
Q-Methodology
Germany
Brazil

ABSTRACT

Cultivated meat offers an alternative to ensure food security and mitigate greenhouse gas emissions from conventional animal production. As the innovation remains in its nascent stages, policymakers require a better understanding of the market's potential, trajectory and future development perspectives. To support policymakers in developing flexible and effective policy frameworks for cultivated meat, we analyze perspectives about the trajectory of the cultivated meat market by 2040 in a comparative study of two countries, which are both major conventional meat markets and developers of alternative protein sources: Brazil and Germany. We use the Q-methodology to identify future perspectives and examine the influence of conventional meat industry incumbents on cultivated meat governance. Our sample includes 59 stakeholders working on cultivated and conventional meat. These perspectives can aid in decision-making related to investments in technological development, improvements in the sensory attributes of cultivated products, support for entrepreneurial ecosystems and startups, product hybridization, consumer and stakeholder engagement, the development of human capital, and regulatory schemes.

1. Introduction

Policymakers have targeted food systems to address the challenges of food security and climate change (Dinesh et al., 2017). In particular, protein production through conventional livestock rearing represents a major source of anthropogenic methane emissions (Godfray et al., 2018), constitutes 57 % of greenhouse gas (GHG) emissions in food production (Xu et al., 2021) and has accelerated deforestation and land use change of areas used for pasture and the production of animal feed (Ellis, 2021; Ramankutty & Foley, 1999). The environmental impact of conventional meat production has been exacerbated by the persistent increase in global meat consumption (OECD, 2022). Furthermore, conventional production is associated with social concerns related to zoonoses, antibiotic resistance (Dhingra et al., 2018; Godfray et al., 2018; Jones et al., 2013; O'Neill, 2016) and animal ethics (Lundmark, Berg, &

Röcklinsberg, 2013). The environmental and social challenges associated with conventional production underscore the need to establish sustainable food systems, including technological advancements and innovations for production, processing, and consumption (Herrero et al., 2020). This evolution can be complemented by shifts in dietary patterns and food consumption (Godfray et al., 2018).

The transition from animal-based meat to alternative sources of proteins, such as cultivated meat, is expected to reduce the environmental impacts of conventional animal-based production chains (Tuomisto et al., 2022; Sinke et al., 2023; Smetana et al., 2015). Cultivated meat involves the production of edible products (i.e. dairy and meat) through cell cultivation and multiplication in bioreactors. In terms of market acceptance, cultivated meat is considered more appealing to typical meat consumers compared to plant-based and fermentation-based substitutes, due to its production from animal cells

* Corresponding author.

E-mail addresses: glufkereis@ufpr.br (G.G. Reis), beatrice.martins@ufpr.br (B.F. Martins da Silva), AnnaLoraine.Hartmann@Kern.bayern.de (A.L. Hartmann), terese.venus@uni-passau.de (T.E. Venus).

<https://doi.org/10.1016/j.foodpol.2025.102820>

Received 13 May 2024; Received in revised form 19 January 2025; Accepted 24 January 2025

Available online 13 February 2025

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Alternative proteins production: current scenario, bioreactor types, and scale-up strategies

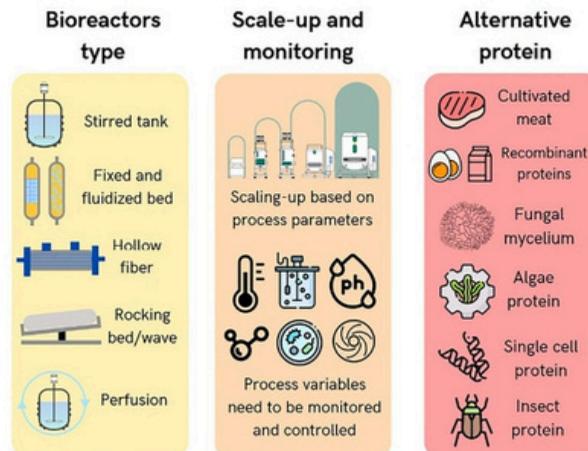
Luciana Porto de Souza Vandenberghe¹ · Ariane Fátima Murawski de Mello¹ · Clara Matte Borges Machado¹ · Giuliana Biagini¹ · Patricia Beatriz Gruening de Mattos¹ · Igor Negreiros Piazenski¹ · João Pedro Manica Candelario¹ · Carlos Ricardo Soccol¹

Received: 28 June 2024 / Revised: 28 September 2024 / Accepted: 7 October 2024 / Published online: 18 October 2024
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Abstract

Interest in the technology for producing alternative proteins is rapidly increasing, driven by the need to find new ways to produce and consume protein for the global population. This technology involves growing different microorganisms and animal cells under controlled conditions to ensure their viability and efficient growth. The cultivation process takes place in different types of bioreactors, from traditional models to innovative new designs, each offering unique features and capabilities. The most commonly used bioreactors are stirred tank reactors, which are mechanically agitated, and airlift or bubble column bioreactors, which are pneumatically agitated. These bioreactors are often adapted or modified to optimize the production of cultured meat. Essential to the process are microcarriers or scaffolds that support cell adhesion and proliferation. Other bioreactor models, such as hollow fiber and packed bed bioreactors, are also being explored. The trend towards single-use technology is growing due to benefits like easier cleaning and sterilization, and reduced operation times, though it does raise concerns about plastic waste. This review not only describes various bioreactor models but also discusses instrumentation and control systems. It aims to present the main bioreactor models currently in use for cultivated meat production, detailing their features, advantages, disadvantages, and the technological challenges that need to be addressed.

Graphical abstract



Keywords Stirred tank reactors · Airlift · Wave bioreactors · Scale-up · Perfusion bioreactors · Packed bed bioreactors

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Raw material selection for sustainable fermentation-derived alternative protein production: a review

Lachi Wankhede¹ · Gaurav Bhardwaj¹ · Gilberto Vinícius de Melo Pereira² · Carlos Ricardo Soccol² · Satinder Kaur Brar¹

Received: 22 May 2024 / Revised: 10 July 2024 / Accepted: 15 July 2024 / Published online: 3 September 2024
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Abstract

The expanding field of alternative proteins represents a transformative approach to addressing global food security and sustainability challenges. Among these, fermentation-derived alternative proteins cultivated from microorganisms such as fungi, bacteria, and algae offer a promising avenue for sustainable protein production. This review explores the selection and utilization of raw materials to produce microbial proteins through fermentation processes. Critical raw materials include agricultural byproducts, industrial waste streams, and specifically designed feedstocks, which not only mitigate environmental footprint but also enhance the economic viability of production systems. The utilization of lignocellulosic biomass and molasses has demonstrated considerable promise, attributed to their abundant and renewable nature. The review underscored the necessity of exploring specific areas to enhance the viability of producing microbial protein from diverse raw materials. These areas include improving pre-treatment strategies to enhance substrate suitability for fermentation, optimizing fermentation processes for increased yield and reduced costs, and developing more resilient microorganisms capable of thriving on varied substrates. These strategies are crucial for advancing the production of alternative proteins through fermentation, in addition to raw material selection, which is vital in the scalability and sustainability of alternative protein production through fermentation, emphasizing the need for continued research and innovation in this field.

Keywords Alternative proteins · Lignocellulosic biomass · Agricultural waste · Wastewater and · Gas stream

Introduction

The global population is expected to reach 10 billion by 2050, leading to a substantial increase in food demand. This surge is accompanied by rising wealth, especially in rapidly industrializing nations where improving incomes are leading to changes in dietary preferences. As wealth expands, there is a notable shift towards higher-quality, protein-rich

diets mainly centred on meat, which demands substantial resources for production, including water, energy, feedstock, fertilizers, pesticides, and veterinary medicines. This evolving dietary landscape, driven by population growth and rising wealth, emphasizes adopting sustainable consumption and production practices to ensure food security and environmental sustainability [1, 2]. Animal-based protein value is also linked to significant health risks, including cardiovascular diseases and cancer [3, 4]. These pressing issues highlight the urgent need for alternative protein sources that promise lower environmental impacts and enhanced sustainability with a promise to achieve the Sustainable Development Goal of Zero Hunger.

The alternative protein market is expected to reach \$290 billion by 2035, underscoring the significance of these innovative food sources [5, 6]. Alternative proteins encompass a diverse range of sources, including plant-based proteins (e.g., peas, soy, and rice), proteins from cultivated animal cells, insect-based proteins with robust nutritional

Lachi Wankhede and Gaurav Bhardwaj contributed equally.

✉ Satinder Kaur Brar
satinder.brar@lassonde.yorku.ca

¹ Department of Civil Engineering, Lassonde School of Engineering, York University, North York, Toronto, Ontario M3J 1P3, Canada

² Department of Bioprocess Engineering and Biotechnology, Federal University of Paraná (UFPR), Curitiba, PR 81530-900, Brazil



Enzymes in the production of cultivated meat products

Susan Grace Karp¹ · Mariana Zanlorenzi Weber¹ · Giuliana Biagini¹ · Kely Priscila de Lima² · Gilberto Vinícius de Melo Pereira^{1,2} · Vanete Thomaz-Soccol¹ · Carlos Ricardo Soccol¹

Received: 30 April 2024 / Revised: 5 June 2024 / Accepted: 7 June 2024 / Published online: 27 June 2024
© Jiangnan University 2024

Abstract

Enzymes play a pivotal role in meat processing and maturation, starting with endogenous enzymes that catalyse a partial proteolysis in natural meat that enhances texture and flavor, to exogenous enzymes that may be incorporated for additional processing. Therefore, a question is raised whether endogenous and exogenous proteases could be used to improve the quality of meat products originated from in vitro cell-based technology. This manuscript aims at presenting the main applications of enzymes in meat processing, starting with conventional meat products and expanding to reported and potential applications in cultured meat technologies. Enzymes are applied since the early stages of cell isolation, multiplication and detaching from supports. The use of endogenous enzymes, such as cathepsins and calpains, has been proposed to improve the palatability of cultivated meat, and the application of transglutaminases has already been reported in scientific papers and patent documents, with the aim of promoting crosslinking reactions among proteins. This feature can be used to modulate the texture of cultivated meat products. Also, their use has been directed to the manufacture of scaffolds and microcarriers for animal cell cultivation. As concluded from the scientific and technological literature survey, it is evident that a substantial area of study remains unexplored regarding the utilization of enzymes in cultivated meat products.

✉ Susan Grace Karp
susan.karp@ufpr.br

Carlos Ricardo Soccol
soccol@ufpr.br

¹ Department of Bioprocess Engineering and Biotechnology, Federal University of Paraná (UFPR), Curitiba, Paraná, Brazil

² Graduate Program in Biotechnology, PPGBIOTEC, Federal Technological University of Paraná - UTFPR, Curitiba, Paraná, Brazil

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The Role of NGOs in the Transition Towards More Sustainable and Innovative Agri-food GVCs

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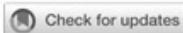
[ISBN](#): 978-1-83549-118-8, [eISBN](#): 978-1-83549-117-1

Publication date: 16 May 2024

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Abstract

Multinational enterprises (MNEs) in the agri-food sector are continuously transforming their global value chains (GVCs) to address sustainable development challenges of food security (SDG2) and climate change (SDG13). However, the central role of non-governmental organisations (NGOs) in (re)creating GVCs across multilevel stakeholders through innovative approaches to solve sustainability challenges remains under investigated. This explorative study investigates how international NGOs influence the transformation of large-scale industrial animal agriculture to a more sustainable (cell-based) agri-food GVC. The authors conducted a case study on the Good Food Institute (GFI), an international NGO, that has been an active player in the transition to alternative sources of protein to solve animal-based agriculture sustainability issues. The results show that an international NGO can contribute to the transition to a more sustainable GVC and can enhance the GVC's innovation capabilities.



OPEN ACCESS

EDITED BY
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REVIEWED BY
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University of Illinois at Urbana-Champaign,
United States
Adriano Gomes Cruz,
Federal University of Rio de Janeiro, Brazil

*CORRESPONDENCE
Peter Newton
✉ peter.newton@colorado.edu

[†]These authors have contributed equally to
this work

RECEIVED 28 September 2023
ACCEPTED 05 February 2024
PUBLISHED 27 February 2024

CITATION
Newton P, Eichhorst W, Hegwood M,
Morais-da-Silva RL, Heidemann MS,
Hoffmann A and Reis GG (2024) Price above
all else: an analysis of expert opinion on the
priority actions to scale up production and
consumption of plant-based meat in Brazil.
Front. Sustain. Food Syst. 8:1303448.
doi: 10.3389/fsufs.2024.1303448

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Price above all else: an analysis of expert opinion on the priority actions to scale up production and consumption of plant-based meat in Brazil

Peter Newton^{1*}, Waverly Eichhorst^{1†}, Margaret Hegwood^{1,2†},
Rodrigo Luiz Morais-da-Silva³, Marina Sucha Heidemann⁴,
Alexandre Hoffmann⁵ and Germano Glufke Reis^{3,4}

¹Department of Environmental Studies, Sustainability, Energy, and Environment Community, University of Colorado Boulder, Boulder, CO, United States, ²Center for Social and Environmental Futures, Cooperative Institute for Research in Environmental Sciences, University of Colorado Boulder, Boulder, CO, United States, ³Department of Business and Management, Federal University of Paraná, Curitiba, Paraná, Brazil, ⁴Sustainable Food Value Chains Lab, Federal University of Paraná, Curitiba, Paraná, Brazil, ⁵Brazilian Agricultural Research Corporation (Embrapa), Pelotas, Rio Grande do Sul, Brazil

Introduction: Plant-based meats (PBM) are an emerging set of food technologies that could reduce the environmental impacts of food systems by mitigating consumer demand for animal products. However, scaling up the production and consumption of plant-based meats requires overcoming multiple technological, regulatory, political, and market barriers. An evidence-based prioritization of needs and actions may help actors (e.g., investors, funders, policymakers) who wish to help scale PBM achieve desired outcomes with limited resources.

Research question: What actions could most effectively help to scale up the production and/or consumption of plant-based meat in Brazil?

Methods: We selected Brazil as a case study of a country with a significant animal agriculture sector and a burgeoning PBM sector. We constructed a panel of nine experts and employed the Delphi technique during two rounds of an online survey to iteratively assess the degree of consensus and disagreement around the relative priority of 14 possible actions (identified from relevant literature) that could help to scale up the production and/or consumption of PBM in Brazil. We used the Importance, Neglect, and Tractability framework.

Results: The panelists collectively concluded that the top priority action for scaling up both the production and the consumption of plant-based meat in Brazil was to reduce the price of products for consumers. For most priority actions, there was greater consensus among panelists in the second round of the survey.

Discussion: Our findings contribute to an improved understanding of (a) which actions may be of highest priority for investors, funders, and policymakers, (b) synergies and differences between priority actions to scale up the production versus consumption of PBM in Brazil, (c) the relative merits of focusing on scaling up PBM production versus consumption, and (d) the strengths and limitations of assessing expert opinion on alternative protein futures using the Delphi technique.

KEYWORDS

alternative protein, consensus, cost, Delphi, effective altruism, policy, technology

Ética animal e proteínas alternativas: questões atuais em terminologia da língua portuguesa

Vivien Patrícia Garbin¹, Paula Tavares Pinto², Márcia de Souza Luz-Freitas³, Carla Forte Maiolino Molento^{4*}

Submitted: 02/01/2024

Accepted: 20/03/2024

¹ Bióloga, Pós-doutoranda em Ciências Veterinárias pela Universidade Federal do Paraná, UFPR, Curitiba, Paraná, Brasil. ORCID: 0000-0002-2865-9785

² Linguista, Livre-Docente em Tradução e Ensino de Línguas Baseado em Corpora, UNESP, S.J. do Rio Preto, Brasil. ORCID: 0000-0001-9783-2724

³ Terminóloga, Docente de Língua Portuguesa, Instituto de Física e Química, UNIFEI, Itajubá, Minas Gerais, Brasil. ORCID: 0000-0002-7085-3047

⁴ Médica Veterinária, MSc, PhD, Coordenadora do Laboratório de Zootecnia Celular, Universidade Federal do Paraná, Brasil. ORCID: 0000-0003-1408-7891

Email para correspondência: Carla Forte Maiolino Molento, email: carlamolento@ufpr.br

Resumo: Ao longo da história da humanidade, a relação entre seres humanos e animais comporta e reflete os questionamentos acerca da ciência e dos direitos dos animais. Tais questionamentos têm se tornado mais prevalentes e aprofundados, gerando termos específicos em língua inglesa, o idioma atualmente predominante na literatura sobre o tema. Assim, o objetivo deste trabalho foi contribuir para a construção de uma terminologia apropriada em língua portuguesa, a partir de um *corpus* coletado em inglês, para proposição de um glossário bilingue. No total, foram selecionados 37 termos relevantes para tradução, sendo 18 para área de ética animal e 8 para área de zootecnia celular, sendo que 22 termos foram traduzidos por transposição, oito por tradução literal, cinco por explicitação e dois por adaptação. Dessa forma, foi possível construir um glossário bilingue inglês-português dos 37 termos. Em um mundo cada vez mais complexo nas questões relativas aos produtos de origem animal e seus análogos, a dificuldade de compreender tantos cenários e suas implicações para os animais, para os seres humanos e para a sustentabilidade ambiental pode ser atenuada a partir do glossário apresentado. A disponibilização dos principais 37 termos utilizados nas discussões sobre ética animal e zootecnia celular que eram inacessíveis aos falantes exclusivamente de língua portuguesa oferece inéditas oportunidades pedagógicas, de formação profissional, de mídia e *marketing*, de construção de normas e políticas públicas, de participação e de tomadas de decisão. Assim, a terminologia pode proporcionar maior facilidade de acesso à discussão de tais conteúdos para a sociedade, aumentando as possibilidades de divulgação, esclarecimento, participação e reflexão qualificada. Adicionalmente, se espera que o conjunto de termos traduzidos possa servir de estímulo a novas publicações com o objetivo de enriquecer a nossa língua portuguesa e a nossa participação nos necessários debates sobre ética animal e zootecnia celular.

Palavras-chave: Glossário bilingue inglês-português, carne cultivada, proteção animal, terminologia bilingue, termos equivalentes, unidades terminológicas.

1. Introdução

As reflexões sobre a relação entre seres humanos e animais acompanham a história da humanidade. De Pitágoras, na Grécia antiga, ao contemporâneo Peter Singer, são muitos aqueles que discutem a necessidade de se considerar o que atualmente chamamos de ciência dos animais e, conseqüentemente, seus interesses. Tal discussão ocorre em contraposição à visão antropocêntrica e instrumentalizadora dos animais, predominante nas culturas ocidentais, tanto epitomizada pela teoria dualista de René Descartes como consolidada por abordagens religiosas tais como a judaico-cristã e a muçulmana. Assim, ao longo da maior parte da história da civilização, predominou uma visão que exclui a consideração moral dos animais como seres sencientes. Apenas recentemente surgiu um questionamento mais generalizado sobre a importância de se considerar a ciência dos animais em sua plenitude, com obrigações morais de evitar sofrimento e de se fomentar sentimentos positivos aos animais.

Pode-se considerar o livro *Animal Machines* (Harrison, 1964) como um importante marco na abertura da discussão sobre o bem-estar e os direitos dos animais utilizados para a produção de alimentos. A publicação de *Animal Machines* em 1964 causou tal controvérsia na sociedade inglesa, que culminou com reações governamentais e está na base do fomento aos grupos de estudo em bem-estar animal. Entretanto, após quase seis décadas de sua publicação, tal livro permanece indisponível em língua portuguesa, fato que restringe significativamente o acesso à discussão para os brasileiros. Subseqüentes publicações importantes em ética animal continuaram a ocorrer em inglês, como *Animal Liberation* (Singer, 1975) e *A Case for Animal Rights* (Regan, 1986). Assim, naturalmente várias frentes da questão surgem em língua inglesa (Jenkins, 2013). Ainda, o inglês é atualmente a língua mais utilizada nas publicações sobre ética animal, de forma que mesmo autores que têm outros idiomas como língua materna frequentemente publicam em língua inglesa. Tal contexto culmina com uma discussão sobre ética animal que avança sobretudo em inglês.

O mesmo fenômeno, de predominância do idioma inglês, também permeia as publicações nas áreas de inovação. O fenômeno é bem caracterizado na biotecnologia, provocando com frequência anglicismos na comunicação que se dá em idiomas outros que o inglês. Se a linguagem científica pode dificultar a compreensão de determinados tópicos pela sociedade em geral, é provável que, ao importar uma grande quantidade de termos diretamente do inglês, ela se torne ainda menos acessível. A questão parece ainda mais relevante quando se considera a pesquisa aplicada, pois ela traz inovações de uso mais direto pela população. Desta forma, uma população que entende a terminologia empregada está mais bem posicionada para compreender as inovações, conversar sobre elas e tomar as melhores decisões sempre que houver oportunidade. Ao considerar as novas formas de produção de alimentos, envolvendo as proteínas alternativas, a questão aparece em toda a sua relevância e complexidade. Como um brasileiro poderá compreender, por exemplo, quais os novos tipos de carne pelos quais poderá optar e quais as conseqüências de suas opções se a terminologia utilizada não estiver em sua língua cotidiana?

Optimization of the Extraction Process of Bioactive Compounds from *Zingiber officinale* Roscoe, Evaluation of Acetylcholinesterase Enzyme Inhibition and Cytotoxic Activity of the Free and Encapsulated Extract

Danielli A. Nardino,^a Ana C. R. Aranha,^{a,b} Lilian T. D. Tonin,^c Rafael O. Defendi,^c Sabrina Ishikawa,^d Patricia A. Bressiani,^d Ana B. S. Santana,^d Elisângela Dusman,^d Murilo K. A. Yonekawa,^e Jeandre A. S. Jaques,^e Edson A. Santos,^e Angélica P. P. Tonin,^f Eduardo C. Meurer,^{g,*f,g} Caroline C. Sipoli^e and Rúbia M. Suzuki^e

^aDepartamento de Química, Universidade Estadual de Maringá (UEM),
87020-900 Maringá-PR, Brazil

^bDepartamento de Engenharia Química, Universidade Estadual de Maringá (UEM),
87020-900 Maringá-PR, Brazil

^cPrograma de Pós-Graduação em Engenharia Química (PPGEQ-AP),
Universidade Tecnológica Federal do Paraná (UTFPR), 86812-460 Apucarana-PR, Brazil

^dDepartamento de Química e Biologia, Universidade Tecnológica Federal do Paraná (UTFPR),
85602-863 Francisco Beltrão-PR, Brazil

^eSetor de Bioquímica, Instituto de Biociências,
Universidade Federal do Mato Grosso do Sul (UFMS), 79070-900 Campo Grande-MS, Brazil

^fLaboratório Fenn de Espectrometria de Massas, Departamento de Química,
Universidade Federal do Paraná (UFPR), 86900-000 Jandaia do Sul-PR, Brazil

^gPrograma de Pós-Graduação em Biotecnologia Ambiental (PEB),
Universidade Estadual de Maringá (UEM), 87020-900 Maringá-PR, Brazil

The present study optimized the extraction process of bioactive compounds present in ginger (*Zingiber officinale*) dried at 80 °C, using ethanol:water 70:30 (v/v) as solvent. The extracts were evaluated for antioxidant activity by the 2,2'-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid (ABTS) and 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical reduction methods and by the chelating activity of Fe^{II} ions. It was found that the extraction condition with a temperature of 60 °C and an extraction time of 12 h showed better responses to the tests. Then, the characterization of the compounds was carried out by mass spectrometry and thermal analysis (thermogravimetric (TG), differential thermal analysis (DTA), and differential scanning calorimetry (DSC)), identifying that the main compounds of ginger were gingerols and shogaols, being confirmed by the intensities and characteristics of the thermal graphs. The inhibition of the enzyme acetylcholinesterase (AChE) was evaluated using the Ellman test, which did not show an inhibitory action. Regarding cytotoxic activity, the free extract and encapsulated in liposomes were tested, showing antiproliferative effect at different concentrations for human kidney tumor cells (786-0), liver cells (HUH7.5), and *Macaca mullata* normal kidney cells (LLC-MK2). Given the results obtained, ginger presents itself as a renewable source of bioactive compounds and can be indicated for applications in the pharmaceutical industry.

Keywords: antioxidants, main component analysis, factorial planning, AChE, cancer

*e-mail: eduardo.meurer@ufpr.br

Editor handled this article: Andrea R. Chaves (Associate)





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Contents lists available at ScienceDirect

Trends in Food Science & Technology

journal homepage: www.elsevier.com/locate/tifs

From lab to table: The path of recombinant milk proteins in transforming dairy production.

Igor Negreiros Piazenski¹, João Pedro Manica Candelário¹, Vanete Thomaz Soccol,
Luciana Porto de Souza Vandenberghe, Gilberto Vinícius de Melo Pereira,
Carlos Ricardo Soccol*

Department of Bioprocess Engineering and Biotechnology, Federal University of Paraná, Centro Politécnico, 81531-980, Curitiba, Paraná, Brazil

ARTICLE INFO

Handling Editor: Dr. J O'Brien

Keywords:

Recombinant milk protein
Precision fermentation
Alternative protein
Dairy analogues
Caseins
Lactoglobulin

ABSTRACT

Background: Recombinant milk protein production is emerging as a pivotal innovation in the dairy industry, driven by the need for sustainable and ethically produced dairy alternatives. Traditional dairy production faces challenges such as greenhouse gas emissions, ethical concerns about animal welfare, and fluctuating productivity due to environmental factors. Recombinant technology offers a promising avenue, using genetically modified organisms to produce milk proteins that closely mimic their natural counterparts.

Scope and approach: This work encompasses a comprehensive review of articles and patents aimed at understanding the current state and advancements in the production of recombinant milk proteins. It addresses technical aspects such as raw milk composition, protein expression in various hosts, the importance of post-translational modifications, and the challenges of scaling up for commercial production. The study also explores the implications and possibilities of these advancements for the food industry.

Key findings and conclusions: Recombinant milk protein production holds significant promise in revolutionizing the dairy industry. Key findings from this review include the identification of efficient host organisms and vectors, advancements in genetic engineering and bioprocessing, and innovative strategies for large-scale production. The future of this technology is promising, especially in creating sustainable, efficient production methods. However, challenges remain in achieving cost-effectiveness, scalability, and a nutritional profile comparable to traditional milk. Continuous research and development are essential for optimizing the technology and enhancing its commercial viability to meet the increasing demand for sustainable dairy alternatives.

1. Introduction

Cow's milk stands as one of the most vital agricultural commodities globally, with billions of people consuming it daily in various forms. In 2023, global milk production reached 944 million tons, reflecting a 0.9% increase from 2022 (Aratchilage & Dekermendjian, 2022). This growth underscores the enduring demand for milk and its derivatives. Milk proteins, as fundamental components of dairy, play a crucial role in nutrition. They currently contribute more than 10% of the global population's total protein intake (Smith et al., 2022). Dairy proteins show highly desirable solubility, gelling, and emulsification properties, ensuring their versatility in numerous applications. These characteristics not only make milk proteins indispensable for nutrition, but also

irreplaceable in various industrial uses (Behm et al., 2022).

The traditional dairy industry faces several challenges to meet market consumption. The greenhouse gas (GHG) emissions related to livestock account for 18% of total global emissions (Hettinga & Bijl, 2022). Additionally, farm animals require extensive land use or confinement, raising concerns over milk contamination at dairy farms due to disease outbreaks, hormone treatments, and antibiotics abuse (Awasthi et al., 2012; Behm et al., 2022; Pandya et al., 2015). These factors, alongside natural climate, and environmental fluctuations, create market uncertainties and impact productivity (Geistlinger, Jensen, et al., 2020; Vestergaard et al., 2016). Considering these inefficiencies, demand for sustainable alternatives in food production is increasing, leading academia and the food industry to explore

* Corresponding author.

E-mail address: soccol@ufpr.br (C.R. Soccol).

¹ These authors contributed equally to the work.

Optimization of Hydrolysis and Identification of Bioactive Peptides in Brewery Yeast Residuals

Fernanda A. Della Rosa,^{a,b} Angelica P. Tonin,^{a,b} Beatriz S. Rocha,^b
Marco A. R. Santos,^b Fabiane M. Silveira,^a Lucio Cardoso-Filho,^c
Valquíria M. S. Ribeiro^{a,b} and Eduardo C. Meurer^{*a,b,d}

^aDepartamento de Biotecnologia, Genética e Biologia Celular, Universidade Estadual de Maringá (UEM), 87020-900 Maringá-PR, Brazil

^bLaboratório Fenn de Espectrometria de Massas, Universidade Federal do Paraná (UFPR), 86900-000 Jandaia do Sul-PR, Brazil

^cDepartamento de Engenharia Química, Universidade Estadual de Maringá (UEM), 87020-900 Maringá-PR, Brazil

^dDepartamento de Química, Universidade Estadual de Maringá (UEM), 87020-900 Maringá-PR, Brazil

Industrial waste products are of biotechnological interest due to their abundance and can be utilized as protein sources for the production of bioactive peptides through hydrolysis. The utilization of yeast residues from the brewing industry has been demonstrated to be a viable method for obtaining protein hydrolysates. The degree of hydrolysis and soluble total protein of the hydrolysates were evaluated for optimization purposes to achieve a product with a high proportion of soluble organic nitrogen, increased levels of bioactive peptides and amino acids. Both alkaline and enzymatic hydrolysis processes were tested. The hydrolyses were carried out with the aim of large-scale implementation. The treatments were effective in liberating intracellular content and producing biologically functional hydrolysates, with degree of hydrolysis values ranging from 28 to 63% and total protein from 2.95 to 8.28% at the optimum points confirmed by statistical analysis (analysis of variance (ANOVA)). The hydrolysate produced with Alcalase[®] exhibited the highest peptide intensity, while the hydrolysate produced with Flavourzyme[®] showed the highest concentration of free amino acids. The peptides were identified by mass spectrometry and were found to have biological activities according to the Biopep database. This study presents a quick and economically feasible approach for the implementation of a pilot project for the reuse of this waste.

Keywords: bioactive peptides, industrial waste, protein sources, hydrolysis, yeast residues, brewing industry

Introduction

Proteins, peptides, and amino acids are crucial molecular components of living organisms. Unlike amino acids, the notion of proteins and peptides as functional foods aimed at enhancing quality of life is a recent phenomenon.¹ Bioactive peptides obtained from food-derived proteins have been demonstrated to exhibit positive effects on human health, both nutritionally and functionally.² After undergoing cleavage, proteins acquire biologically relevant functions and are typically composed of 2 to 20 amino acids.³

The consumption of these protein hydrolysates has been shown to improve overall health by reducing the potential for chronic diseases. This is due to various bioactive effects, including inhibition of the angiotensin-converting enzyme (ACE), leading to anti-hypertensive activity, antioxidant properties due to their affinity for reactive oxygen species, antidiabetic effects through inhibition of dipeptidyl peptidase 4 (DPPIV) and dipeptidyl peptidase 3 (DPPIII), chelating abilities towards transition metals, antimicrobial properties, opioid-like effects, immunomodulatory properties, and cytokine-modulating effects.⁴

In the pharmaceutical industry, there is an ongoing effort to develop molecular drug carrier systems using peptides for the chemotherapy treatment of cancers. Peptides

*e-mail: eduardo.meurer@ufpr.br

Editor handled this article: Eduardo Carasek



Article

Optimization and Characterization of Protein Extraction from Asparagus Leafy By-Products

Aline Cristini dos Santos-Silva ¹, Bianka Rocha Saraiva ², Anderson Lazzari ¹, Henrique dos Santos ³, Évelin Lemos de Oliveira ⁴, Francielle Sato ³, Eduardo César Meurer ⁴ and Paula Toshimi Matumoto-Pintro ^{1,2,*}

- ¹ Food Science Graduate Program, State University of Maringá, Maringá 87020-900, Brazil; alinecristinisantossilva@gmail.com (A.C.d.S.-S.); andersonlazzari29@gmail.com (A.L.)
- ² Animal Science Graduate Program, State University of Maringá, Maringá 87020-900, Brazil; bianka_saraiva@hotmail.com
- ³ Physics Graduate Program, State University of Maringá, Maringá 87020-900, Brazil; rique.love@gmail.com (H.d.S.); fsato@uem.br (F.S.)
- ⁴ Chemistry Department, Federal University of Paraná, Jandaia do Sul 86900-000, Brazil; evelynlemos@hotmail.com (É.L.d.O.); eduardo.meurer@gmail.com (E.C.M.)
- * Correspondence: ptmpintro@uem.br; Tel.: +55-44-99964-6766

Abstract: Asparagus production generates significant amounts of by-products during the summer and post-harvest growth period. By-products can be good sources of nutrients and phytochemicals. The interest in increasing the availability of proteins for human consumption has led to the use of new plant sources rich in proteins. The objective of this study was to use response surface methodology (RSM) to optimize the aqueous extraction process of proteins from asparagus leafy by-products, for the production of new protein ingredients. The optimum extraction condition was at pH 9, with 40 min of extraction at 50 °C, and the concentration was fixed at 5 g·L⁻¹. The isolate obtained presented 90.48% protein with 43.47% protein yield. Amino acids such as alanine, proline, valine, leucine/isoleucine, asparagine, and phenylalanine were identified, and the antioxidant activity for 2,2 AZINO BIS (3-ethylbenzo thiazoline 6 sulfonic acid diammonium salt) was 145.76 equivalent to Trolox μmol.100g⁻¹ and for DPPH 65.21 equivalent to Trolox μmol.100g⁻¹. The product presented favorable technological properties (water absorption capacity 4.49 g·g⁻¹ and oil absorption capacity 3.47 g·g⁻¹) and the color tended towards dark green (L* 31.91, a* -1.01, b* -2.11). The protein isolate obtained through the extraction optimization process showed high potential to be used as a protein ingredient.

Keywords: protein isolate; extraction process; vegetable proteins



Citation: dos Santos-Silva, A.C.; Saraiva, B.R.; Lazzari, A.; dos Santos, H.; de Oliveira, É.L.; Sato, F.; Meurer, E.C.; Matumoto-Pintro, P.T. Optimization and Characterization of Protein Extraction from Asparagus Leafy By-Products. *Foods* **2024**, *13*, 894. <https://doi.org/10.3390/foods13060894>

Academic Editor: Hanna (John) Khouryieh

Received: 16 February 2024
Revised: 11 March 2024
Accepted: 13 March 2024
Published: 15 March 2024



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1. Introduction

Asparagus (*Asparagus officinalis* L.), popularly known as the “king of vegetables”, is a perennial herbaceous vegetable belonging to the Asparagaceae family. Asparagus spears are considered a healthy food due to their low-calorie content, high protein, and bioactive phytochemical content. Once the asparagus shoots begin to open, they quickly become woody and are not commercially accepted. After this period, the spears can transform into ferns with modified stems, called cladophylls or cladodes, which are photosynthetically active, leaf-like organs [1].

New applications for agricultural and industrial waste have been investigated, aiming at a positive environmental impact and transformation into usable compounds. The plant commercial part corresponds to the asparagus edible stem, which comprises less than 25% of the plant; the remaining 75% includes the hard stem, root, and leaves. These fractions are characterized as by-products, but the same nutrients and phytochemicals present in the spear can be found in them, and, therefore, these by-products have high potential for use as food ingredients with nutritional value and health-promoting properties [2].

Article

Cultivated Manatee Meat Aiding Amazon Biodiversity Conservation: Discussing a Proposed Model

Ana Flavia S. Abrahao ^{1,*} , Joao Paulo F. Rufino ², Germano Glufke Reis ¹  and Alexandre Cabral ³

¹ Management School, UFPR Federal University of Parana, Av. Lothário Meissner, 632, Jd. Botânico, Curitiba 80210170, Brazil

² Department of Animal and Plant Production, Agrarian Sciences Faculty, Federal University of Amazonas, Manaus 69080900, Brazil

³ Policy Department, The Good Food Institute Brazil, Rio de Janeiro 22031020, Brazil

* Correspondence: anaflavia.abrahao@gmail.com; Tel.: +353-083-378-2346

Abstract: Cultivated meat (CM) is a disruptive technology that provides an alternative to animal protein. In this context, the Amazon manatee (*Trichechus inunguis*) emerges as an important case. Although it is illegal to hunt this large mammal, its meat continues to be consumed, causing several threats to its natural habitat. The aim of this study is to explore the impacts of introducing the Amazon manatee CM into the traditional meat value chain as a tool to aid the biodiversity of the Amazon Basin. Thus, we developed a strengths, weaknesses, opportunities, and threats matrix from the content analysis of 11 interviews conducted between October 2021 and May 2022. The interviewees were experts in different fields, ranging from financial analysts of novel food technologies to biologists, researchers, and others. We presented the theme of illegal hunting and its consequences during the interviews, followed by the CM process, and explained how the royalties from the sale of this innovative product could help to preserve Amazon biodiversity through the proposal of a new business model. The main findings suggest that the proposed model would produce good results, but the threat of a rebound effect from the consumption of wild animals was mentioned in most responses, especially by actors involved in conservation. The strengths and opportunities of this disruptive narrative mainly focused on preserving biodiversity and promoting environmental awareness, combining the conservation of wildlife and the consumption of novel food. The weaknesses included the lack of knowledge and the non-existent market. This framework is relevant for policymakers, nongovernmental organizations, and researchers seeking to improve the sustainability not only of the species found in the Amazon, but also around the world.

Keywords: cultivated meat; wildlife trade; Amazon; biodiversity; business model



Citation: Abrahao, A.F.S.; Rufino, J.P.F.; Reis, G.G.; Cabral, A. Cultivated Manatee Meat Aiding Amazon Biodiversity Conservation: Discussing a Proposed Model. *Conservation* **2023**, *3*, 303–318. <https://doi.org/10.3390/conservation3020021>

Academic Editor: Iain J. Gordon

Received: 4 March 2023

Revised: 12 April 2023

Accepted: 5 May 2023

Published: 22 May 2023



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1. Introduction

Biotechnology processes based on tissue engineering and stem cell multiplication have made it possible to address a disruptive issue that might be found in all equations for the mitigation of climate change. These processes involve moving away from obtaining protein for human consumption through livestock and opting for cultivated meat (CM). The production of meat from a cell culture establishes a disruptive approach in many layers of this process. One of the most important of these layers is food safety and involves the donor animal's tissue [1,2], shifting the focus from big ranchers, with large herds, to a small group of cell donor individuals. The use of fewer scarce natural resources, such as land and water [3,4], qualifies this case as an object of study.

Meat production based on traditional species used in livestock (poultry, cattle, pigs, sheep, and fish) can be reviewed from the CM supply of the same species, thereby reducing the pressure on these supply chains to meet the growing demand for food [3,4]. This enables a reduction in the deforestation caused by the need for new pastures and grains required to feed all these animals. However, the meat of wild species, when multiplied



Demand changes meat as changing meat reshapes demand: The great meat revolution

Jennifer C. Biscarra-Bellio, Gabriela B. de Oliveira, Maria C.P. Marques, Carla F.M. Molento*

Cellular Animal Science Laboratory, Federal University of Paraná, Rua dos Funcionários, 1540, 80035-050 Curitiba, Paraná, Brazil

ARTICLE INFO

Keywords:
Alternative protein
Brazil
Cultivated meat
Veganism
Vegetarianism

ABSTRACT

As consumer acceptance and overall demand for the different types of meat are important determinants of the new balance between conventional and alternative meats, our goal was to approach the changes in meat demand, as affected by the increasingly available alternative meats coupled to the challenges of conventional meat including the meat paradox, with emphasis on the Brazilian scenario. Then, some aspects of the demand for alternative meats are presented, with a brief historical background. As the decisions taken in the present shape this unprecedented revolution in the way we produce and choose whether to eat meat and, if so, which one, the details of the transition to alternative meat chains in Brazil are yet to be written. It seems even more difficult to predict which food protein items will be in higher demand in the next decades, as new products will likely present themselves for their quality as food items as well as for their ethical and environmental attributes.

1. Introduction

The global human population is constantly increasing and developing, and along with these processes some additional challenges may arise. An example is the steady increase in meat demand, a contributor to environmental degradation (Sanchez-Sabate, Badilla-Briones, & Sabaté, 2019). Animal production contributes to gas emissions deriving from land-use changes – especially deforestation – caused by expansion of pastures and arable land for feed crops. According to the World Economic Forum (2019), agriculture is responsible for 10–12% of greenhouse gas emissions, with meat, poultry and dairy farming producing nearly three quarters of that percentage. Other concerns are related to welfare conditions for most animals raised under industrialized farming conditions and the scale of their slaughter (Webster, 2013). In 2018, an estimated 68.8 billion chickens, 1.5 billion pigs and 302 million cattle were slaughtered for meat production (Ritchie & Roser, 2019). In addition, the number of aquatic animals worldwide involved is difficult to estimate, although the dimension of the industry may be perceived by the 150 million tonnes of seafood which were used for human consumption in 2016 (FAO, 2018). In Brazil, 29,7 million cattle, 6 billion chickens and 49,3 million pigs were slaughtered in 2020 (IBGE, 2021). Animal production activities are such that the total biomass of terrestrial animals used for food production is one order of magnitude higher than that of human beings and two orders of magnitude higher

than all wild mammals combined (Bar-On, Phillips, & Milo, 2018).

Regardless of the issues associated with conventional meat, the fact is that many people like to eat it, while simultaneously many people care for animals and are concerned with the environmental impacts of meat production. In Brazil, consumer research on opinions and demand for conventional meat have traditionally shown the importance of taste and price; however, recent research suggests that other meat attributes may be gaining importance as well. For example, Marques, Mauad, Domingues, Borges, and da Silva (2022) reported that the most important meat attributes in Brazilian consumer's preferences were healthiness, safety, animal welfare and environmental impact.

Generally, the decisions about eating meat are complex and consumer attitudes seem constantly reshaping with the changes in underlying factors. Examples of such factors are the amount of information accessed by consumers on the practices involved in conventional meat production, – e.g., animal suffering and environmental impacts –; increases in consumer purchase power and the availability, quality and comparative price of conventional meat substitutes. In fact, concerns about the ethics and environmental consequences of conventional meat consumption have led to a rapid expansion in the development of substitutes (Godfray et al., 2018). Such meat substitutes, denominated alternative proteins, include (1) meat cultivated from the multiplication of relevant animal cells in bioreactors, (2) meat analogues produced by molecular combinations of plant ingredients to mimic conventional

* Corresponding author.

E-mail address: carlamolento@ufpr.br (C.F.M. Molento).

Article

Will the Cows and Chickens Come Home? Perspectives of Australian and Brazilian Beef and Poultry Farmers towards Diversification

Diana Bogueva ^{1,*}, Maria Marques ^{2,*}, Carla Forte Maiolino Molento ², Dora Marinova ¹ and Clive J. C. Phillips ^{1,3}

¹ Curtin University Sustainability Policy Institute, Faculty of Humanities, Curtin University, Perth 6845, Australia; d.marinova@curtin.edu.au (D.M.); clive.phillips@curtin.edu.au (C.J.C.P.)

² Animal Welfare Laboratory and Cellular Animal Science Laboratory, Animal Science Department, Federal University of Parana, Curitiba 80035-050, Brazil; carlamolento@ufpr.br

³ Institute of Veterinary Medicine and Animal Science, Estonia University of Life Sciences, 51014 Tartu, Estonia

* Correspondence: diana.bogueva@curtin.edu.au (D.B.); maria.marques@ufpr.br (M.M.)

† These authors contributed equally to this work.

Abstract: Farmers across the world face criticism on environmental and animal welfare concerns, as well as are increasingly being affected by climate change. We explored the willingness of cattle and poultry producers in Australia and Brazil to consider alternative enterprises and diversification of their businesses. Twenty-seven farmers, 14 from Australia and 13 from Brazil, current or former beef or poultry producers, were interviewed to explore their perspectives about making such changes. The interviews were qualitatively analysed using Atlas.ti to generate key insights. Although the farmers were actively interested or had engaged in alternative enterprises, they recognised these presented a less certain future if they had been previously contracted to large companies. Some were critical of their respective governments and former contract companies for lack of assistance in finding suitable alternative enterprises. Farmers showed inconsistent recognition of the current challenges of animal production in relation to climate change. Our results indicate that most farmers are open to diversifying, but they face many challenges that have serious connotations. Public policies, knowledge transfer and a secure demand for alternative products emerged as major influential factors for Australian and Brazilian farmers in a fast and just transition from meat cattle and chicken raising to alternative activities.

Keywords: beef; climate change; environmental; sustainability; business challenges; plants; poultry



Citation: Bogueva, D.; Marques, M.; Molento, C.E.M.; Marinova, D.; Phillips, C.J.C. Will the Cows and Chickens Come Home? Perspectives of Australian and Brazilian Beef and Poultry Farmers towards Diversification. *Sustainability* **2023**, *15*, 12380. <https://doi.org/10.3390/su151612380>

Academic Editors: Xianhui Hou and Liguang Zhang

Received: 9 July 2023

Revised: 5 August 2023

Accepted: 8 August 2023

Published: 15 August 2023



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1. Introduction

The animal farming sector is increasingly criticised for excessive use of land, water and grains suitable for feeding humans [1], negatively impacting food security, as well as for greenhouse gas emissions contributing to climate change, overuse of antibiotics leading to the spread of antimicrobial resistance, and poor welfare of animals within the farming systems [2–4]. Studies with regenerative animal farming represent attempts to improve this scenario (e.g., [5]); however, there is uncertainty regarding the ability of such improvements to mitigate the situation.

Furthermore, the future of farmers around the world is becoming increasingly uncertain because of climate change impacts and other environmental challenges [6]. Within the prevailing market economy, globalisation, government policy and new technology development, combined with other economic and social forces, are at the forefront of changes in animal production systems, influencing traditional business models, supply chains and patterns of employment [7]. Current market forces are driving increased demand in some animal production systems, most notably poultry, which is resulting in widespread



Original article

Obtaining of bioactive di- and tripeptides from enzymatic hydrolysis of soybean meal and its protein isolate using Alcalase® and Neutrase®

Thamara Thaiane da Silva Crozatti,¹ Juliana Harumi Miyoshi,¹ Angélica Priscila Parussolo Tonin,¹ Larissa Fonseca Tomazini,¹ Marco Aurélio Schuler Oliveira,¹ José Uebi Maluf,² Eduardo Cesar Meurer³ & Graciette Matioli^{1*} 

1 State University of Maringá (UEM), Av. Colombo, 5790, 87020-900, Maringá, PR, Brazil

2 BR Foods, Av. Senador Atilio Fontana, 4040, 85902-160, Toledo, PR, Brazil

3 Federal University of Paraná (UFPR), Advanced Campus Jandaia do Sul, 86900-000, Jandaia do Sul, PR, Brazil

(Received 24 January 2022; Accepted in revised form 24 May 2022)

Summary The obtaining of bioactive di- and tripeptides using Alcalase® and Neutrase® enzymes in the hydrolysis of soybean meal (SM) and its protein isolate (SPI) was evaluated. An innovative system by fast LC-MS/MS neutral loss screening and *de novo* sequencing was used to identify bioactive peptides. Soy protein characterisation, gel electrophoresis and antioxidant activity of the obtained peptides were performed. Results achieved showed that the use of Alcalase® and SPI preparation potentiated the peptide breaking bonds and favoured the obtainment of bioactive peptides. The antioxidant activity of tested samples was significantly improved with enzymatic hydrolysis. LC-MS/MS analyses identified nineteen peptides in SM and 51 in SPI, all obtained after hydrolysis with Alcalase® and, according to BIOPEP, with relevant bioactivities and expressive functional potential. Therefore, it is suggested that bioactive peptides achieved in this study can enable the development of new ingredients and provide greater added value to soy by-products.

Keywords Soybean meal, enzymatic hydrolysis, dipeptides, tripeptides, bioactivities.

Introduction

The demand for higher nutritional and sensory quality food products has increased significantly and, based on this scenario, the valuation of the food with functional ingredients also increases, among which bioactive peptides stand out.

Bioactive peptides are short-chain amino acid fragments joined by peptide bonds, which can vary between two and twenty amino acid segments (Hartmann & Meisel, 2007; Li-Chain, 2015). Nowadays, more than 4372 bioactive peptides already identified are available in the literature, which may come from sources such as plants and animals (Minkiewicz *et al.*, 2019).

The heightened interest in peptides is associated with their high bioactivity and, above all, their functional properties and health promotion (Coscueta *et al.*, 2016; Liu *et al.*, 2020). Such organic compounds can be obtained by different chemical processes, such

as hydrolysis processes and fermentation methods, which consist of breaking the protein into smaller pieces to modify the protein structures and improve its functional characteristics (Shen *et al.*, 2020).

Enzymatic hydrolysis processes are highly beneficial to the food industry, especially because it has advantages, such as greater control of protein breakdown degree and low cost (Sigh *et al.*, 2014). In this context, the use of different proteases is highlighted, which are classified into endopeptidases and exopeptidases, such as Alcalase®, Neutrase®, papain and trypsin (Liu *et al.*, 2020; Tacias-Pascaio *et al.*, 2020).

The largest number of isolated peptides comes from animal sources such as milk protein and dairy products (Hartmann & Meisel, 2007; Sigh *et al.*, 2014). However, some vegetable sources have been expanding and showing up in recent years, such as soy protein, that in addition to exhibits one of the most important production chains in the world agribusiness, standing out mainly in soybeans, bran and oil production, presents, together with its by-products, a rich source of

*Correspondent: Fax: +55 44 3011-4119; E-mail: gmatioli@uem.br

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Research Article

Stakeholders' justifications in innovation: the case of cell-based meat

Helna Almeida de Araujo Góes , Germano Glufke Reis, Gustavo Abib & Felipe Mendes Borini

Received 30 May 2023, Accepted 26 Apr 2024, Published online: 11 Jun 2024

 Cite this article  <https://doi.org/10.1080/13511610.2024.2352744> Check for updates

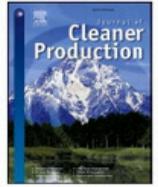
Abstract

Cell-based meat (CBM) is a novel technology that employs the cultivation of animal cells in bioreactors to produce edible meat, representing a breakthrough innovation in the meat production chain. However, innovations are embedded in uncertainty and ambiguity; thus, several stakeholders shape their development and legitimacy. Stakeholders attempt to set their priorities by employing and disseminating justifications when facing novelty situations. This study builds on stakeholder and justification theories to explore the justifications employed by stakeholders and their impacts on innovations such as CBM technology. To this end, interviews with representatives of five stakeholder groups were conducted - startups, NGOs, investors, researchers, and conventional animal-based meat processing firms - and triangulated with secondary data from websites and news. Public Justification Analysis was applied to analyze the data. The results indicate that the analyzed stakeholders converge toward CBM legitimacy and development by sharing similar purposes and values. On the other hand, disputes and justifications contrary to CBM legitimacy are mainly related to traditional values, which can raise obstacles to product development. Hence, by analyzing stakeholders' justifications, we can understand their behaviors and demonstrate how they shape innovation and a nascent high-tech industry.

Q Keywords: [cell-based meat](#) [justification theory](#) [stakeholders](#) [innovation](#)

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David vs Goliath: The challenges for plant-based meat companies competing with animal-based meat producers

Germano Glufke Reis^a, Eduardo Guedes Villar^b, Toni Ryyänen^c, Vinicius Picanço Rodrigues^{d,e,*}

^a School of Management and Sustainable Food Value Chains Lab, UFPR Federal University of Parana, Av. Lothário Meissner, 632 Jd Botânico, Curitiba, 80210-170, Brazil

^b Management Department, IFSC Federal Institute of Education, Science and Technology of Santa Catarina, Av. Faldó Thomé, 3000, Champagnat, Caçador, SC, 89503-550, Brazil

^c Ruralia Institute, Faculty of Agriculture and Forestry, University of Helsinki, Lönnrotinkatu 7, 50100, Mikkeli, Finland

^d Design, Manufacturing and Engineering Management Department, Faculty of Engineering, University of Strathclyde, James Weir Building, Office JW704, 75 Montrose Street, Glasgow, United Kingdom

^e Insper Institute of Education and Research, Rua Quatá, 300, Vila Olímpia, 04546-042, São Paulo, Brazil

ARTICLE INFO

Handling Editor: Cecilia Maria Villas Bôas de Almeida

1. Introduction

An extensive body of literature has recently discussed how the transition from animal-based meat to alternative sources of proteins could help to reduce the environmental impacts of livestock chains, such as greenhouse gas (GHG) emissions (Sinke et al., 2023; Smetana et al., 2015; Takacs et al., 2022; Tuomisto and Teixeira de Mattos, 2011; Tuomisto et al., 2022). Alternative proteins are broadly characterized as being made with ingredients that replace traditional protein sources and have a lower environmental impact (Grossmann and Weiss, 2021), while the terms “meat analogs” and “meat substitutes” refer more specifically to alternative protein products that incorporate the nutritional and sensory characteristics of meat (McClements and Grossmann, 2021; Smetana et al., 2023). Plant-based meats are produced with vegetable proteins such as soy, pea or wheat to mimic the characteristics of animal meat products (Choudhury et al., 2020; He et al., 2020). These plant-based products can have 50% less GHG emissions than animal-based food (Xu et al., 2021; Smetana et al., 2023). Moreover, the dietary, nutritional, and health benefits of plant-based meats have also drawn the interest of consumers seeking meat substitutes (Michel et al.,

2021; Rizzo et al., 2023). For instance, plant-based meat consumption may be associated with a lower risk of developing chronic diseases (e.g., heart diseases) and can contribute to greater general well-being among consumers (Fehér et al., 2020).

Despite the expected benefits, potential bottlenecks to the development and expansion of the meat analogs sector have been discussed in the literature. Plant-based meat is already available but has challenges regarding product cost, the need to develop novel vegetable protein sources, and improving the sensory attributes of products (Choudhury et al., 2020; He et al., 2020).

Driven by the alleged environmental benefits of plant-based meats, the mainstream animal-based meat companies - associated with high levels of GHG emissions, extensive land use, animal suffering, and other negative externalities - have invested in alternative proteins. These plant-based meat products complement their existing portfolios. Examples include Tyson Food's Raised & Rooted, Jimmy Dean plant-based brands and JBS's Seara Incrivel plant-based products. Thus, while keeping and promoting their animal-based products they also have branches in plant-based meat segments.

Tyson Foods, a major global food company, reported that 81.13% of

* Corresponding author. Design, Manufacturing and Engineering Management Department, Faculty of Engineering, University of Strathclyde, James Weir Building, Office JW704, 75 Montrose Street, Glasgow, United Kingdom.

E-mail addresses: glufkereis@ufpr.br (G. Glufke Reis), eduardo.villar@ifsc.edu.br (E.G. Villar), toni.ryyänen@helsinki.fi (T. Ryyänen), vinicius.picanco-rodrigues@strath.ac.uk (V. Picanço Rodrigues).

<https://doi.org/10.1016/j.jclepro.2023.138705>

Received 20 June 2023; Received in revised form 18 August 2023; Accepted 4 September 2023

Available online 5 September 2023

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 Restricted access | Research article | First published online February 6, 2022

When Justification Theory Meets Responsible Innovation: A Study of Cell-Based Meat

[Helna Almeida de Araujo Góes](#) , [Giovanna Colin Zeny](#), and [Germano Glufke Reis](#) [View all authors and affiliations](#)

[Volume 27, Issue 2](#) | <https://doi.org/10.1177/09717218221075158>

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Abstract

The benefits and challenges associated with cell-based meat (CBM) influence actors' perspectives on the importance of its development and production. We build on Boltanski and Thévenot's framework to analyse the values that start-ups and investors address to a responsible innovation (RI). In an uncertain and complex context, interactions among actors shape innovative enterprises. Our research question is as follows: In what ways do the justifications employed by start-ups and investors converge (or not) in order to foster investment in the CBM industry? By identifying the prioritised values by start-ups and investors concerning the importance of developing and producing CBM, we demonstrate how two key groups are providing justifications, shifting from conflicting interests and towards the observance of the common good. Twenty-two start-ups were analysed alongside ninety-four investors. The analysed justifications were obtained from start-ups and investors' official websites and interviews. Moreover, this study aims to provide an interdisciplinary study of a RI phenomenon, insomuch as there is insufficient research on this topic.



ARTICLE



<https://doi.org/10.1057/s41599-022-01316-z>

OPEN

The expected impact of cultivated and plant-based meats on jobs: the views of experts from Brazil, the United States and Europe

Rodrigo Luiz Morais-da-Silva ^{1✉}, Eduardo Guedes Villar ², Germano Glufke Reis¹, Hermes Sanctorum³ & Carla Forte Maiolino Molento¹

Cultivated and plant-based meats are substitutes for conventional animal meat products. As radical innovations, they may trigger profound social and economic changes. Despite the many benefits of alternative meats, such as environmental sustainability, animal welfare, human health and food safety, some unintended consequences remain unexplored in the literature. In this paper, we studied the potential impact of the meat production system transition on jobs. Using a survey, we compared opinions regarding the impact on jobs in Brazil, the United States and Europe, according to alternative protein experts. Our results showed the potential of plant-based and cultivated meat production to create new and higher-skilled jobs. The data analysis also suggested that the impact of novel food production systems on jobs in conventional meat production may be different for each stage of the value chain. In particular, the results showed a pressure point on animal farmers, who may be most affected in a fast transition scenario. Considering the studied geographical contexts, Brazilian professionals were more optimistic about the potential of plant-based and cultivated meat production to create new jobs. Our findings may provide new insights for the development of policies, measures and strategies that promote job creation, skills and income in view of the ongoing transition.

¹UFPR Federal University of Paraná, Paraná, Brazil. ²FURB Regional University of Blumenau, Blumenau, Brazil. ³GAIA Global Action in the Interest of Animals, Brussels, Belgium. ✉email: rodrigo.morais.silva@ufpr.br



OPEN ACCESS

EDITED BY
Sergiy Smetana,
German Institute of Food
Technologies, Germany

REVIEWED BY
Hayley Hesselin,
University of Saskatchewan, Canada
Cor Van Der Weele,
Wageningen University and
Research, Netherlands

*CORRESPONDENCE
Rodrigo Luiz Morais-da-Silva
✉ rodrigo.morais.silva@ufpr.br

SPECIALTY SECTION
This article was submitted to
Social Movements, Institutions and
Governance,
a section of the journal
Frontiers in Sustainable Food Systems

RECEIVED 29 September 2022
ACCEPTED 30 November 2022
PUBLISHED 22 December 2022

CITATION
Morais-da-Silva RL, Reis GG,
Sanctorum H and Molento CFM (2022)
The social impact of cultivated and
plant-based meats as radical
innovations in the food chain: Views
from Brazil, the United States and
Europe.
Front. Sustain. Food Syst. 6:1056615.
doi: 10.3389/fsufs.2022.1056615

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The social impact of cultivated and plant-based meats as radical innovations in the food chain: Views from Brazil, the United States and Europe

Rodrigo Luiz Morais-da-Silva^{1*}, Germano Glufke Reis¹,
Hermes Sanctorum² and Carla Forte Maiolino Molento³

¹UFPR Business School, Federal University of Paraná, Curitiba, Brazil, ²GAIA Global Action in the Interest of Animals, Brussels, Belgium, ³Cellular Animal Science Laboratory, Federal University of Paraná, Curitiba, Brazil

Cultivated and plant-based meats have been recognized as radical innovations that may revolutionize food production worldwide. Despite potentially being more sustainable than conventional meat, little is known about the consequences these innovations can bring to society. To help to clarify this topic, we studied the social impacts that cultivated and plant-based meats may bring to Brazil, the United States and Europe. Based on the perspective of 136 experts, our results are divided into market expectations, consumer access, consumer acceptance, impacts on farms, and business opportunities along the new chains. Experts generally predicted an optimistic picture of the social effects with several opportunities as alternative meats become available. However, the consequences for animal farmers seemed worrying in the experts' views. Overall, the opinion of Brazilian and American experts seemed more optimistic than that of Europeans. Our findings may be helpful for practitioners and people involved in rural policy interested in better guiding this transition process in the food production chain.

KEYWORDS

cultivated meat, plant-based meat, radical innovation, social impact, sustainable food production chain

Introduction

Meat has been considered essential by humans in their diets (Stanford and Bunn, 2001; van der Weele et al., 2019), although it is currently known that it is not, according to the Academy of Nutrition and Dietetics of the United States (Melina et al., 2016) and the National Health Service in England (NHS, 2018), amongst others. Even so, meat consumption records are expected in the coming years, especially with the projected increase in consumption in developing regions (OECD-FAO, 2020). With this scenario envisaged, several problems linked to meat production and consumption may increase, especially in the environmental, animal welfare, and public health domains.



REVIEW ARTICLES

Is the development of low-cost media one of the greatest challenges to produce cultivated meat on an industrial scale?

Carlos Ricardo Soccol^{a*}, Susan Grace Karp^a, Luiz Alberto Junior Letti^a,
Giuliana Biagini^a, Gabriel Balla^a, Ana Paula Boligon^a, João Pedro Manica Candelario^a,
Thiago Feliciano Faria^a, Patricia Beatriz Gruening de Mattos^a, Igor Negreiros Piazenski^a,
Lilian Cristina Klein Raymundo^a, Daniel Augusto Ribeiro Rolim Valeixo^a,
Vanete Thomaz Soccol^a

^aDepartment of Bioprocess Engineering and Biotechnology, Federal University of Paraná, Cel. Francisco H. dos Santos Street, 100, Polytechnic Center, Zip Code 81.531-990, Curitiba, PR, Brazil.

Highlights

- Traditional culture media for animal cells contain animal-derived ingredients
- Serum-based media are associated to ethical, safety, and economic concerns
- Alternative “animal-free” ingredients are key inputs in cultivated meat production
- Cost reduction of culture media is one of the greatest challenges for process scale-up

Received 08 September, 2022; Accepted 11 November, 2022

KEYWORDS

Alternative proteins;
Animal cell meat;
Animal cell culture;
Serum-free media.

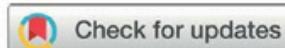
Abstract: Cultivated meat (CM) has emerged as an “ethical” alternative for the consumption of meat, avoiding animal slaughter and safeguarding animal care. The idea behind animal cell cultivation, differentiation and proliferation is old, but the investments, technological developments and first efforts to produce CM on industrial scale are very recent. There are many challenges and bottlenecks within this new market, including social, environmental, technological, regulatory and logistic aspects; however, the emphasis of this article is the composition of the culture media for animal cells development, which is strongly attached to economy (component costs) and ethics (components of animal origin). Traditional basal media (such as Eagle’s Minimum Essential Medium and Ham’s F-12) comprise energy and carbon sources, vitamins, amino acids and trace elements; but the requirements for development and differentiation of skeletal muscle cells demand other components of animal origin, such as fetal bovine serum and/or other growth factors, hormones and inducers. Recent articles and patents have reported the substitution of these components, including the use of recombinant albumin, postbiotics, and microalgal extracts. Despite these efforts, the current market of CM is still in its “first childhood” with 107 enterprises around the world, and just a few of them are authorized to commercialize CM; the current price to the final consumer is, in the best case, 7.5 times higher when compared to traditional meat. Therefore, from our point of view, there is still a long way to go in developing this new product and establishing a new global market.

*Corresponding author.

E-mail: soccol@ufpr.br (C. R. Soccol).



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WHAT ABOUT ALTERNATIVE MEAT? THE EFFECT OF NEOPHOBIA AND NEGATIVE AFFECT ON THE INTENTION TO BUY MEAT SUBSTITUTES

 **Caio Pedrinho da Silva**

Federal University of Paraná - UFPR.
Curitiba, Paraná – Brazil.
caio_pedrini@hotmail.com

 **Elder Semprebon**

Federal University of Paraná - UFPR.
Curitiba, Paraná – Brazil.
elder.semprebon@gmail.com

 **Germano Glufke Reis**

Federal University of Paraná - UFPR.
Curitiba, Paraná – Brazil.
germanoglufkereis@yahoo.com.br

Objectives: Assess the consumer's low intention to purchase meat substitutes (cultivated meat, plant-based meat, and insect-based meat) compared to conventional meat, considering negative affect as an explanation mechanism and neophobia as an intensifier.

Methods: To achieve the objective proposed, we carried out an experimental study to understand the relationships between conventional meat substitutes (cultivated meat, plant and insect-based meat) and the purchase intention, the mediating effect of negative affect (aversion, danger, and disgust) and the moderating effect of neophobia.

Originality/Relevance: Little is known about the low acceptance of conventional meat substitutes; therefore, this study presents a unique explanation mechanism for this fact, as well as an intensification moderator.

Results: Negative affect explains the low intention to buy insect-based meat, and high levels of neophobia are a moderator only in the direct relationship for all meat substitutes.

Theoretical/Methodological contributions: The results contribute to understanding the influence of negative affect as a mechanism to explain the low intention to buy meat substitutes compared to conventional meat, the role of the neophobia trait in this context, and the comparisons between types of meat.

Keywords: Negative affect. Cultured meat. Insect-based meat. Plant-based meat. Neophobia.

How to cite the article

American Psychological Association (APA)

Silva, C. P., Semprebon, E., & Reis, G. G. (2022, July/ Sept.). What about alternative meat? the effect of neophobia and negative affect on the intention to buy meat substitutes. *Brazilian Journal of Marketing*, 21(4) 1244-1262. <https://doi.org/10.5585/remark.v21i4.20166>.





The social impacts of a transition from conventional to cultivated and plant-based meats: Evidence from Brazil

Rodrigo Luiz Morais-da-Silva^{a,*}, Germano Glufke Reis^a, Hermes Sanctorem^b, Carla Forte Maiolino Molento^c

^a Management School, UFPR Federal University of Paraná, Av. Lothário Meissner, 632, Jd Botânico, Paraná, Curitiba, Paraná, Brazil

^b GAIA Global Action in the Interest of Animals, Galerie Ravenstein 27, 1000 Brussels, Belgium

^c Animal Welfare Laboratory, UFPR Federal University of Paraná, Rua dos Funcionários, 1540 Juvevê, Curitiba, Paraná, Brazil

ARTICLE INFO

Keywords:

Social impact
Meat production chain
Cultivated meat
Plant-based meat
Stakeholder engagement
Transition policies

ABSTRACT

Cultivated and plant-based meats are emerging as innovative alternatives to improve the food production system. Although some environmental impacts and market acceptance assessments have already been developed, little emphasis has been given to potential social impacts. Based on the Brazilian case, one of the largest meat producers in the world, this study seeks to answer what the social impacts of a transition from conventional to cultivated and plant-based meats may be. Empirical data were collected from in-depth interviews with 35 experts involved in animal production and alternative products. Our results indicated nine opportunities and five challenges that the country may face. We discussed these findings in relation to the degree of involvement of relevant actors and suggested that high stakeholder engagement may contribute to capitalizing on social opportunities, and that low stakeholder engagement will likely not mitigate the challenges. We also highlight the need for policies that better drive a transition process, even if partially, in a fair and inclusive way. Our study advances the field of food systems in transition, being the first one to investigate the social impacts of alternative proteins on a developing country. Many of our findings seem to be generalizable to other countries involved in the production of food from animals.

1. Introduction

Food systems have been gaining more attention from policymakers due to their wide-ranging consequences in different dimensions (Béné et al., 2019; de Krom and Muilwijk, 2019; De Schutter et al., 2020; Moragues-Faus and Battersby, 2021), such as food security and environmental sustainability. Important guidance documents with a global reach emphasize these concerns. ‘Zero hunger’ and ‘Sustainable consumption and production’ are listed within the 17 sustainable development goals of the 2030 Agenda (United Nations, 2015); both are directly connected to food systems. The Intergovernmental Panel on Climate Change report also highlights the need for change in food production models, to alleviate the pressures on climate (IPCC, 2020).

Changes in the meat production systems and consumption seem to be the most frequently requested. Current meat consumption is around 325 million tons, with a tendency to grow in the coming years (OECD-FAO, 2020). Nevertheless, animal production brings several environmental,

animals ethics, and human health challenges (Bozzo et al., 2021; van der Weele et al., 2019). Despite these negative consequences, conventional meat is considered a traditional nutrient source, additionally recognized as an important cultural element (Loughnan et al., 2010; Oleschuk et al., 2019). Its production chain generates jobs and income for around 1.3 billion people worldwide (FAO, 2022).

Considering this scenario of various negative consequences of the conventional meat production system coupled to the prospect of increased global meat consumption, some alternative proteins have drawn attention. Cultivated and plant-based meats have been receiving investments from companies and government incentives, as well as arousing academic interest. Cultivated meat, also called cultured meat, cell-based meat or clean meat, is developed by removing a small amount of stem cells from a live animal and cultivating them in a bioreactor (Broad, 2020; Post et al., 2020). In its new version, plant-based meat is made from vegetable ingredients, processed through technological methods, with flavor, texture and nutrition characteristics similar to

* Corresponding author.

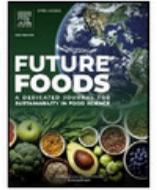
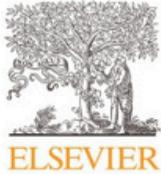
E-mail addresses: rodrigo.morais.silva@ufpr.br (R. Luiz Morais-da-Silva), glufkereis@ufpr.br (G. Glufke Reis), info@huginemnunin.be (H. Sanctorem), carlamolento@ufpr.br (C. Forte Maiolino Molento).

<https://doi.org/10.1016/j.foodpol.2022.102337>

Received 13 October 2021; Received in revised form 27 July 2022; Accepted 2 August 2022

Available online 13 August 2022

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Reducing meat consumption: Insights from a bibliometric analysis and future scopes

Mirian Natali Blézins Moreira^a, Claudimar Pereira da Veiga^{a,*}, Cássia Rita Pereira da Veiga^b, Germano Glufke Reis^a, Lucilaine Maria Pascuci^c

^a Department of General and Applied Administration, School of Management, Federal University of Paraná—UFPR, Av. Lothário Meissner, 632, Curitiba-PR 80210-170, Brazil

^b Department of Health Management, School of Nursing, Federal University of Minas Gerais - UFMG, Av. Alfredo Balena, 190, Belo Horizonte-MG 30130-100, Brazil

^c Department of Management, Center of Legal and Economic Sciences, Federal University of Espírito Santo—UFES, Av. Fernando Ferrari, 514-Goiabeiras, Vitória-ES 29075-910, Brazil

ARTICLE INFO

Keywords:

Consumer behavior
Reduction in meat consumption
Literature mapping
Future Foods

ABSTRACT

Several studies have indicated that a global reduction in meat consumption is inevitable for sustainability and public health, despite the challenges inherent to changing eating habits. The purpose of this article is to pursue a stock-take of consumer behavior with regard to reducing meat consumption through a literature review using bibliometric analysis. The findings show the multidisciplinary nature of the field, which is in full development and with many knowledge gaps. Publications are concentrated in a few dominant journals and originated exclusively in developed countries. Six thematic subareas are central to the theme in question and helped to structure the field. The findings also show that few authors have been recurrent in publications on the subject and that three thematic groups represent promising areas for future research: behavior, sustainability, and interventions. The contributions of this article lie in the fact that helps organizations and researchers achieve a panoramic view of the field, identifying unanswered questions and possible partners for research. From a practical perspective, this research can also support new studies to develop public policies aimed at reducing (or replacing) meat consumption or encouraging enterprises and investments related to alternative products for conventional meat.

Introduction

Meat consumption has been part of human evolutionary history (Dakin et al., 2021). However, several studies have pointed to the problems caused by the production and consumption of meat (da Silva and Sempregon, 2021; Corrin and Papadopoulos, 2017; Spencer et al., 2018; Trewhern et al., 2021). In particular, meat production and consumption have been associated with environmental degradation, ethical issues, health problems, and compromised animal welfare (Graça et al., 2014; Singer, 1975/2009; Steinfeld et al., 2006). In this respect, few studies have analyzed consumer behavior with regard to reducing meat consumption (Grasso et al., 2021; Patel and Buckland, 2021). However, some studies have shown that reducing meat consumption and adopting plant-based diets will be critical when addressing health and environmental sustainability challenges (Graça et al., 2019; Hartmann and Siegrist, 2017; Macdiarmid et al., 2016; Hedenus et al., 2014; Sage et al., 2021; Dagevos and Voordouw, 2013).

Meat consumption behavior is complex and difficult to change (Macdiarmid et al., 2016; Hansen et al., 2021). In fact, despite the inher-

ent harm, meat consumption has increased considerably in specific locations (Bonnet et al., 2020), demonstrating that changes towards healthier and more ecological behaviors mean having to overcome barriers (Tobler et al., 2011).

Several factors are involved in reducing meat consumption, such as the consumer's personal, social and cultural values (Macdiarmid et al., 2016; Smetana et al., 2021). Therefore, meat is an essential component for consumers, who in general may not be willing to reduce consumption or exclude it from their diets (Tobler et al., 2011). There is evidence that some consumers are moving in the opposite direction towards a growth in meat consumption. A significant group of European consumers is becoming flexitarian (Bonnet et al., 2020); that is, they reduce their consumption by not eating meat at least one day a week (de Bakker and Dagevos, 2012; Dagevos 2021). Knowing the motivations and barriers perceived by these meat reducers can help to promote diets with less meat (Kemper, 2020).

Attention has been paid to research on consumer behavior concerning reduced meat consumption in recent years (for example: Cheah et al., 2020; Chuck et al., 2016; Schenk et al., 2018). Given the context and relevance of the topic for companies operating in the field and recent

* Corresponding author.

E-mail address: claudimar.veiga@gmail.com (C.P. da Veiga).

Article

Social Media Analysis to Understand the Expected Benefits by Plant-Based Meat Alternatives Consumers

Mirian Natali Blézins Moreira ¹, Cássia Rita Pereira da Veiga ¹, Zhaohui Su ², Germano Glufke Reis ¹, Lucilaine Maria Pascuci ³ and Claudimar Pereira da Veiga ^{1,*}

- ¹ Department of General and Applied Administration, School of Management, Federal University of Paraná—UFPR, Av. Lothário Meissner, 632, Curitiba 80210-170, Brazil; mirian.ufpr@gmail.com (M.N.B.M.); cassia.veig@gmail.com (C.R.P.d.V.); glufkereis@ufpr.br (G.G.R.)
- ² Mays Cancer Center, Center on Smart and Connected Health Technologies, School of Nursing, UT Health San Antonio, San Antonio, TX 78229, USA; szh@utexas.edu
- ³ Department of Management, Center of Legal and Economic Sciences, Federal University of Espírito Santo—UFES, Av. Fernando Ferrari, 514-Goiabeiras, Vitória 29075-910, Brazil; lucilaine.pascuci@gmail.com
- * Correspondence: claudimar.veiga@gmail.com; Tel.: +55-(41)-3360-4366

Abstract: The plant-based alternative meat products market has attracted attention in recent years, as the demand for these products has grown worldwide. To meet the needs of this promising market, marketers must pay attention to the expected benefits of consumers and the insights that can be gleaned from comments posted on social media. This article proposed an investigation of the potential of the content analysis of comments posted on the Instagram social network of food companies that manufacture plant-based alternative meat products to understand the expected benefits by end consumers from the perspective of the classic marketing mix variables. The content posted voluntarily by consumers was organized into 13 categories of expected benefits analyzed within a proposal of evidence from the perspective of the marketing mix. The results showed that, among the insights obtained, 63% were related to the place variable, 21% to the product variable, 11% to the price variable, and 5% to the promotion variable. The insights reinforce the notion that marketing mix variables are crucial factors for companies to make products available in the right place, in the right quantity, and at a fair price, in addition to engaging with consumers through social media.

Keywords: foods; plant-based alternative meat; social media; classic marketing mix; manufactures; consumer



Citation: Moreira, M.N.B.; da Veiga, C.R.P.; Su, Z.; Reis, G.G.; Pascuci, L.M.; da Veiga, C.P. Social Media Analysis to Understand the Expected Benefits by Plant-Based Meat Alternatives Consumers. *Foods* **2021**, *10*, 3144. <https://doi.org/10.3390/foods10123144>

Academic Editor: Cuixia Sun

Received: 15 November 2021

Accepted: 15 December 2021

Published: 18 December 2021

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.



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1. Introduction

The plant-based alternative meat products market has attracted attention in recent years [1,2] from researchers, the food industry, and public health policymakers [3] since the demand for these products has grown worldwide [4]. Plant-based products that resemble animal meat have stood out among alternatives to meat [5]. In the literature, several studies present the main definitions and differences between new plant-based alternative meat products about those based on original animal proteins [6]. To succeed in this new market, companies seek to maintain their products' sensory, textural, visual, and taste components. These actions become important to assist consumers of traditional meat in the transition to a more plant-based diet [7,8].

Plant-based alternative meat products are part of this market and present a different proposal regarding traditional meat substitutes. Vegetable-based meat analogs aim to attract new consumers, including those who consume meat [9]. To attract new consumers in this expanding market, companies need to pay attention to classic marketing mix strategies to make products available in the right place, in the exact quantity, and at a fair price, in addition to engaging in assertive communication with their target audience [6].



REVIEW ARTICLE

Cultivated meat: recent technological developments, current market and future challenges

Luiz Alberto Junior Letti^a, Susan Grace Karp^a, Carla Forte Maiolino Molento^b,
Brigitte Sthepani Orozco Colonia^a, Raphael Aparecido Boschero^a,
Vanete Thomaz Soccol^a, Leonardo Wedderhoff Herrmann^a, Rafaela de Oliveira Penha^a,
Adenise Lorenci Woiciechowski^a, Carlos Ricardo Soccol^{a*}

^aDepartment of Bioprocess Engineering and Biotechnology, Polytechnic Center, Federal University of Parana, Rua Cel. Francisco H. dos Santos - 100, CEP 81530-000, Curitiba, PR, Brazil

^bAnimal Welfare Laboratory, Agrarian Sector, Federal University of Parana, Rua dos Funcionários - 1540, CEP 80035-050, Curitiba, PR, Brazil

Highlights

- Cultivated Meat is a potential candidate to (partially) substitute animal meat in the future decades;
- Current technological developments and tendencies are presented;
- Bioeconomy and sustainable aspects of CM production are discussed;
- Cultivated Meat Market is growing fast in the last few years;
- Challenges regarding CM production comprises public acceptance and social, economical and environmental aspects.

Received 01 September, 2021; Revised 22 September, 2021; Accepted 01 October, 2021.

KEYWORDS

Future food;
Cultivated meat;
Tissue engineering;
Food sustainability;
Bioeconomy;
Recent patents.

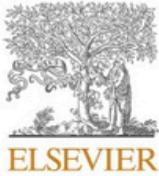
Abstract: The increasing demand for food, the debates regarding the ethics involved in slaughtering animals and the many associated environmental issues promote the emergence of an interesting question: is it possible to substitute conventional meat? In this context, Cultivated Meat (CM) is a promising alternative to replace meat, or at least to complement protein nutrition for humans. This overview aims to show the current technological developments for the production of CM, starting with the tissue engineering used to collect, grow and differentiate the cells, and also the characteristics of matrixes, culture media, types of bioreactors and techniques employed for cell cultivation. In addition, bioeconomy and sustainability issues are discussed, as well as social aspects and policy regulation. Furthermore, the fast growing market is presented, starting with the first meat ball in 2016, passing through some examples of recent funding and operating companies and start-ups, the continuous efforts to lower production costs, besides the most recent patented processes. Finally, and in the light of recent developments, future challenges and expectations for the future of CM are discussed, such as tissue engineering bottlenecks, bioreactor design optimization and public acceptance issues.

*Corresponding author.

E-mail: soccol@ufpr.br (C. R. Soccol)



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Can radical innovation mitigate environmental and animal welfare misconduct in global value chains? The case of cell-based tuna

G.G. Reis^{a,*}, M.S. Heidemann^b, H.A.A. Goes^a, C.F.M. Molento^b

^a School of Business Administration, Federal University of Paraná, Av. Lothário Meissner, 632, 80210-170, Curitiba, Paraná, Brazil

^b Animal Welfare Laboratory, Federal University of Paraná, Rua dos Funcionários, 1540, 80035-050, Curitiba, Paraná, Brazil

ARTICLE INFO

Keywords:

Radical innovation
Global value chain
Environmental misconduct
Animal welfare
Cultivated meat

ABSTRACT

Organizational misconduct, defined as illegal, unethical or irresponsible organizational behavior, concerning the environment can lead to resource depletion, threats to biodiversity, animal suffering and environmental damage. Some chains have been scrutinized due to the massive depletion of environmental resources caused by illegal exploitation, such as the tuna chain. In search for solutions, regulations and product traceability have been used. Despite the urgency of the subject, less attention has been given to how radical innovations may lead to preventing animal welfare and environmental misconduct. Technological radical innovations are characterized by their uniqueness, novelty, and potential to promote significant transformations in a chain. Thus, we adopted an exploratory approach to analyze the case of a radical technological innovation – cell-based meat – which can substantially transform the meat value chain and, more specifically, mitigate overwhelming environmental and animal welfare misconduct in the tuna global chain. The case illustrates how radical innovation can significantly change global value chain's activities and redefine its geographic scope; it may also represent a shift from natural resource-intensive to technology-intensive activities. More importantly, by substituting animal-based inputs, severe environmental and animal welfare issues will be mitigated.

1. Introduction

Organizational misconduct involves illegal, unethical or irresponsible behaviors practiced by organizations (Greve et al., 2010), encompassing frauds, product safety issues, employee mistreatment, among others (Hersel et al., 2019). Environmental misconduct in particular can lead to depletion of natural resources, threats to biodiversity, wildlife biomass decrease and environmental damage, which can put the world's natural systems at risk. Animal welfare misconduct, in turn, involves keeping animals in conditions of suffering and slaughtering through inhumane methods, i.e., slaughter without prior stunning (Lundmark et al., 2014). Moreover, slaughtering animals is *per se* a major ethical debate, which has been increasingly challenged, especially after the seminal works by philosophers (Peter Singer 1975) and Tom Regan (Regan, 1983). The risk for such environmental and animal welfare misconducts also relates to the organization of global value chains. As a consequence of trade globalization and international business, global value chains have emerged putting pressure on the use of environmental resources worldwide (Plank et al., 2018); thus, how to prevent environmental and animal welfare issues in global value chains has been a

major concern (Marchi et al., 2013; Reis and Molento, 2020).

Most actions aiming to restrain environmental and animal welfare misconduct in value chains involve normative or regulatory initiatives and other control mechanisms, which may be either private or state-based, at both the national and international levels (Nadvi, 2008; Reis and Molento, 2020; Vogel, 2010). Furthermore, companies have adopted labels, sustainability and corporate social responsibility standards, which intend to certify that their products stem from environmentally and socially responsible activities. Despite such fruitful efforts, organizations' environmental damage persists. Several examples exist in this regard, such as ocean plastic pollution (Stafford and Jones, 2019), the Amazon deforestation (Assunção and Rocha, 2019) and the intense animal suffering and mistreatment involved in many animal products, both mainstream products such as poultry and pork from intensive industrialized systems (Harrison, 1964), and less paradigmatic ones, such as the production of *ejiao*, a popular Chinese medicine, which demands immense amounts of donkey hides (Matlhola and Chen, 2020). Environmental and animal welfare misconduct have been a source of concern among many consumers who have increasingly avoided or substituted products that may relate to sustainability issues (Vermeir

* Corresponding author.

E-mail addresses: glufkereis@ufpr.br, germanoglufkereis@yahoo.com.br (G.G. Reis).

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

Received: 12 October 2020; Accepted: 6 November 2020; Published: 12 November 2020



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, Cargill) have already invested in the technology, several startups have been created worldwide, and investments are increasing [9]. Major meat-processing multinationals from developed countries



Uncoupling Meat From Animal Slaughter and Its Impacts on Human-Animal Relationships

Marina Sucha Heidemann^{1*}, Carla Forte Maiolino Molento¹, Germano Glufk Reis² and Clive Julian Christie Phillips³

¹Animal Welfare Laboratory, Federal University of Parana, Curitiba, Brazil, ²School of Business Administration, Federal University of Parana, Curitiba, Brazil, ³Centre for Animal Welfare and Ethics, Faculty of Science, The University of Queensland – Gatton Campus, Gatton, QLD, Australia

OPEN ACCESS

Edited by:

Cédric Sueur,
UMR7178 Institut pluridisciplinaire
Hubert Curien (IPHC), France

Reviewed by:

Giovanna Bertella,
UiT The Arctic University of Norway,
Norway
Goh Yong Meng,
Putra Malaysia University, Malaysia

*Correspondence:

Marina Sucha Heidemann
msuchah@gmail.com

Specialty section:

This article was submitted to
Theoretical and Philosophical
Psychology,
a section of the journal
Frontiers in Psychology

Received: 17 February 2020

Accepted: 02 July 2020

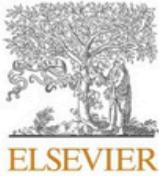
Published: 04 August 2020

Citation:

Heidemann MS, Molento CFM,
Reis GG and Phillips CJC (2020)
Uncoupling Meat From Animal
Slaughter and Its Impacts on
Human-Animal Relationships.
Front. Psychol. 11:1824.
doi: 10.3389/fpsyg.2020.01824

Slaughter sets the debate about what is acceptable to do to animals at an extremely low bar. Recently, there has been considerable investment in developing cell-based meat, an alternative meat production process that does not require the raising and slaughtering of animals, instead using muscle cells cultivated in a bioreactor. We discuss the animal ethics impacts of cell-based and plant-based meat on human-animal interactions from animal welfare and rights perspectives, focusing on industrial meat production scenarios. Our hypothesis is that the insertion of cell-based meat in the global meat market may alleviate farm animal suffering and potentially restore resources for wild fauna. We employed a conservative estimation of the cell-based meat contribution to the global meat market in the year 2040 to analyze the consequences for human-animal relationships for both wild animals and farmed domesticated animals. We discuss possible effects of an animal cell domestication process, previously described as the second domestication, on human-animal relationships. We consider its potential to reduce the impact of human demographic changes and land use on animal life, in particular whether there would be increased biomass availability and free land for wild animals. We anticipate a major reduction in animal suffering due to the decrease in the number of individual animals involved in food production, which justifies the adoption of cell-based meat from a utilitarian perspective. For the conventional animal food production that remains, further consideration is needed to understand which systems, either high or low welfare, will be retained and the impact of the innovation on the average farm animal welfare. Additionally, it seems likely that there will be less acceptance of the necessity of animal suffering in farming systems when meat production is uncoupled from animal raising and slaughter, supported by a deontological perspective of animal ethics. Consequent to this is anticipated the mitigation of relevant barriers to animal protection and to the recognition of animals as subjects by legislation. Thus, the development of the alternative meats may be related to a significant change in our relationship with non-human animals, with greater benefits than the *prima facie* effects on farm animals.

Keywords: animal protection, animal suffering, cell-based meat, second domestication, human-animal relationship



Livestock value chain in transition: Cultivated (cell-based) meat and the need for breakthrough capabilities

Germano Glufke Reis^{a,*}, Marina Sucha Heidemann^b, Felipe Mendes Borini^c, Carla Forte Maiolino Molento^b

^a Management School, UFPR Federal University of Parana, Av. Lothário Meissner, 632, Jd. Botânico, Curitiba, PR, 80210-170, Brazil

^b Animal Welfare Laboratory, UFPR Federal University of Parana, Rua dos Funcionários, 1540, Juvevê, Curitiba, PR, 80210-170, Brazil

^c School of Economics, Business and Accounting of the University of São Paulo (FEA USP), Avenida Professor Luciano Gualberto, 908, Butantã, São Paulo, SP, 05508-010, Brazil

ARTICLE INFO

Keywords:

Clean meat
Slaughter-free meat
Global value chain
Environment
Animal welfare

ABSTRACT

Alternative protein sources such as cell-based meat are potentially associated with improvements in important issues related to intensive industrial livestock production: animal welfare, environmental impact, food safety and the low efficiency of conventional meat production. However, little is known about the potential implications of the new cultivated meat technology for emerging countries. Thus, drawing on the Global Value Chain literature and on the blossoming literature on cell-based meat, we have first discussed how this new chain may be structured. Then, based on the analysis of a set of companies that operate in the fast-developing cultivated meat industry, core enabling capabilities that are required in order to enter the new meat value chain were identified; they encompass technological, business structuring, market positioning and relationship with stakeholder capabilities. It is likely that all listed capabilities are relevant for any country to access the livestock chain in transition. We propose reflections that may contribute to decisions which, in turn, may define aspects of the cultivated meat chain, for the sake of relieving animal suffering and taking care of our home planet, while providing all humans with quality food that meet their nutritional requirements and consumption desires.

1. Introduction

Livestock production in emerging economies represents relevant resources not only for local consumption but also for economic income, job generation and technological upgrading. According to the World Economic Forum [1], over half a billion people are involved in animal production in those countries. Brazil, for instance, is one of the major meat producers in the world and is highly engaged with the meat Global Value Chain (GVC). However, we are witnessing the birth of alternative forms of protein sources, as for example the cell-based meat, which is meat cultured from animal cells, through specific processes and equipment [2,3]. This cultured meat, therefore, does not depend on on-farm animal production and may potentially lead to significant transformations in the conventional meat chain. Major meat processing multinationals from developed countries, such as Tyson Foods, are investing in the technology [4] and startups are appearing worldwide. As investments increase in a fast pace, cell-based meat products are expected to gradually reach the markets within the next few years [3].

Moreover, cell-based meat products are forecasted to be niche and relatively expensive items at first; however, they are likely to become more affordable over time [3,5]. In response to this accelerated trend, the United States Food and Drug Administration (FDA) and the United States Department of Agriculture (USDA) engaged in conversations regarding cell-based meat labeling and regulation, essentially to align on a joint regulatory framework between the two agencies [6,7]. The fact that such institutional alignment was necessary may epitomize the relevance of this new industry.

In spite of the relevance of the subject, little is known about the potential implications of the cell-based technology for emerging countries, especially for those who are important players in the meat industry, as is the case of Brazil. Thus, drawing on the GVC framework [8, 9] and based on the emerging literature on cultivated meat, we have first analyzed how the cultivated meat chain may be structured. Following, we identified a set of core enabling capabilities that are needed for emerging countries to have access to the cultivated meat value chain. Capabilities are defined here as "(...) the ability of an organization to

* Corresponding author.

E-mail addresses: glufkereis@ufpr.br (G.G. Reis), msuchah@gmail.com (M.S. Heidemann), fborini@usp.br (F.M. Borini), carlamolento@ufpr.br (C.F.M. Molento).

RESEARCH ARTICLE

First glimpse on attitudes of highly educated consumers towards cell-based meat and related issues in Brazil

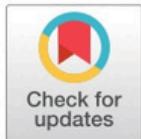
Júlia de Paula Soares Valente[☉], Rodrigo Alonso Fiedler[‡], Marina Sucha Heidemann[‡], Carla Forte Maiolino Molento^{☉*}

Animal Welfare Laboratory, Federal University of Paraná, Curitiba, Paraná, Brazil

☉ These authors contributed equally to this work.

‡ These authors also contributed equally to this work.

* carlamolento@ufpr.br



OPEN ACCESS

Citation: Valente JdPS, Fiedler RA, Sucha Heidemann M, Molento CFM (2019) First glimpse on attitudes of highly educated consumers towards cell-based meat and related issues in Brazil. PLoS ONE 14(8): e0221129. <https://doi.org/10.1371/journal.pone.0221129>

Editor: Zhifeng Gao, University of Florida, UNITED STATES

Received: April 30, 2019

Accepted: July 30, 2019

Published: August 30, 2019

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Data Availability Statement: All relevant data are within the paper and its Supporting Information files.

Funding: Grant number 025/2014, CAPES (Coordination for the Improvement of Higher Education Personnel), awarded to C.F.M.M. The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Competing interests: The authors have declared that no competing interests exist.

Abstract

Our aim was to study Brazilian consumer attitudes towards cell-based meat and related issues. From 408 respondents from Curitiba and 218 from Joinville, the majority was women with higher level of education; 65.2% and 70.2% frequently consumed meat and 50.7% and 50.9% would not stop eating meat; 81.6% and 82.6% had little or no knowledge about cell-based meat. After watching an explanatory video, 41.9% and 34.4% stated they would eat cell-based meat without restrictions; 24.5% and 23.9% stated they would try depending on conditionals. Overall, 63.6% declared they would eat cell-based meat; among vegetarians and vegans, 24% and 8% stated they would eat cell-based meat, with additional 25.0% and 27.0% stating “it depends”; thus, the major public for cell-based meat seems to be meat eaters. Animal welfare was the principal reason for considering not eating meat and a major benefit of cell-based meat. In conclusion, the majority of respondents would not stop eating meat; additionally, they would eat cell-based meat.

Introduction

In comparison to the last decades, global population growth up to 2050 is expected to be slower. Despite this fact, the Food and Agriculture Organization of the United Nations published a report showing that meat consumption tends to double midway through the century [1]. Higher consumption necessarily implies increases in meat production, with associated increases in environmental and animal ethics issues. Therefore, new substitutes for traditional animal protein are being researched [2]. Among the options is cellular agriculture, a new technology in food production that in the future may supply large amounts of high-quality protein [3]. Cell-based meat, also known by the names of clean, cultivated, synthetic, artificial, *in vitro*, lab-grown, cell-based and slaughter-free meat, is a novel and disruptive technology. The very name to this new meat is still undecided and a major issue, since it is known that the name influences how positive behavioral intentions towards the product will be [4].



Emerging Market Multinationals and International Corporate Social Responsibility Standards: Bringing Animals to the Fore

Germano Glufke Reis¹ · Carla Forte Maiolino Molento²

Received: 29 July 2018 / Accepted: 7 March 2019 / Published online: 14 March 2019
© Springer Nature B.V. 2019

Abstract

The literature presents a broad approach to Corporate Social Responsibility (CSR), which aggregates a diversity of issues, such as the environment, labor conditions, and human rights. We addressed the impact of increasing CSR demands during the internationalization of emerging market multinationals (EMNs) on one particular subject, animal welfare (AW). This subject raises important ethical concerns, especially as we understand that animals are sentient beings. Through content analysis of annual reports, we tracked the evolution of AW-CSR activities throughout the internationalization of two large Brazilian meat-processing multinationals as they accessed markets with complex AW regulations. We also synthesized findings on broiler chicken on-farm AW research in Brazil and conducted interviews to gauge the impact of CSR standards on animals. Our findings show that, although EMNs that enter developed markets engage with various standards, the impacts of standard enforcement on actual welfare are not straightforward and call for broader AW and animal ethics developments. Uneven results among AW criteria indicate that some aspects are prioritized over others. Furthermore, some actions of actors such as EMNs and low-tier suppliers seem to counterbalance the expected impact of normative pressures to change the lives of animals for the better. We conclude that AW standards may improve AW in emerging markets; but these standards do not appear to be sufficiently stringent, and require improvements to have a more significant positive impact. A major signal emerging from this research is the fundamental need to broaden the animal ethics debate regarding the use of animals to produce meat.

Keywords Animal ethics · Animal welfare · Corporate social responsibility · Emerging market multinationals

Corporate Social Responsibility (CSR) in emerging market multinationals (EMNs) is receiving increasing attention due to their unique features and internationalization patterns (Thite et al. 2014), and the relevance of the social and environmental impacts of their operations at home and abroad (Doh et al. 2015). As they expand outside their home countries, these firms must comply with internationally required safety, quality, and CSR standards. Oftentimes, EMNs CSR

investments are also motivated by the need to strengthen their corporate image, especially when they internationalize to more developed markets (Zyglidopoulos et al. 2016), such as the US and the European Union (EU). These companies face a liability of origin (Marano et al. 2017; Fiaschi et al. 2017) due to institutional voids in their countries of origin (e.g., corruption and poor infrastructure), which may weaken trust in their organizational capabilities by stakeholders in developed countries. Hence, when they enter these markets, investments in CSR systematically improve (Zyglidopoulos et al. 2016) concomitantly with increased reporting of CSR initiatives to stakeholders (Marano et al. 2017).

Notwithstanding the advances in the discussion on CSR in EMNs, we argue that relevant gaps remain that deserve further investigation. First, most research so far has adopted a broad umbrella approach to CSR (Blowfield and Frynas 2005), which includes a broad range of social and environmental efforts (c.f. Marano et al. 2017). However, CSR may encompass issues as diverse as environmental protection,

✉ Germano Glufke Reis
glufkereis@ufpr.br

Carla Forte Maiolino Molento
carlamolento@ufpr.br

¹ Management School, UFPR Federal University of Parana, Av. Lothário Meissner, 632, Jd Botânico, Curitiba, PR, Brazil

² Animal Welfare Laboratory, UFPR Federal University of Parana, Rua dos Funcionários, 1540 Juvevê, Curitiba, PR, Brazil

O NAPI Proteínas Alternativas é financiado pelo Governo do Estado do Paraná, por meio de sua agência de fomento à pesquisa, a Fundação Araucária

The NAPI Alternative Proteins is funded by the Government of the State of Paraná, through its research funding agency, the Araucária Foundation

