gfi / Brazil

Cultivated Meat Health and Safety

Answers to frequently asked questions and technical updates

Cultivated chicken - GOOD Meat

The Good Food Institute is a non-profit organization working globally to accelerate innovation in the alternative protein market. We believe that the transition to a more sustainable food system is fundamental to addressing the climate crisis, reducing the risk of zoonotic diseases, and feeding more people with fewer resources. Therefore, we collaborate with scientists, companies, investors, entrepreneurs, and government officials to develop plant-based, cultivated, or fermentation-derived food analogs.

Our work focuses on three main areas:

Corporate Engagement

We support companies of all sizes in developing, launching, and marketing alternative protein products, connect startups with investors, mentors, and partners, provide market intelligence to help companies make informed decisions, and conduct research to identify and overcome industry challenges.

Science and Technology

We fund cutting-edge research on alternative proteins, promote collaborations between scientists, companies, and governments, publish data and discoveries to drive scientific progress and design educational programs to train the next generation of alternative protein leaders.

Public Policy

We advocate for public policies that support the development and commercialization of alternative proteins, work with governments to create a favorable regulatory environment, educate the public about the benefits of alternative proteins, monitor the political landscape, and defend the interests of the sector.

With our work, we seek solutions to:

- **Feed nearly ten billion people safely, fairly, and sustainably by 2050;**
- **Contain climate change caused by the current food production system;**
- **Create a food production chain that does not rely on animals;**
- **Reduce the food sector's contribution to developing new infectious diseases, some with pandemic potential.**

In just over six years of operation in Brazil, GFI has already helped the country become one of the leading players in the global plant-based protein market. The intention is to continue developing this work to transform the future of food, promoting new sources of protein and offering alternatives analogous to those of animal origin.

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1. What is cultivated meat?

Cultivated meat is animal meat produced by cell culture. Ideally, it is composed of the same types of cells and three-dimensional structures existing in the muscle tissue of animals and can replicate the sensory and nutritional profiles of meat obtained by slaughter (Porto and Berti, 2022). Since the first event for tasting a cultivated hamburger held in 2013 (The Washington Post, 2013), research in the field of cellular agriculture—which seeks to produce products similar to those of animal origin obtained by traditional methods by using cell culture and other biotechnology tools—has advanced to the point of researchers and companies demonstrating the viability of producing several other products in their cultivated version, including fish, chicken, milk, leather and probably any other type of livestock product imaginable (Rischer et al. 2020).

2. Is cultivated meat produced in the laboratory?

The simple answer is: no! Food development almost always begins in a research laboratory; however, after the Research & Development phases are concluded, food needs to be produced in factories that have been properly prepared to comply with all local regulations for food production—which will be no different for cultivated meat. In Brazil, it's expected that the **Animal Products Inspection Department (DIPOA) of the Ministry of Agriculture (MAPA) will be in charge of inspecting cultivated meat facilities.** In a recent report, FAO notes that, although seemingly somewhat futuristic, the reality is that cultivated food is currently produced in regular food production facilities (FAO 2023). In 2023, about 10 new cultivated meat plants were opened, most of which on a pilot scale operating with 25 L to 1000 L *bioreactors* (Bushnell et al. 2023; The Good Food Institute 2024; GFI facilities database). Details about the interior of some of these facilities can be seen in videos and news stories made with companies in the sector (Freethink 2024).

3. Is cultivated meat safe for consumption?

Yes! All foods, including cultivated meat, must undergo several safety tests before being released for sale, in compliance with the regulations in force in each country where they will be produced or sold. Cell culture products that have already reached consumers are safe for consumption because they have undergone extensive safety evaluations, which will be required for future products.

In Brazil, ANVISA is responsible for ensuring the safety of cultivated meat products and their ingredients in accordance with Resolution RDC No. 839 of December 2023. To date (September 2024), no company has submitted an evaluation request to ANVISA. This agency's approval will be the first step in ensuring that the product is safe. However, ANVISA's approval alone does not allow immediate commercialization. Other regulations, such as quality standards, labeling, product registration, and factory inspection, are still required. GFI Brasil is working to ensure that these additional regulations, issued by MAPA and ANVISA, are complete by the end of 2025, allowing cultivated meat to be adequately produced and sold in the country.

Technical and regulatory details on safety

Attest food safety is a prerequisite for marketing; therefore, cultivated meat products that have reached consumers are safe for consumption, as well as products that will be marketed in the future. As per the Codex Alimentarius[1], food safety is the assurance that food causes no harm to consumers when prepared and/or consumed in accordance with the intended use. In order to ensure food safety, food and ingredient companies must comply with the regulations in force in each country where they intend to produce or market their products. That implies detailed hazard analyses at all production stages, as well as the adoption of a safety and compliance management system. These analyses usually include a *Hazard Analysis and Critical Control Points (HACCP)* document submitted to local regulatory bodies. GFI Brasil published a case study of how the safety management of a cultivated meat product can be conducted (Sant'Ana et al. 2023).

Each country has its own rules for this safety assessment. See, for example, what was assessed during the first consultation with the US regulatory body (FDA). In Brazil, the first regulatory agency is Anvisa, responsible for assessing the safety of cultivated products and their ingredients. The issue is regulated by Resolution 839 of December 14, 2023 (RDC No. 839), which regulates the certification of safety and the authorization of the use of new foods and new ingredients in general. The Resolution addresses the format for submission of the technical-scientific report (RTC) for analysis, but GFI Brasil recommends that applicants follow the guidelines suggested in Chapter 4 of the Regulatory Study about Alternative Proteins in Brazil, which covers all the elements required in the Resolution and includes other details that align the RTC with the requirements of other international regulating bodies (Garcia et al. 2022). As of the writing of this text (September 2024), no application had been submitted for analysis by Anvisa.

Anvisa approval means the product is safe, but it is still insufficient for marketing. It requires additional regulations on product identity and quality standards (minimum and maximum allowed levels), nomenclature and labeling issues, product registration rules, and production plant inspection regulations. GFI Brasil works so all these additional regulations, issued by the Ministry of Agriculture and Anvisa, are available by the end of 2025.

Also with regard to safety, cultivated meat may present some advantages compared to conventional meat. As cultivated meat is produced in highly controlled conditions, the chances of contamination by microorganisms such as bacteria are considered extremely low compared to conventional meat. Contamination can occur throughout the process, but in most cases, the proliferation of bacteria would prevent cell growth, leading to disruption of the process. This factor also contributes to reducing the risk of introducing *pathogenic bacteria*, which can occur in conventional meat during slaughter. An application document requesting approval of UPSIDE Foods' cultivated chicken with the FDA shows a drastically reduced bacterial growth in the cultivated product in relation to the same parameter assessed in conventional ground chicken meat samples (Schulze 2021 – see Table 5.51, page 34). Finally, based on knowledge about the process and data

[1] Joint program of the United Nations Food and Agriculture Organization (FAO) and the World Health Organization (WHO), created in 1963, with the objective of establishing international regulations in the area of food, including standards, directives and guidelines on Good Practices and Safety and Effectiveness Assessment.

reported in safety analyses of companies, cultivated meat probably has much lower levels of microplastics and other environmental contaminants that are common in conventional meat, such as mercury commonly found in some forms of seafood.

4. Is cultivated meat healthy?

Currently, there are few registered cultivated meat products and little scientific research that provides detailed data on their health aspects. Since conventional meat is rich in protein, vitamin B12, iron, zinc, and other vital nutrients, cultivated meat is expected to offer a similar nutritional profile. Data from UPSIDE Foods submitted to the FDA shows that its cultivated meat has a similar nutritional composition to the conventional one (Schulze 2021 - see pages 78-82). However, more research is needed to evaluate factors such as *digestibility*, nutrient *bioavailability*, and *sensory characteristics* of cultivated meat.

Additional research on healthiness is needed

Conventional meat contains proteins with high biological value, in addition to vitamin B12, iron, zinc and other nutrients that make meat a nutritious food (Watanabe and Bito 2018; FAO 2023). Therefore, cultivated meat products are expected to provide consumers with a nutritional profile, including a protein, fat, mineral and vitamin composition that is similar to conventional products. However, several different types of cultivated meat products—such as hamburgers, sausages, breaded meat products, beef, and chicken breast, among others—are under development, and there is a very limited number of registered products and few open-access scientific publications that can provide a robust and well-detailed data set on these aspects. Some examples of available data are those UPSIDE Foods submitted to the FDA, which show a similar nutritional composition between the conventional product and the cultivated product produced by the company (Schulze 2021 – see pg. 32, 78-82). Published scientific research on quality aspects of cultivated meat suggests that the process requires optimizations so the products have nutritional and sensory properties that match or exceed the properties of conventional meat Broucke et al. 2023). Possible courses of development indicate, for example, that adjustments in *culture medium* formulations and *cell differentiation* are factors that may influence the nutritional and *sensory characteristics* of the final product (Joo et al. 2022). Therefore, there is an evident need to foster research of this type in the sector. The most urgent research gaps are studies to assess the protein content, bioavailability, and digestibility of these and other components, as well as more in-depth research on sensory and techno-functional aspects (Broucke et al. 2023; Fraeye et al. 2020).

5. Is it already possible to buy cultivated meat?

Yes! But still in a very limited way due to the low production volumes. To date (September 2024), **5 products have been fully approved** for marketing: 2 in the US and 3 in Singapore (Crownhart 2023; Bushnell et al. 2023). Countries such as Australia, Switzerland, and Israel have also received applications for approval of cultivated products, but consultations on marketing approval are still ongoing. Thus, cultivated meat can be tasted in some restaurants after waiting in a queue. In order to enable marketing to more people, the **Singapore company GOOD Meat started to sell in retail**, in May 2024, a hybrid product combining plant-based ingredients with about 3% of cultivated meat (Ellenberg 2024). Marketing cultivated products on scale essentially depends on overcoming the technological challenges posed by the production of several tons of cultivated meat in bioreactors that may be larger than 50,000 L. The viability of the process in these large production volumes (*scale-up*) still needs to be demonstrated. Currently, the largest bioreactors in operation are 2,000 L bioreactors producing a few hundred kilograms of product (The Good Food Institute 2024).

6. Is the process of obtaining cultivated meat safe?

Yes, the process is safe! As in the case of any other food, it is necessary to have well-established controls and criteria that can ensure safety. All production chain stages—from obtaining the initial cells to supplying the product to end consumers—undergo a detailed examination as part of the comprehensive safety analysis that must be conducted on foods, ingredients, production processes, and production facilities, as mentioned above. The cultivated meat production **process can be generically divided into four phases: (1) cell selection, (2) production, (3) collection, and (4) processing and formulation.** However, in the practice of industries, the steps that constitute each of these phases can be numerous and variable depending on the type of final product to be obtained (for example, whole cut, ground meat, hamburger) and the characteristics of the established bioprocess. In order to improve the understanding of what could be a complete process of producing cultivated food and to support evidence-based regulations, GFI Brasil published the study in which 24 steps of producing a cultivated hamburger were described in detail and submitted to a comprehensive hazard analysis (Sant'Ana et al. 2023). As a result, it was found that the **potential hazards observed are common in the conventional food industry, with well established controls, and can also occur in biotechnology-derived foods**, such as those produced by fermentation or derived from *conventional breeding*. The results of the study corroborate the findings of other similar studies and are important to help show that some alleged safety concerns (such as association with tumor cells, DNA transfer, etc.) are not consistent with the current scientific understanding on this subject (FAO and WHO 2023; Ovissipour et al. 2024).

7. Will hormones or antibiotics be used to culture these products? If yes, will the final product contain residues?

The use of hormones and antibiotics is not mandatory in producing cultivated meat! Hormones are naturally produced by organisms, such as humans and animals, and are already present in the meat of slaughtered animals. In some countries, such as the US, the use of hormones to increase milk production or weight gain is permitted, with residue limits set to ensure consumer safety. Using hormones to fatten animals in Brazil is prohibited, but reproductive and therapeutic treatments are allowed. Some producers may use hormones to simulate the cells' natural environment for cultivated meat. In this case, residue limits will follow the same standards as traditional meat.

The scenario is different regarding antibiotics. In animal farming, they are mainly used to treat diseases or as growth promoters, but this raises concerns due to antimicrobial resistance, a global public health problem. Cultivated meat could help reduce the use of antibiotics, as the farming process relies on highly controlled environments free from contamination. Cultivated meat companies currently claim that they do not need to use antibiotics in large-scale production.

Updates on the use of antibiotics and hormones

Antibiotics and hormones are not mandatory for cultivated meat production, and the industry has not reached a consensus on whether to use them throughout production. Hormones are molecules naturally produced by multicellular organisms (for example, humans, animals, plants, etc.) and regulate the physiological and behavioral responses of these individuals. Thus, natural concentrations of hormones must be present in meat obtained by slaughtering animals as they are produced by the animals themselves. In some countries, such as the USA, exogenous applications of hormones—progesterone, estrogen, testosterone, etc.—are allowed in animals raised for meat and milk and have various purposes, for example: improving the reproductive management of females, increasing milk production, and improving weight gain (Jaborek 2023). In these cases, domestic regulators and international authorities such as Codex Alimentarius establish the *maximum levels of residues* that can remain in meat and other tissues of slaughtered animals, thereby ensuring that end-consumer intake levels are safe (CODEX 2023).

In Brazil, the import and use of these substances for growth and fattening of livestock is prohibited, but is allowed for therapeutic and reproductive purposes, by Normative Instruction No. 55, of December 1, 2011 (MAPA 2011). In the case of cultivated meat, some producers may opt for the addition of hormones in the culture medium to reproduce the physiological environment that the cells would have if they were growing within the body of the animals under the hormonal signaling of different glands (Ahmad et al. 2023). In these cases, producers who opt for the use of hormones will probably have to comply with the same *maximum residue levels* already allowed and regulated in conventional meat.

On the other hand, the use of *antimicrobials* in the production of traditional and cultivated meat is expected to be quite different (Bomkamp and McNamara 2022). Antimicrobials are used in conventional meat production mainly to treat or prevent infectious diseases; however, in some cases, these antimicrobials are also used to enhance the growth rate and productivity of animals (Aroeira and Feddern 2021). The use of antimicrobials in animal production is subject to robust regulation but remains a permanent concern because antimicrobial resistance (AMR) has become a global public health issue. According to the WHO[2], AMR develops when a microorganism (bacterium, fungus, virus or parasite) cannot be destroyed or have its growth limited by a drug to which it was previously sensitive, leading to difficulties in the treatment and control of infections. Conventional animal production is one of the sectors with potential as a reservoir of resistant bacteria, and the United Nations (UN) General Assembly recognized the inappropriate use of antimicrobials in animals as a leading cause of rising AMR (Lentz 2022; Van Boeckel et al. 2017).

In this scenario, meat production through cell culture has a positive impact by reducing antimicrobials in the food chain and helping deal with the AMR issue. Cell culture is

[2] The United Nations agency working to promote health, keep the world safe and serve the vulnerable.

successful only in the absence of bacterial contamination; therefore, an industrial-scale process must be highly controlled to prevent any contamination and the consequent loss of production batches. Cell culture contamination can be prevented by adopting *aseptic techniques* and without using antibiotics, as already occurs in the pharmaceutical industry. For now, cultivated meat companies report that the use of antimicrobials is not required in the large-scale production phases, only in the cell isolation phases, as confirmed in the documentation that UPSIDE Foods submitted to the FDA (pg. 40). The initial processing phases—such as cell isolation—employ extremely low volumes of antimicrobials, thus being improbable that any residue will remain in the final product.

8. Will other animal-derived products such as fetal bovine serum be used in the production?

Currently, animal-derived products are still used in cultivated meat research but are gradually being replaced as technology advances. Fetal bovine serum (FBS), one of the most common examples, is obtained from animal fetuses (usually bovine) and contains a mixture of proteins, hormones, and other nutrients that help cells grow. However, its use can cause problems, such as variations in the quality of the final product, the risk of contamination by microorganisms, and high costs. In addition, the use of FBS in cultivated meat goes against the ethical principles of this type of production.

Therefore, replacing FBS with *animal-free* alternatives is a priority for the industry. Many companies are already developing their own FBS-free culture media formulas, such as GOOD Meat, which has obtained approval to use an FBS-free medium in its products. While viable alternatives exist, reducing costs, increasing production scale, and ensuring a supply chain meeting this demand are still necessary.

The problem of using animal-derived products in cultivated meat

Animal-derived cell culture products—such as enzymes, culture medium supplements, and others—have a long history of use in science and are applied at different times during culture so as to serve various functions. However, the use of these products in commercial production processes—such as cultivated meat—causes issues in terms of cost and animal welfare; consequently, developing alternatives to them is one of the current priorities of the industry. Fetal bovine serum (FBS) is probably the most common example of an animal derivative used in cell culture. This serum is obtained from animal fetuses, most often bovine fetuses, and contains a complex mixture of proteins, hormones, lipids and several other components. It is used as a culture medium supplement with the primary function of stimulating cell proliferation. Since FBS is obtained from different animals, the composition of this element varies according to diet, collection season, and animal characteristics such as gestational age and history of use of antibiotics and hormones received by the breeding mother. This variability can compromise the reproducibility of final product batches; moreover, FBS can be a potential source of microorganisms (such as *mycoplasma*) that compromise cell growth and affect product safety. Finally, high costs, limited global supply, and ethical issues of its use in a product like cultivated meat make the use of FBS for large-scale cultivated meat production improbable (Swartz 2021).

The need to develop FBS substitutes, cell culture reagents, and culture media without animal-derived elements is a priority and has driven research and innovation in academia and industries. In a recent GFI survey, 74% of cultivated meat companies surveyed said they were working on in-house formulas of FBS substitutes to be used in their production (Harsini and Swartz 2024). GOOD Meat, a pioneer company in the approval of a cultivated meat product worldwide, announced in 2023 that it had obtained regulatory approval for using an FBS-free culture medium in its products that were previously produced in a medium containing the animal derivative (Good Meat, 2023). In addition, major Life Sciences companies—such as Merk and Kerry—have been developing lines of FBS-free products suitable for cultivated meat production.

Finally, the development of non-animal alternatives to cell culture inputs is the focus of recent scientific publications (Stout et al. 2022). Although the viability of producing *animal-free* inputs has been demonstrated, research efforts still need to be focused on reducing costs, scaling up production, and creating a supply chain that can serve this industry.

9. Is cultivated meat an ultra-processed food?

According to the Dietary Guidelines for the Brazilian Population, cultivated meat should be classified as ultra-processed, but this classification does not fully reflect reality. The Guidelines classify foods into four categories, with ultra-processed foods being those that undergo several industrial stages and use many refined ingredients.

However, cultivated meat has characteristics that differentiate it from other ultra-processed foods, especially concerning sustainability and climate impact. The Dietary Guidelines recognize the importance of considering the current context, such as climate change and the need for innovation in food systems. Livestock farming is one of the largest emitters of greenhouse gases, and cultivated meat can be a sustainable solution, using fewer natural resources such as water and land.

While conventional meat is classified as in natura, cultivated meat and conventional meat have similar cell growth processes, whether in an animal's body or in a bioreactor. Therefore, despite being classified as ultra-processed, cultivated meat can be seen as an innovation that responds to the demands of sustainability and public health, showing that this classification may not be the most appropriate to reflect all of its benefits.

The principles that guide the Dietary Guidelines and cultivated meat

According to the Dietary Guidelines for the Brazilian Population, cultivated meat should be defined as ultra-processed food. However, those products, as well as other innovations, do not fit properly into Dietary Guide definitions, especially considering climate mitigation and adaptation strategies.

The Dietary Guide notes four food categories, defined according to the type of processing used in their production. The **first** category includes fresh or minimally processed foods. Fresh foods are obtained directly from plants or animals (such as leaves and fruits or eggs and milk) and purchased for consumption without having undergone any change after being obtained from nature. Minimally processed foods are fresh foods that, prior to purchase, have undergone minimal changes.

Examples include dried, polished, packaged or ground grains in the form of flours, washed roots and tubers, chilled or frozen cuts of meat, and pasteurized milk. The **second** category corresponds to products extracted from fresh foods or directly from nature and used by people to season and cook food and create culinary preparations. Examples of these products are oils, fats, sugar and salt. The **third** category corresponds to products manufactured essentially with the addition of salt or sugar to fresh or minimally processed foods, such as preserved vegetables, fruits in syrup, cheeses and breads. The **fourth** category corresponds to products whose manufacture involves several processing steps and techniques and several refined ingredients, many exclusively for use in large-scale manufacturing. According to this concept, any product that does not "exist" in nature (such as cultivated meat) falls in the fourth category and should be considered as an ultra-processed food.

However, the five principles that direct the Guide's elaboration can put categories' concepts in perspective when food systems are necessary to tackle the challenges brought about by climate change. The first principle argues that food consumption is more than nutrient intake, as it also concerns the foods that contain and provide nutrients, and how they are combined, prepared, and eaten, emphasizing the cultural and social dimensions of food consumption practices. The second principle states that food consumption recommendations should be consistent with their time by considering the context of the evolution of foods and the health conditions of the population. The third principle argues that adequate and healthy food consumption results from a socially and environmentally sustainable food system, noting that food consumption recommendations should consider the impact of food production and distribution practices on social justice and integrity in the environment. The fourth principle indicates that individuals with different expertise (nutritionists, food engineers, environmentalists, internationalists, social scientists, among others) generate knowledge for the formulation of food guides, given the various dimensions of food consumption and the complex relation between these dimensions and people's health and well-being. And, finally, the fifth principle states that food guides increase autonomy in food choices because access to reliable information on characteristics and determinants of adequate and healthy food contributes toward people, families and communities expanding their autonomy to make food choices and demanding compliance with the human right to adequate and healthy food.

According to one of the most recent reports released by the United Nations Environment Programme, food systems (agriculture, livestock and transport) are among the sectors with the highest greenhouse gas emissions (UNEP 2023). Among these, livestock has a preponderant role, either by the extensive use of finite natural resources (water and land) or by the methane gas naturally produced by livestock. Therefore, addressing this challenge through more sustainable livestock production systems, with incremental innovations in animal feeding and waste management and crop-livestock-forest integration strategies is an inexorable path. At the same time, radical innovations in the means of obtaining animal proteins for human consumption such as cultivated meat also deserve a prominent place in strategies to deal with climate change, as they require much smaller amounts of finite natural resources.

Therefore, animal meat classified as fresh in the first category is strongly affected by the third principle in terms of sustainability.

On the other hand, cultivated meat classified as ultra-processed in the fourth category responds quite adequately as an innovative (fourth principle) and sustainable (third principle) solution.
Finally, it is essential to emphasize that the purpose of using industrial ingredients in producing cultivated meat - which will result in its classification as ultra-processed - is very different from the purpose of using industrial ingredients in other processed products. Just as animals are fed, digest, and absorb nutrients to nourish their body cells and grow their meat, the cells inside the bioreactors will also be fed with ingredients that will be “digested” for the nutrition and growth of the cells of the cultivated meat. Therefore, from a certain point of view, it may be incoherent for conventional meat to be classified as in natura and cultivated meat as ultra-processed since they are produced by similar processes that occur in “different systems,” whether inside a living organism or a bioreactor.

10. Is cultivated meat a genetically modified food?

Cultivated meat is not genetically modified by definition. However, as in animal breeding, genetic modification can facilitate the final product’s process and characteristics. In Brazil, the Biosafety Law defines genetically modified organisms (GMOs) as those whose DNA or RNA has been altered by genetic engineering.

Genetic modification is not necessary for the production of cultivated meat. Depending on the species, some characteristics, such as rapid cell multiplication, can arise naturally and be selected without genetic intervention.

However, some companies may choose to use genetic engineering to improve cell resistance or the nutritional value of meat, for example. **Modern genetic engineering tools allow specific cell adjustments without adding genes from other organisms, avoiding transgenic problems.** In Brazil, products from these techniques are evaluated case-by-case to determine whether they are classified as GMOs.

Technical and regulatory details on genetic modifications

Fundamentally, no, cultivated meat is not inherently genetically modified. However, similar to conventional animal production, genetic modification is a tool that can enhance productivity and nutritional aspects. In addition, it can help us reduce the frequency with which it will be necessary to collect cells from animals to start a new production of cultivated meat.
In Brazil, the Biosafety Law (Law No. 11,105, of March 24, 2005) (CEDI 2005) determines that genetically modified organisms (GMOs) are those organisms that have been submitted to manipulation of their genetic material, being DNA and/or RNA, through genetic engineering techniques. Although the possibilities of genetic manipulation can be varied, in the context of agriculture the term GMO is understood as a synonym for transgenic, that is, an organism that has received a gene from another organism to exhibit a characteristic that it did not have before, such as resistance to a certain virus or tolerance to certain herbicides used in cultivars (EMBRAPA). In the case of foods produced by cell culture, genetic modifications—whether transgenic or any other modifications—are not a prerequisite to enable the production of cultivated meat; therefore, cultivated meat products are not necessarily GMOs. Depending on the species

from which cultivated meat is intended to be produced, characteristics such as short *doubling time* and *cell viability* after several multiplications can be selected, for example, through *spontaneous immortalization* (Soice and Johnston 2021).
However, as occurs with other biotechnology-derived foods, some developers may choose to use genetic engineering tools in their cell strains so as to, for example, obtain cells with greater resistance to the process or with a better nutritional profile. Modern genetic engineering tools—such as New Breeding Technologies (NBTs) or, in Portuguese, *Técnicas Inovadoras de Melhoramento de Precisão (TIMPs)* —allow directed adaptations in organisms and generally do not involve transgenics, excluding related safety issues (FAO 2022; Giraldo et al. 2019). In Brazil, products resulting from TIMPs are classified as GMO or non-GMO on a case-by-case basis, as established by Normative Resolution No. 16, of January 15, 2018 (CTNBio 2018).

11. What are the main opportunities in producing cell culture-derived foods like cultivated meat from a nutritional standpoint?

As these foods are obtained through a controlled process, producers have **numerous possibilities to adjust the properties of final products** by eliminating certain components considered less interesting as to the nutritional value and increasing the content of components considered beneficial. An example would be the production of meat with less saturated fats and more unsaturated fats, making it possible to enrich cultivated beef, chicken or pork with high levels of omega 3 (GFI 2023).

In a study published in 2023, for example, scientists were able to control the lipid composition of a prototype of cultivated Wagyu (Japanese beef) by adjusting the fatty acid composition of the culture medium during cell differentiation (Louis et al. 2023).

In addition, combinations of different animal cells and product structuring approaches—such as 3D printing—**can provide products with unprecedented flavor, texture and nutritional profile** and that can enable personalized nutrition for people with specific conditions—such as food selectivity and chewing difficulties, among others (Charelli 2023). The development of such products will surely be challenging, but it is a **unique opportunity to develop products** suitable for different publics and purposes, with combinations that are impossible or unfeasible to be obtained through traditional livestock farming, thus providing a vast field for innovative projects.

Glossary

Animal-free: Used to indicate that a substance is free of ingredients of animal origin.

Antimicrobial: Chemical compounds that kill or inhibit the growth of microorganisms.

Aseptic techniques: Procedures used in cell culture to avoid contamination by microorganisms and cross-contamination with other cell lines.

Bioavailability: Refers to the extent to which an ingested protein is absorbed and utilized by the body.

Bioreactors: Equipment used in biotechnological processes to cultivate cells under controlled conditions.

Cell culture medium: Nutrient liquids used for cell growth and differentiation.

Cell culture reagents: Chemical substances used in conducting experiments and analyzing samples. Example: enzymes used to detach cells from the bottom of culture plates.

Cell differentiation: Process by which cells become specialized to perform a particular function. For example, muscle cells specialize in contracting and relaxing.

Cell viability: Term used to describe the ability of cells to remain alive and functional.

Conventional breeding: Refers to the targeted selection of specific characteristics in animals and plants by man. For example, cross two plants with a desired profile to generate descendants that are more resistant to pests or more nutritious.

Digestibility: Refers to the ease with which an ingested protein is broken down into smaller components (amino acids) during digestion.

Doubling time: Time it takes for a cell culture to double.

Hazard Analysis and Critical Control Points (HACCP): A system of control over food safety through the analysis and control of biological, chemical, and physical hazards at all stages of production.

Maximum residue levels: Maximum permitted concentration of a specific residue in a food product.

Mycoplasma: A type of microorganism that can infect several cells. Mycoplasma contamination is a common problem in cell cultures.

Pathogenic bacteria: Bacteria capable of causing disease in their host.

Técnicas Inovadoras de Melhoramento de Precisão (TIMPs): A set of new methodologies and approaches that differ from the genetic engineering strategy by transgenesis, as they result in the absence of recombinant DNA/RNA in the final product.

Scale-up: In the context of bioprocesses, scale-up refers to scaling systems using increasingly larger bioreactors to increase production capacity. On the other hand, in scale-out systems, production capacity is increased by using parallel bioreactors of the same size.

Sensory characteristics: Refers to the color, texture, flavor, aroma, and appearance of food.

Spontaneous immortalization: During cell culture, some cells can spontaneously turn off their aging and death mechanisms and acquire the ability to multiply indefinitely.

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