Cellular agriculture education in Brazilian undergraduate programs: not as far as it seems

Educação em agricultura celular nos cursos de graduação no Brasil: não tão distante quanto parece

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Abstract

Cellular agriculture has the potential to transform global food production through alternative proteins, necessitating a skilled workforce. This study aimed to analyze the curricula of Brazilian graduate programs related to food production to identify those addressing cellular agriculture topics. We reviewed nineteen undergraduate curricula from Veterinary Medicine, Animal Science, Bioprocess and Biotechnology Engineering, and Food Engineering across twelve institutions. These were compared with the curriculum of the *Introduction to Cellular Animal Science* course at Universidade Federal do Paraná and the undergraduate minor in Cellular Agriculture at Tufts University, as well as knowledge required for cultivated meat production. Our comparative analysis found that courses such as Microbiology and Biochemistry exhibited 100% similarity, while Statistics and Economics (94.7%) and Cellular Biology and Genetics (68.4%) also showed consistent content. In contrast, courses in Sustainability (94.7%), Administration and Entrepreneurship (89.5%), and others revealed significant variability. The study concludes that existing programs provide foundational knowledge for professionals entering this emerging field, but further specialization is necessary. Additionally, our findings could inform the development of new curricula specifically designed to prepare professionals for careers in cellular agriculture.

Keywords: Cellular animal science. Courses. Curriculum. Professionals.

Resumo

A agricultura celular tem o potencial de transformar a produção global de alimentos por meio de proteínas alternativas, exigindo uma força de trabalho qualificada. Este estudo teve como objetivo analisar as ementas dos cursos de graduação brasileiros relacionados à produção de alimentos para identificar aqueles que abordam temas de agricultura celular. Dezenove currículos de graduação de Medicina Veterinária, Zootecnia, Engenharia

de Bioprocessos e Biotecnologia, e Engenharia de Alimentos em doze instituições foram analisados. Estes foram comparados com a ementa da disciplina Introdução à Ciência Animal Celular *da Universidade Federal do Paraná e com o curso de graduação* em Cellular Agriculture *da Universidade Tufts, bem como com o conhecimento necessário para a produção de carne cultivada. Através de análise comparativa, verificou-se que disciplinas como Microbiologia e Bioquímica apresentaram 100% de similaridade, enquanto Estatística e Economia (94,7%) e Biologia Celular e Genética (68,4%) também mostraram conteúdo consistente. Em contraste, disciplinas de Sustentabilidade (94,7%), Administração e Empreendedorismo (89,5%) e outras revelaram variabilidade significativa. Conclui-se que os programas existentes oferecem conhecimento fundamental para profissionais que ingressam neste campo emergente, mas é necessária maior especialização. Além disso, os achados deste estudo podem auxiliar no desenvolvimento de novos currículos especificamente projetados para preparar profissionais para carreiras na agricultura celular.*

Palavras-chave: *Currículo. Disciplinas. Profissionais. Zootecnia celular.*

Introduction

Conventional animal-origin food production systems face several challenges, including environmental impacts, animal welfare and public health concerns, food insecurity, and sustainability issues (Post et al., 2020). In this context, new technologies and systemic innovation are crucial for transforming the global food system (Herrero et al., 2020). The increasing demand for protein combined with growing scrutiny of the environmental, ethical, and human health impacts of the animal products industry reinforces the urgent need for more sustainable and ethical protein production methods (Scollan et al., 2010).

Cellular agriculture emerges as a multidisciplinary field that offers new ways to produce animal-derived foods without the need to raise and slaughter animals. Among its applications, cultivated meat represents one possible approach, with the potential for reduced environmental impacts (Tuomisto and Ellis, 2014) and improvements in animal welfare (Heidemann et al., 2020). Additionally, it may reduce zoonotic and food-borne disease risks and relieve pressure on natural resources, contributing to environmental protection and public health benefits (Bhat et al., 2015).

As investments increase, cultivated meat products are expected to gradually reach the market in the coming years (Godfray, 2019). Since they do not rely on conventional animal farming, significant changes in the conventional meat chain are likely (Reis et al., 2020). This creates opportunities for professionals in the conventional meat chain, such as veterinarians and animal scientists, as well as in the food industry, including food, bioprocess, and biotechnology engineers, with expertise in genetics, nutrition, human health, cell development, management, and meat processing, packaging, and inspection (Heidemann et al., 2020; Biscarra-Bellio et al., 2025).

In addition to this knowledge, professionals who play key roles in reducing resistance from farmers and other stakeholders to the adoption of alternative meats, supporting the transition, preventing animal disease and suffering, and managing skills such as supply chain management will be crucial (Morais-da-Silva et al., 2022a). Identifying these necessary competencies makes it possible to determine which courses already offer relevant subjects and to suggest adaptations to existing programs.

In Brazilian higher education, curricular guidelines ensure quality standards. Veterinary Medicine programs train professionals in agricultural and health sciences, animal and food production, and public health. In Animal Science, the focus is on scientific and technological knowledge, ethical awareness, and management of animal production systems (MEC, 2024). Engineering programs also follow specific regulations. Bioprocess and Biotechnology Engineering prepare graduates to work with biological systems in health, agriculture, food, energy, and the environment, according the CONFEA resolution 1108. Food Engineering, regulated by resolution 2 of April 24, 2019, equips professionals to research, develop, and apply new technologies with innovative and entrepreneurial skills (CONFEA, 2018).

The relevance of the scope of the four undergraduate programs related to new forms of animal-origin products or similar foods indicates a positive scenario, considering the growing interest in expanding the training of scientists and engineers in the field of alternative proteins (Porto and Berti, 2022).

If more programs and courses are offered in this area, and provided they meet quality standards in terms of content, faculty, and infrastructure, it is likely that more graduates will acquire relevant qualfications (OECD, 2019).

It will also lead to the establishment of new businesses and institutes, facilitating market competition and scientific collaboration with a greater likelihood of generating products and ideas for the advancement of new industries (Porto and Berti, 2022). Meanwhile, the greater the engagement of professionals from different fields, the lower the resistance to new food systems among those involved in the food production chain. The study by Bogueva et al. (2023) shows that many producers are willing to diversify their activities to meet the alternative protein market, provided that public policies, knowledge transfer, and a stable demand for these products are ensured. This alignment between cellular agriculture and conventional animal-based production helps reduce both neophobia and fear of job loss (Morais-da-Silva et al., 2022b).

Currently, several universities offer courses in cellular agriculture, reflecting the growing global interest in this field. For instance, Tufts University in Massachusetts, USA, provides an undergraduate minor in Cellular Agriculture for students in Engineering and Arts & Sciences, as well as a graduate certificate in Cellular Agriculture for graduate students in Biomedical Engineering, Nutrition, and Veterinary Medicine. Similarly, the University of North Carolina offers *The Cellular Agriculture Revolution* in the Department of Biology, which is open to both undergraduate and graduate students. In Asia, Nanyang Technological University in Singapore provides an alternative proteins course for undergraduate students in Food Science and Technology. Meanwhile, in Europe, Wageningen University & Research in the Netherlands offers a cellular agriculture course for master's students in the Department of Bioprocess Engineering. In Brazil, some universities are also contributing to education in this emerging field. The State University of Campinas (Unicamp) offers a postgraduate course through the Faculty of Food Engineering, titled *Alternative Proteins: Made from Plants, Fermentation, and Cultivated Meat*. Likewise, the Federal University of Minas Gerais (UFMG) provides a theoretical and practical course, *Cellular Agriculture in the Context of Alternative Proteins*, for undergraduate and graduate students at the Institute of Biological Sciences. Furthermore, since July 2020, the Federal University of Paraná (UFPR) has offered the course *Introduction to Cellular Animal Science*, available to both undergraduate students in Veterinary Medicine and Animal Science, and graduate students in Veterinary Sciences.

As teaching initiatives advance, there is a growing need to discuss education in cellular agriculture in line with the National Curricular Guidelines of the Ministry of Education in Brazil. In response to the increasing demand from professionals and students from different regions of the country for courses in this area, the present study focuses on analyzing the curricula and courses of selected Brazilian undergraduate programs related to food production, aiming to identify those that already include topics in cellular agriculture and that can serve as a reference for the development or incorporation of cellular agriculture courses and modules in other educational institutions.

Material and methods

The programs in veterinary medicine, animal science, and bioprocess and biotechnology engineering were selected for this study because they are actively engaged in research on alternative proteins at UFPR, where the study was conducted. The *Introduction to Cellular Animal Science* course was specifically chosen due to the strong interest it generated during its initial online offerings, attracting students and professionals from across the country. This demonstrated demand helped justify focusing on these programs and courses as a representative starting point for analyzing cellular agriculture education in Brazil. Additionally, the food engineering program was included due to its critical role in food production and its significant contribution to the advancement of cellular agriculture. While this study focuses on these four programs, it is important to note that this selection is not exhaustive, and other programs may also play a key role in the development of alternative proteins.

This study was carried out between September 2021 and February 2022. For data gathering and the analysis of the curricula and courses, we first accessed the website of the Brazilian Ministry of Education where a list of all higher education institutions in the country was available.

The following three inclusion criteria were used: (1) programs offered by federal universities that make (2) their curricula and courses available on the institution's websites, with (3) one institution per geographical region of the country.

After the selection of universities, a survey and listing of all the mandatory courses that make up the curriculum of each of the 19 analyzed courses were conducted. In total, 1,065 mandatory courses were listed, all defined based on the official curricula, including 299 courses in the Veterinary Medicine programs, 284 in Animal Sciences, 210 in Bioprocess and Biotechnology Engineering, and 272 in Food Engineering. The courses were separated by undergraduate program and grouped into categories according to their similarity. For example, all disciplines involving anatomy were grouped into one category, those involving physiology into another, and so forth. Next, in the initial general analysis, curricula and courses were selected based on their relevance, determined by their similarity to the *Introduction to Cellular Animal Science* course at UFPR and to the courses offered in the Tufts University program for teaching cellular agriculture.

A thorough reading of each course curriculum was carried out to identify courses that presented relevant content. Such courses were divided into two groups: the first group was composed of courses that presented curricula with similar contents among different institutions and programs, here called consolidated courses. The second group was composed of courses that presented different curricula according to the specificity of each course, here called non-consolidated. Curricula with the same name but belonging to different institutions and different undergraduate programs were compared to verify the degree of consolidation. The degree of consolidation was measured using the Collective Subject Discourse method (Duarte et al., 2009) and the frequency of the courses in the programs studied, indicating how consistent the content was across programs and institutions, and should not be interpreted as a measure of the quality of the courses.

In total, 220 courses from 19 undergraduate programs were analyzed, considering the stages of the cultivated meat production chain (Figure 1), as well as the curricula of the undergraduate minor in Cellular Agriculture at Tufts University, USA, and of the *Introduction to Cellular Animal Science* course at UFPR, Brazil (Table 1).

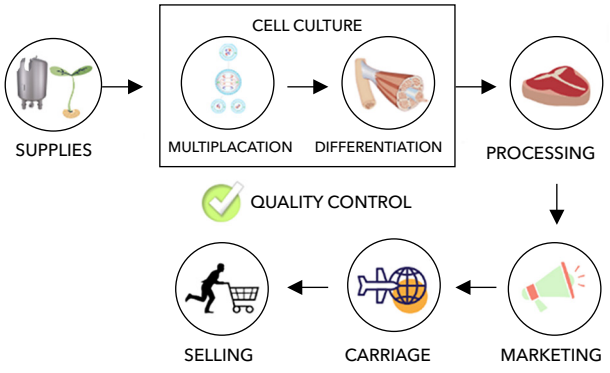

Figure 1 - Likely stages of the cultivated meat chain, adapted from Tuomisto and Ellis, 2014, Santo et al., 2020, and Morais-da-Silva et al., 2022b.

Table 1 - Curricula of the undergraduate minor in Cellular Agriculture at Tufts University, USA, and and of the *Introduction to Cellular Animal Science* course at Federal University of Paraná (UFPR), Brazil

University - Course	Stage of production chain	Curricula
Tufts University – Undergraduate minor in Cellular Agriculture	Conceptual	Food, Nutrition, and Culture
		Food Systems: From Farm to Table
	Market	Practicing in Food Systems
		Food Consumer
		Politics, Policies and Risks in Science and Technology
		Entrepreneurship & Strategy
		Technical & Managerial Communication
		Creativity, Innovation and Entrepreneurial Thinking
		Entrepreneurial Leadership, Societal Aspects of Design
		Bringing Products to Market
		Nutrition and Entrepreneurship

Table 1 - Curricula of the undergraduate minor in Cellular Agriculture at Tufts University, USA, and and of the *Introduction to Cellular Animal Science* course at Federal University of Paraná (UFPR), Brazil (continued)

University - Course	Stage of production chain	Curricula
Tufts University – Undergraduate minor in Cellular Agriculture	Sustainability	Ecology, Technology & Sustainability
		Sustainability in Action
		Sustainability on the Farm
	Health	American Meat
		Nutrition-related Consumption
	Technology	Reactor Design
		Synthetic Biology
		Cell & Microbe Cultivation
		Mechanics of Materials at the Micro & Nano Scale
	Conceptual	Secondary Domestication
		Disruptive Innovations
		Issues in Conventional Meat Production
		New Food System
	Ethics	Animal Welfare
		Social Impacts of Alternative Proteins
	Market	Value Chain of Conventional and Cultivated Meat
		Consumer Market for Alternative Proteins
		Transition for Producers
		Investments and Startups in Brazil and Worldwide
		Cellular Agriculture Associations in Brazil and globally
UFPR – Introduction to Cellular Animal Science	Sustainability	Alternative Proteins and SDGs
	Health	One Health and One Welfare
		Food Safety
	Technology	Industrial Development
		Biotechnology Fundamentals for Alternative Proteins
		Technology of Products of Animal Origin and Inspection
	Education	Education and Research in Cellular Animal Sciences

Results

No federal university offering the Bioprocess and Biotechnology Engineering program was found in the Brazilian Midwest region. Thus, five institutions for each undergraduate program were selected, except for the Bioprocess and Biotechnology Engineering program, for which only four institutions were chosen. Finally, the sample was composed of 19 programs (Table 2). The curricula and courses identified in the 19 programs analyzed that have content related to cellular agriculture are listed in Table 3.

From the analysis of curricula, courses that presented relevant content for the teaching of cellular agriculture were identified across all the programs examined in this study, such as Microbiology and Biochemistry (present in 100% of the programs), Statistics (94.7%), Economics (94.7%), Cellular Biology (68.4%), and Genetics (68.4%). These courses were considered consolidated, and the list of institutions and programs that offered these courses is described in Tables 4 and 5.

Among the six consolidated courses, four are present in at least one of the institutions of each of the four programs analyzed: Biochemistry, Statistics, Economics, and Microbiology. The courses on Cellular Biology and Genetics, which were present in the curriculum of at least one of the programs in Veterinary Medicine, Animal Science, and Bioprocess and Biotechnology Engineering, were not present in any of the studied food engineering programs.

Table 2 - Undergraduate programs and federal universities per regions of Brazil selected for the study conducted from September 2021 to February 2022

Region of Brazil	Undergraduate programs			
	Veterinary Medicine	Animal Science	Bioprocess	Food Engineering
North	UFAC (Acre)	UFAM (Amazonas)	UFT (Tocantins)	UFAM (Amazonas)
Northeast	UFBA (Bahia)	UFBA (Bahia)	UFCG (Campina Grande)	UFC (Ceará)
Midwest	UFG (Goiás)	UFG (Goiás)	-	UFG (Goiás)
Southeast	UFMG (Minas Gerais)	UFMG (Minas Gerais)	UFRJ (Rio de Janeiro)	UFU (Uberlândia)
South	UFPR (Paraná)	UFPR (Paraná)	UFPR (Paraná)	UFFS (Fronteira Sul)

Note: *Bioprocess and Biotechnology Engineering.

Table 3 - Consolidated, non-consolidated and relevant curricula and courses identified as related to cellular agriculture in the 19 undergraduate programs in the study conducted from September 2021 to February 2022

Courses	Curricula
Consolidated	
Biochemistry	Study of biochemical principles, including cellular function, metabolism, and molecular biology
Cellular biology	Core concepts of cell biology, including structure, function, and interactions
Economics	Core principles of economics, covering market behavior, policies, and resource allocation
Statistics	Statistical methods and techniques used for data analysis
Genetics	Fundamentals of inheritance, genetic variation, and genetics in health and disease
Microbiology	Study of microorganisms, their ecological roles, and applications in health, industry, and the environment; includes lab identification and manipulation
Non-consolidated	
Administration and Entrepreneurship	Foundational knowledge and skills for developing, managing, and growing ventures, including strategic management and practical business insights
Biosafety	Foundational knowledge and practical skills to ensure safety in labs handling biological materials, covering principles, regulations, and practices to minimize biological hazards
Ethics and Deontology	Ethical principles and frameworks guiding professional conduct and moral-legal obligations
Inspection of Animal Products	Methods and regulations to ensure health, safety, and quality across production, processing, and distribution
Public Health	Principles and practices of public health, focusing on promoting community health, implementing interventions, and addressing health disparities
Sustainability	Sustainability principles and practices, focusing on environmental, social, and economic integration, assessing challenges, and applying sustainable solutions
Technology of Animal Products	Technology and methods for producing, processing, and ensuring the quality and safety of animal-derived products
Relevant	
Bioreactors	Design, operation, and applications of bioreactors for producing biological products, including pharmaceuticals, chemicals, and biofuels
Animal Cell Culture	Techniques and applications of animal cell culture, including preparation, maintenance, and manipulation for research, biotechnology, and medical purpose
Fundamentals of Bioprocess and Biotechnology Engineering	Core principles of bioprocessing and biotechnology, including design, optimization, and management of biotechnological systems and industrial applications
Introduction to Animal Science	Fundamentals of animal science, covering biology, management, welfare, genetics, nutrition, health, and behavior of domesticated animals
Fermentation Processes	Fermentation principles, system design and optimization, and applications in food, pharmaceuticals, and biofuels

The non-consolidated courses, belonging to the second group, include Sustainability related subjects (present in 94.7% of the programs), Administration and Entrepreneurship (89.4%), Technology of Animal Products (89.4%), Ethics and Deontology (57.8%), Inspection of Animal Products (26.3%), Biosafety (21.0%), and public health (21.0%). The list of institutions and programs that offer these courses is described in Tables 4 and 5.

Among the six non-consolidated courses, four were present in at least one institution in each of the four analyzed programs: Sustainability, Administration and Entrepreneurship, Food Technology, and Ethics and Deontology. In the studied undergraduate programs of Food Engineering, no specific courses on ethics were found; however, some content on ethics was present within other courses, demonstrating that the content was offered to students.

In addition, some courses related to the alternative protein industry and market were found in only a few programs. These courses are particularly relevant, as they provide essential knowledge of the main technologies applied in the sector, serving as a foundation for all professionals seeking to develop the skills to work in this emerging field (Figure 2). The list of programs that offer such courses is indicated in Tables 4 and 5.

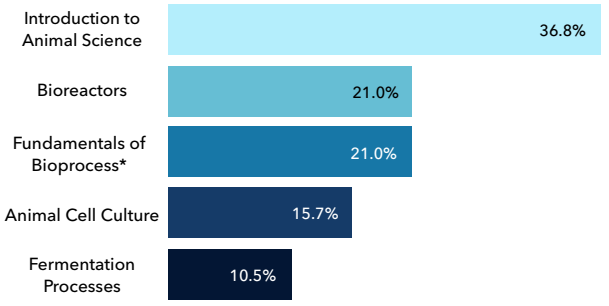

Figure 2 - Prevalence of key courses for training students in the alternative proteins industry across undergraduate programs among the studied universities.

Note: *Fundamentals of Bioprocess and Biotechnology Engineering.

Table 4 - Courses offered (O) or not offered (N) in the programs of Veterinary Medicine and Animal Science in the studied institutes, based on the survey conducted from September 2021 to February 2022, divided into consolidated, non-consolidated, and relevant mandatory courses

Courses	Veterinary Medicine					Animal Science				
	UFAC	UFBA	UFG	UFMG	UFPR	UFAM	UFBA	UFG	UFMG	UFPR
Consolidated mandatory courses										
1.	O	O	O	O	O	O	O	O	O	O
2.	O	O	O	O	O	O	O	O	O	O
3.	O	O	O	N	O	O	O	O	O	O
4.	O	O	O	O	O	O	O	O	O	O
5.	O	O	O	O	O	O	O	O	O	O
6.	O	O	O	O	O	O	O	O	O	O
Non-consolidated mandatory courses										
1.	O	O	O	O	O	O	O	O	O	O
2.	N	N	N	N	N	N	N	O	N	N
3.	O	O	O	O	O	O	O	O	N	N
4.	O	O	O	O	O	O	O	O	N	N
5.	O	O	O	N	O	N	N	N	N	N
6.	O	O	O	O	O	O	O	O	O	O
7.	O	O	O	O	O	O	O	O	O	O

Note: Consolidated mandatory courses: 1. Biochemistry; 2. Cellular Biology; 3. Economics; 4. Statistics; 5. Genetics; 6. Microbiology. Non-consolidated mandatory courses: 1. Administration and Entrepreneurship; 2. Biosafety; 3. Ethics and Deontolog; 4. Inspection of Products of Animal Origin; 5. Public Health; 6. Sustainability; 7. Technology of Products of Animal Origin. Federal universites of Acre (UFAC), Bahia (UFBA), Goiás (UFG), Minas Gerais (UFMG), Paraná (UFPR), and Amazonas (UFAM).

Table 4 - Courses offered (O) or not offered (N) in the programs of Veterinary Medicine and Animal Science in the studied institutes, based on the survey conducted from September 2021 to February 2022, divided into consolidated, non-consolidated, and relevant mandatory courses (continued)

Courses	Veterinary Medicine					Animal Science				
	UFAC	UFBA	UFG	UFMG	UFPR	UFAM	UFBA	UFG	UFMG	UFPR
	Relevant mandatory courses									
1.	N	N	N	N	N	N	N	N	N	N
2.	N	N	N	N	N	N	N	N	N	N
3.	N	N	N	N	N	N	N	N	N	N
4.	O	N	O	N	O	O	O	O	N	O
5.	N	N	N	N	N	N	N	N	N	N

Note: Relevant mandatory courses: 1. Bioreactors; 2. Animal Cell Culture; 3. Fundamentals of Bioprocess; 4. Engineering and Biotechnology; 5. Introduction to Animal Science. Federal universites of Acre (UFAC), Bahia (UFBA), Goiás (UFG), Minas Gerais (UFMG), Paraná (UFPR), and Amazonas (UFAM).

Table 5 - Courses offered (O) or not offered (N) in the programs of Bioprocess Engineering and Food Engineering in the studied institutes, based on the survey conducted from September 2021 to February 2022, divided into consolidated, non-consolidated, and relevant mandatory courses

Courses	Bioprocess Engineering				Food Engineering				
	UFT	UFCG	UFRJ	UFPR	UFAM	UFC	UFG	UFU	UFFS
	Consolidated mandatory courses								
1.	O	O	O	O	O	O	O	O	O
2.	O	O	O	N	N	N	N	N	N
3.	O	O	N	O	O	O	O	O	O
4.	N	O	O	O	O	O	O	O	O
5.	O	O	N	O	N	N	N	N	N
6.	O	O	O	O	O	O	O	O	O
	Non-consolidated mandatory courses								
1.	O	O	O	O	O	O	O	N	N
2.	O	O	N	O	N	N	N	N	N
3.	O	O	N	O	N	N	N	N	N
4.	N	N	N	N	N	N	N	N	N
5.	N	N	N	N	N	N	N	N	N
6.	O	O	O	O	O	O	O	N	O
7.	O	N	O	O	O	O	O	O	O
	Relevant mandatory courses								
1.	O	O	O	O	N	N	N	N	N
2.	O	O	N	N	N	N	N	N	N
3.	O	O	N	O	N	N	O	N	N
4.	N	N	N	N	N	N	N	N	N
5.	O	N	N	O	N	N	N	N	O

Note: Consolidated mandatory courses: 1. Biochemistry; 2. Cellular Biology; 3. Economics; 4. Statistics; 5. Genetics; 6. Microbiology. Non-consolidated mandatory courses: 1. Administration and Entrepreneurship; 2. Biosafety; 3. Ethics and Deontolog; 4. Inspection of Products of Animal Origin; 5. Public Health; 6. Sustainability; 7. Technology of Products of Animal Origin. Relevant mandatory courses: 1. Bioreactors; 2. Animal Cell Culture; 3. Fundamentals of Bioprocess; 4. Engineering and Biotechnology; 5. Introduction to Animal Science. Federal universisties of Tocantins (UFT), Campina Grande (UFCG), Rio de Janeiro (UFRJ), Paraná (UFPR), Amazonas (UFAM), Ceará (UFC), Goiás (UFG), Uberlândia (UFU), and Fronteira Sul (UFFS).

Discussion

The development of cultivated meat production involves a series of biological principles on how muscle cells are organized in the animal body and aim to generate complex molecular structures that mimic meat, including muscle fibers, connective tissue, and fat (Tomiyama et al., 2020). However, replicating such processes on an industrial scale presents some technical challenges (Hocquette, 2016). Therefore, it may be beneficial to consider a curriculum associated with the various stages of the production process, such as sourcing inputs, cell cultivation itself, harvest, product processing in some cases, quality control, and the final stages of transportation and sales.

During the supplies stage, the Genetics, Cellular Biology, and Histology courses present in the studied programs, except for Food Engineering, provide fundamental knowledge for understanding the initial materials used in cultivated meat production. These inputs are cells capable of multiplying and differentiating to develop specialized functions, also known as stem cells (Warner, 2019). The knowledge gained in the Genetics course, which covers topics such as molecular genetics and the biotechnology of gene expression and regulation in eukaryotes, helps to understand the behavior and potential of these cells. In the Cellular Biology course, topics include the morphofunctional information of cells, cellular organization, and the functional aspects of various cellular components, while the Histology course complements this content by providing knowledge about muscle structure and tissue composition, which is essential for students to understand the initial phases.

The *ex vivo* growth of cells requires nutrients in a similar way to the growth of the cells within the animal organism (Riquelme-Guzmán et al., 2024). In the absence of blood circulation for nutrient supply and waste removal, the *ex vivo* cells are bathed in a culture medium, an important input that provides essential nutrients and cell-signaling substances, such as carbohydrates, lipids, amino acids, vitamins, growth factors, and hormones required at different stages (Warner, 2019). The nutrients required for the culture medium are studied in the discipline of Biochemistry, and present in all programs studied, with contents related to amino acids, proteins, carbohydrates, lipids, nucleotides, nucleic acids, biological membranes, vitamins, coenzymes, hormonal control of metabolism, metabolic interrelationships in animal tissues, and biochemical studies of animal cells.

A common ingredient in stem cell culture has been fetal bovine serum, a supplement containing proteins and thousands of metabolites at variable concentrations (Lee et al., 2023). However, animal-derived components, such as fetal bovine serum, pose risks of contamination and raise ethical concerns (Post et al., 2020). Current research aims to replace it with alternatives obtained through fermentation, for example. In this context, the *Fermentative Processes* course, offered in the Bioprocess and Biotechnology Engineering and Food Engineering programs, covers growth variables of organisms, their characteristics, and applications, including culture media. The Microbiology course, present in all programs, complements this content by addressing morphology, cytology, physiology, metabolism, and genetics of microorganisms, as well as the conduct and purification of products through fermentation, industrial applications, and legislation regarding genetic resources.

To produce structured and thick meat products, cells must be transferred to a support, also called a scaffold or structure (Porto and Berti, 2022). The Modeling and Simulation course, offered in the Bioprocess Engineering program, can provide foundational knowledge related to generic fermentation processes, types of microorganisms, fermenters, and fermentation techniques.

The second essential step to produce cultivated meat is cell culture itself. During this stage, the Cell Culture course, present in Bioprocess Engineering programs, allows students to acquire knowledge related to cell culture techniques, preparation of materials and solutions necessary for cell culture, selection of high-density culture media, and obtaining animal cell products. It also involves studying the behavior and growth in different bioreactor models, which are fundamental knowledge for this stage of the process. The proliferation phase aims to produce many cell duplications while keeping the cells in an undifferentiated and proliferative state (Bomkamp et al., 2022). In the differentiation phase, cells are cultivated under conditions that promote their differentiation and maturation. They may be placed on scaffolds to obtain more structured and thicker products, as previously mentioned.

An ideal scaffold allows the attachment, differentiation, and maturation of cells in a specified manner, imitating the 3D cytoarchitecture of conventional meat while enabling continuous perfusion of the culture medium, analogous to tissue vascularization in living organisms (Bomkamp et al., 2022).

The Bioreactors course, present in Bioprocess Engineering programs, covers topics such as basic concepts of bioreactors, scaling up, ingredients, and medium quality. It provides students with the fundamentals for specifying reactors and how to use them, hence both phases of cell culture, multiplication, and differentiation, occur within bioreactors. Bioreactors provide housing and control of the environmental conditions, such as temperature and oxygen levels, that allow cells to grow (Porto and Berti, 2022). In cultivated meat production, certain parameters of the bioreactors need to change according to the phase of the process. Different factors need to be removed and added during the proliferation and differentiation phases (Specht et al., 2018).

Through the research and development activities, and likely for the upstream stages of the cultivated meat chain, it is important for professionals to know the basics of biosafety regulations. Such knowledge forms the basis for the rationales for the establishment of standard operating procedures to be used by the large-scale cultivated meat industry.

During the processing stage, concepts from the Technology of Products of Animal Origin course, present in almost all studied programs, are relevant for training in cellular agriculture. Understanding conventional processes allows these concepts to be applied to cultivated meat products, including indus-trialization and preservation of animal products and by-products, technological aspects of derivatives and meat processing, and regulatory standards. Some cultivated meat products resemble traditionally processed meats, in which the product portion no longer retains the characteristics of fresh meat (FAO, 2005). These products can be produced from the proliferation of myoblasts, followed by expansion and an additional processing phase. For example, minced cultivated meat can be obtained by separately cultivating muscle and adipose tissue on three-dimensional scaffolds and then combining them to form the final product (Ong et al., 2020).

The production and products of conventional meat pose public health challenges at different stages of the production chain. The risks associated with fresh and processed meats include contamination by pathogens (*Salmonella*, *Escherichia coli*, *Campylobacter*, *Listeria*) and antibiotic-resistant microorganisms (Erickson and Doyle, 2012; Haskell et al., 2018), especially related to animal rearing and slaughter. In the case of cultivated meat, potential risks involve chemical safety, biosafety, and nutritional safety, linked to culture medium components, additives, scaffold materials, and the use of antibiotics or hormones (Chriki and Hocquette, 2020; Zhang et al., 2020). Accordingly, courses already present in the curricula of programs such as Veterinary Medicine, such as Public Health, enable students to understand sanitary surveillance activities and prepare them to work in different areas of public health, including those related to alternative proteins, while Inspection of Animal products courses provide knowledge on risks associated with inadequate processes and applicable legislation, which are also essential for cultivated meat products.

Large conventional animal product companies are involved in the cultivated meat sector, such as JBS, which received around US$62 million in investment for the construction of the JBS Biotech Innovation Center, a research facility focused on cultivated meat biotechnology (JBS, 2023), and BRF, the only Brazilian company participating in investment in Aleph Farms, an Israeli startup for cultivated meat production (BRF, 2021). These companies are also likely to be involved in distribution and logistics, with potential consumers including supermarkets, retailers, and fast-food chains, all analogous to the conventional meat supply chain (Reis et al., 2020).

Knowledge related to the discipline of economics, present in almost all studied programs such as Introduction to Economics and Management of Agri-food Businesses, market potential determination, analysis for various economic and financial decision-making, market structure, conduct, and performance, enables students to understand the organization and functioning of the economy and the main market structures present in the process. Considering that cellular agriculture is an emerging field, it would be advisable to include content related to this new sector in the curriculum of the Economics course.

Although there are marketing professionals responsible for product promotion, it is important for students to understand the cultivated meat market.

In this context, understanding market demand becomes an essential area within the production chain. The media plays a crucial role in this process, serving as a source of information for the public and shaping perceptions of food technologies (Bryant, 2020). The Administration and Entrepreneurship course, present in all Veterinary Medicine, Animal Science, and Bioprocess Engineering programs, and in some of the food engineering programs analyzed, significantly contributes to professional training by covering topics such as entrepreneurial culture and activity, globalization and business opportunities, entrepreneurship in Brazil, the entrepreneurial process, and business planning.

Furthermore, how cultivated meat is presented to the public is critical. The Good Food Institute (GFI) conducted a nomenclature study to determine the most appropriate term, indicating that "cultivated meat" was well received by consumers, while terms like "in vitro meat" or "lab-grown meat" may carry negative connotations and harm public perception. The terminology used directly affects the interpretation of existing research on cultivated meat (GFI, 2016), and it is essential that professionals understand these nuances to effectively communicate products and engage with consumers, regulators, and other stakeholders in the sector.

In addition to the courses directly involved in the cultivated meat production process, other disciplines are indirectly involved. Courses related to sustainability and the environment, with content related to the contextualization of environmental changes and their consequences for individual well-being and the relationship among the environment, ecology, animal farming, and processing of animal-derived products are relevant for the formation of a critical and ethical professional. This is important because conventional meat production is one of the main contributors to environmental degradation. Currently, animal farming uses 26.0% of the world's land area for grazing and 29.0% of total agricultural water use while contributing to 14.5% of global greenhouse gas emissions (FAO, 2015). Nevertheless, there is a strong rhetoric of denial (Hannan, 2020). Thus, educating professionals for critical abilities is of paramount importance, regarding any food production system, including conventional and alternative production of animal-derived foods.

Some authors argue that cultivated meat does not eliminate animal farming because some animals need to be raised for their cells to be harvested (Chriki and Hocquette, 2020). Additionally, some components of the culture medium are currently animal-derived, such as chicken embryo extract, fetal bovine serum, or horse serum. To fulfill the purpose of cultivated meat, which is to avoid animal farming and slaughter, all animal components must be abolished from the manufacturing process (Benny et al., 2022). These issues seem more like challenges to be overcome than perennial problems, since there is intense research activity to find alternatives to culture media, and the use of animals as a cell source depends on the small number of animals that can be kept in sanctuaries without the need for slaughter. It is likely that the production of meat dissociated from animal slaughter will positively alter the entire relationship between humans and animals (Heidemann et al., 2020). In this scenario, courses related to Ethics and Deontology, which aim to provide the foundations for ethical and legal professional behavior and are present in all the Veterinary Medicine programs studied, can be revised to include ethical issues related to the production and commercialization of cultivated meat products, as well as the comparison of the ethical issues in other production systems, such as conventional and plant-based meat chains. In terms of animal ethics, there is an intrinsic relationship with Animal Welfare courses.

The course in Statistics, present in almost all studied programs is relevant for professionals to understand the highly active research in this field and be able to both works directly in the research and development of new technologies and to incorporate state-of-the-art research publications.

In recent years, there has been increasing interest in cultivated meat production (Bryant and Barnett, 2020; Mendes et al., 2025). Advances have been made by startups and research groups to establish animal cell lines, improve culture conditions, propose manufacturing platforms, and even create prototypes for taste testing (Ong et al., 2020). Non-profit organizations such as GFI and New Harvest have published various reports, and teaching support material, and held conferences and lectures to discuss issues such as the social impacts, feasibility, and food safety regulations of cultivated products (Porto and Berti, 2022).

The basis for suggesting the creation of the two new courses came mostly from courses in Bioprocess and Biotechnology Engineering programs.

This is because of the technical aspects present in the production of all cultivated meats, which require knowledge and integration of cellular cultivation techniques, molecular biology, and engineering in the areas of biological tissues, chemistry, food, mechanics, materials, control, and automation, as well as biochemistry, bioinformatics, biomaterial science, and technology (Porto and Berti, 2022).

Considering courses interested in covering cellular agriculture in their curricula, one strategy is to integrate the so-called non-consolidated courses, in order to more broadly encompass the fundamental and formative knowledge of the area, strengthening the curricular foundation and promoting greater uniformity in student training. Institutions interested in offering undergraduate or graduate programs, as well as in promoting transdisciplinarity among the studied programs, could use both consolidated and non-consolidated courses as a reference for the basic training in their new curricula.

Conclusion

Our study indicates that the curricula of Veterinary Medicine, Animal Science, Bioprocess and Biotechnology Engineering, and Food Engineering programs at 19 Brazilian universities provide an initial foundation to train professionals capable of working in cellular agriculture, an emerging field that is developing through the work of specialists trained in these and other related areas. The findings highlight opportunities to strengthen training in the field of alternative proteins and underscore the need for curriculum updates and critical reflection on how existing content can be expanded or supplemented to meet the demands of emerging food technologies. It is important to acknowledge the methodological limitations of this study, which include the focus on federal universities, the exclusion of elective courses, and the subjective categorization of content, factors that should be considered when interpreting and generalizing the results.

Additionally, the analysis was primarily descriptive, based on the presence or absence of content in publicly available curricula during a specific data collection period, without assessing the quality or depth of the courses. The study also did not include all programs in all regions, due to the absence of one of the courses analyzed in a certain region.

Nevertheless, the findings offer guidance for educational policies by identifying strategic areas for curriculum enhancement and expansion, promoting alignment between academic training and the needs of the alternative protein industry. Future studies could build on this work by incorporating more quantitative and inferential analyses, such as measures of concordance between institutions, to provide a deeper understanding of curriculum standardization and relevance. In this way, the study provides a starting point for initiatives that connect universities, the market, and public policy, strengthening the preparation of professionals for an evolving sector and supporting evidence-based curriculum development in emerging food technologies.

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Authors´contributions

JCBB, GP and CFMM contributed to the conceptualization, data curation, formal analysis, investigation and methodology. JCBB, GP, GM and CFMM, to the visualization. JCBB and GP, to writing the original draft. GM and CFMM, to writing, reviewing and editing. CFMM was responsible for funding acquisition, project administration, resources, and supervision. All authors approved the final manuscript.

Data availability statement

The research data are not publicly available.

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