SJIF Impact Factor: 5.464

WORLD JOURNAL OF ADVANCE HEALTHCARE RESEARCH

ISSN: 2457-0400
Volume: 7.
Issue: 8.
Page N. 121-129
Year: 2023

Review Article www.wjahr.com

SYNTHETIC MEAT, A SUSTAINABLE ALTERNATIVE IN THE FUTURE OF FOOD

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Received date: 20 June 2023 **Revised date:** 10 July 2023 **Accepted date:** 30 July 2023

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ABSTRACT
Synthetic meat, also known as cultured or lab meat, is a food product created through the cultivation of animal cells in a controlled laboratory environment. This process involves taking a small sample of cells from a living animal and culturing them in a suitable culture medium for them to multiply and form muscle tissue. This aims to replicate the characteristics and properties of conventional meat, but with potential advantages, such as a smaller environmental footprint, reduced animal suffering, and mitigation of food safety risks associated with conventional meat production. The synthetic meat production process involves several stages, such as obtaining stem cells or progenitor cells, their multiplication in a bioreactor and their subsequent differentiation into muscle tissue. Once enough muscle tissue has been produced, it can be processed and used to create meat products such as hamburgers, sausages, and steaks. Synthetic meat has potential advantages, such as less use of natural resources, reduced greenhouse gas emissions and the elimination of the need to raise and slaughter animals. It is also expected to offer greater traceability and food safety, while providing an alternative to consumers concerned about animal welfare. However, synthetic meat still faces significant challenges, such as high production costs, the need for large-scale scalability, consumer acceptance, and regulatory challenges. As technology continues to advance and these challenges are overcome, synthetic meat is expected to become a widely available and viable alternative on the market. Therefore, synthetic meat is a food product created through the cultivation of animal cells in a laboratory setting. It has the potential to offer environmental, ethical and food safety benefits, although it still faces challenges for its large-scale production and consumer acceptance.

KEYWORDS: synthetic meat, in vitro meat, production, cultured meat.

INTRODUCTION

Global meat production is a complex and constantly changing subject due to various factors such as population growth, food demand, natural resource availability and dietary trends.

According to available data, world meat production is dominated by three main types: beef (bovine), pork (porcine), and chicken (avicola). There is also significant production of other meats, such as lamb, goat and game meat, but on a smaller scale.[1-5]

Pork meat has traditionally been the most consumed meat worldwide, closely followed by chicken meat. However, beef remains a significant source of protein in many parts of the world. China is the largest producer of this meat worldwide, and its production has been very high due to high domestic consumption. Other important countries are the US, Brazil, Russia and Germany.

As for chicken meat, the US is one of the largest producers, followed by China and Brazil. Chicken production has experienced significant growth due to its lower production cost compared to other meats.

As for beef, the US, Brazil, China and the European Union are the main producers. However, beef production tends to require more resources, such as grazing land and water, which has led to debates about its environmental sustainability.[6-10]

These data are subject to change as trends and policies in meat production evolve. In addition, there are other important considerations related to health, animal

welfare and environmental sustainability that are influencing meat production and consumption globally.

Figure 1 shows how meat production has been increasing worldwide in recent years.

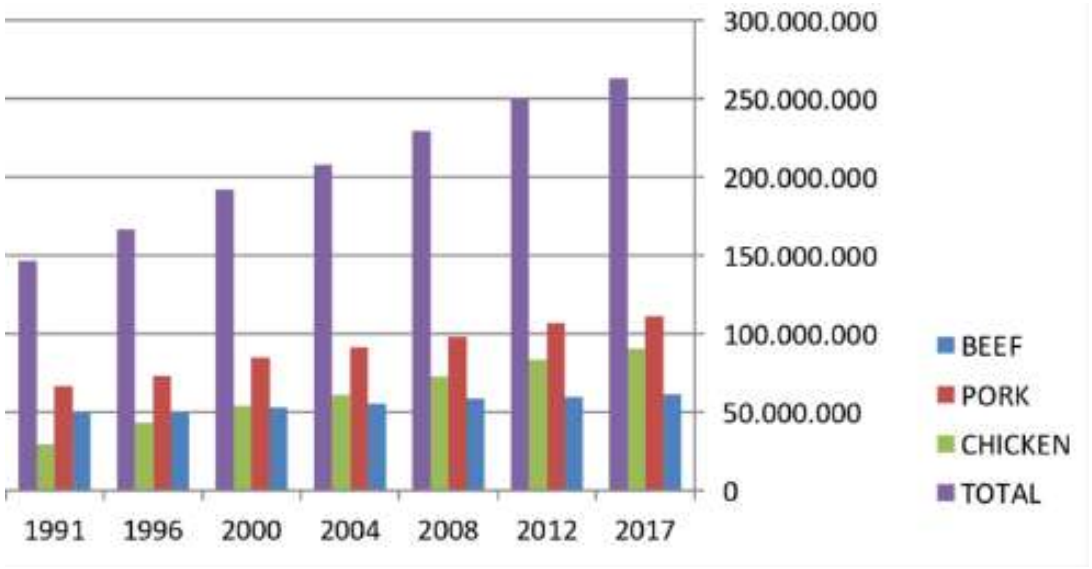

Figure 1. Impact of meat production worldwide in recent years.

The livestock sector is currently made up of a huge number of farms. The pig sector is the majority followed by the bovine and ovine sector, apart from poultry. Regarding the type of farms, they can be divided into[11-13]:

-Intensive Livestock: Includes the industrialization of livestock farming. The cattle are stabled, under artificially created conditions, with the aim of increasing meat production in the shortest possible time.

In which large investments are made in facilities, technology, labor, etc. to be able to put livestock plants of this type into operation.

The increase in the world population has caused the increase in meat consumption per inhabitant, and the decrease in operating costs, have caused this industry to increase.

-Extensive Livestock: uses traditional methods of livestock development in which it imitates natural ecosystems to promote animal welfare. Its objective is to use the territory sustainably. This type of livestock also includes sustainable livestock, which maintains a level of production and does not harm the environment.

In the European Union and in the rest of the world there are a multitude of animal species for human consumption. Among these species are: Chicken is the most consumed animal in terms of fresh meat. However, depending on the culture and the country, other types of animals are consumed. For example, in China, the dog is a very typical dish, in Japan it is typical to eat dolphin meat, in Mexico turtle meat is consumed and in Cambodia it is very typical to eat fried tarantulas as a starter.

Meat is an essential part of the human diet, and provides great health benefits as it is:

• One of the main sources of protein.

• Rich in vitamin B12, which is the only source where this vitamin is found. A person whose diet does not include meat of animal origin should take vitamin B12 supplements to complete nutritional requirements.

haem iron, which is a necessary nutrient for the formation of hemoglobin and its main function is to carry oxygen to all the cells of the body. The form in which the body absorbs and makes the best use of this nutrient is haem iron.

• It is rich in zinc, as it helps protect against oxidative damage and skin healing.

However, the high consumption of meat, mainly red and processed, leads to the development of diseases such as diabetes or those due to high cholesterol, saturated fats, added salt, etc. Although these diseases are often associated with older people, they can affect all age groups. Also low- and middle-income countries are vulnerable to these cardiovascular diseases due to economics, as unhealthy foods are more economically affordable. For all these reasons, current dietary recommendations recommend reducing the intake of animal protein and increasing the intake of vegetable protein.[11]

Conventional meat production has been a fundamental part of our diet for centuries. However, in recent years, increasing concerns have been raised around the environmental impacts, animal health and welfare associated with this industry. As a result, the search for sustainable alternatives has become a priority in the field of food.

In this context, synthetic meat has emerged as a promising solution. Also known as cultured meat, in vitro meat or cellular meat, this innovative technology offers the possibility of producing meat without the need to mass raise and slaughter animals. Instead, animal stem

cells are grown in laboratories and allowed to multiply and differentiate into muscle tissue.

In recent years, there has been an increase in demand for meat alternatives, such as plant-based and lab-grown meats. These options seek to address concerns related to health, animal welfare, and environmental sustainability (5,8,10).

Plant-based meats, also known as "plant-based" or "vegan" meat, are made from ingredients of plant origin, such as soy proteins, peas, wheat, among others. These products have experienced significant growth in popularity, with several well-known and start-up companies bringing innovative products to market. This has led to an increase in the supply and availability of plant-based meat options around the world.[12-14]

On the other hand, lab-grown meat, also known as "cellular meat" or "lab meat," involves growing animal cells in a controlled environment to produce meat without the need to raise and slaughter animals. Although it is still a developing technology and not widely available, there have been significant advances in cultured meat research and production. Several countries are exploring the regulation and marketing of this new form of meat.

These alternatives to conventional meat are gaining acceptance and popularity in different parts of the world, especially among those seeking to reduce their consumption of animal meat for ethical, environmental, or health reasons. However, animal meat production and consumption remain prevalent globally, and the transition to meat alternatives is still in its early stages.

It is important to highlight that meat production globally faces significant challenges in terms of environmental sustainability, especially in relation to deforestation, the emission of greenhouse gases and the consumption of natural resources. Therefore, environmental considerations and consumer demands are expected to continue to influence meat production and consumption in the future.[7,9]

Figure 2 represents the two production methods, comparing how much It takes time to produce cultured meat compared to conventional production.

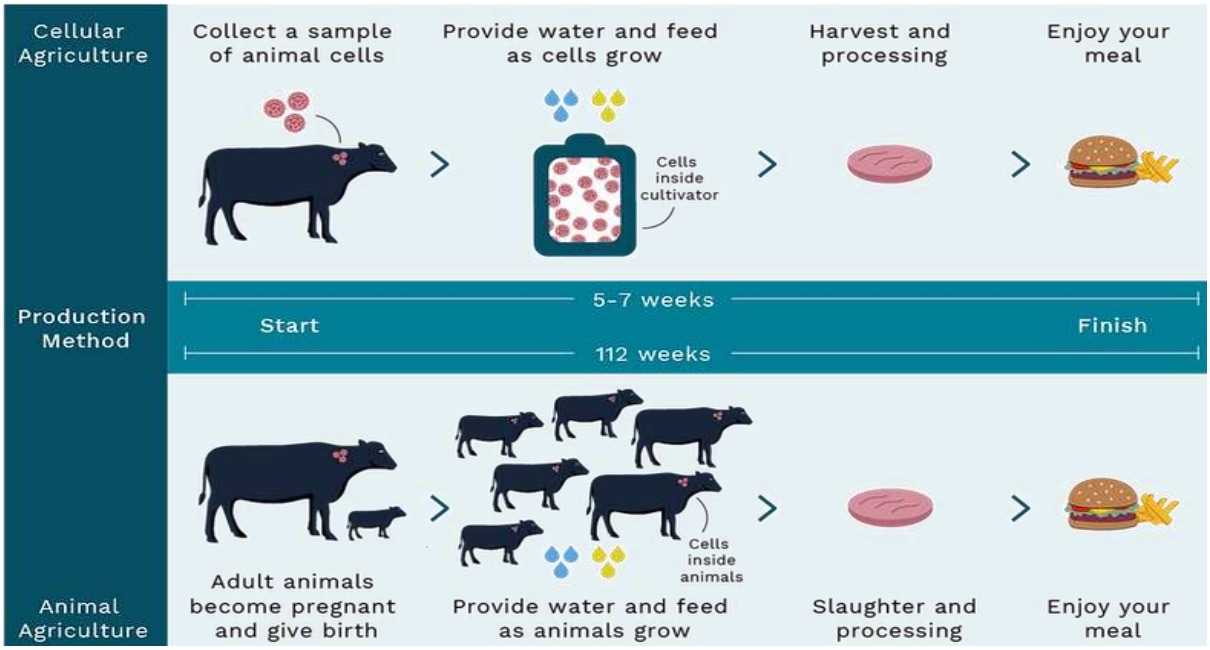

Figure 2. Comparative graph of time it takes to produce cultured meat versus conventional meat.

Synthetic meat not only poses significant advantages in terms of environmental sustainability and animal welfare, but also offers the potential to meet the growing global demand for animal-based protein without the drawbacks associated with conventional production. As technology continues to advance and challenges are met, synthetic meat could radically transform the way we source our meat and other meat products.[6,9,13]

It explains what synthetic meat is, how it is produced, the advantages it offers and the challenges it faces. In addition, we examine its potential to revolutionize the food industry and contribute to a more sustainable future. As we delve deeper into this fascinating area of research, we will be able to better understand the benefits and implications of synthetic meat and assess its role in the way we eat for decades to come.

SYNTHETIC MEAT

Also known as cultured meat, in vitro meat or cellular meat, it is a type of food of animal origin that is produced through tissue engineering and cell biology techniques. Unlike conventional meat, which is obtained from animal husbandry and slaughter, synthetic meat is

created by culturing animal stem cells in a controlled environment in the laboratory.[2,6,9,12]

The process begins with obtaining a small sample of stem cells from a living animal through a biopsy. These stem cells have the ability to self-renew and differentiate into different types of specialized cells. The stem cells are then placed in a culture medium that provides them with the necessary nutrients to grow and multiply.[15-20]

Over time, the cells clump together and form muscle fibers. These muscle fibers can be electrically stimulated to contract and take on a texture similar to conventional meat. Once a sufficient amount of muscle tissue has developed, the muscle fibers are combined and processed to create meat products such as hamburgers, sausages, or steaks.

It is important to note that synthetic meat is composed solely of muscle tissue, not including other components present in conventional meat, such as blood vessels, fat, or connective tissue. However, scientists continue to research and work on improving the composition and texture of synthetic meat so that it is as close as possible to conventional meat in terms of flavor, juiciness, and appearance.[3,7,10]

Synthetic meat represents an innovative approach to address challenges associated with conventional meat production, such as the environmental impact of animal husbandry, animal welfare concerns, and food safety. By producing meat without the need to mass raise and slaughter animals, synthetic meat offers a more sustainable and ethical alternative to meet the growing global demand for animal protein.[20]

In Figure 3, the meat growing cycle is represented. 1. Non-invasive uptake of cow stem cells; 2 and 3 steps in which cell culture takes place in a culture environment to grow and divide; 4. Differentiation of tissues from cells that are identical to those extracted from the animal; and 5. Processing of meat to reach the consumer directly.

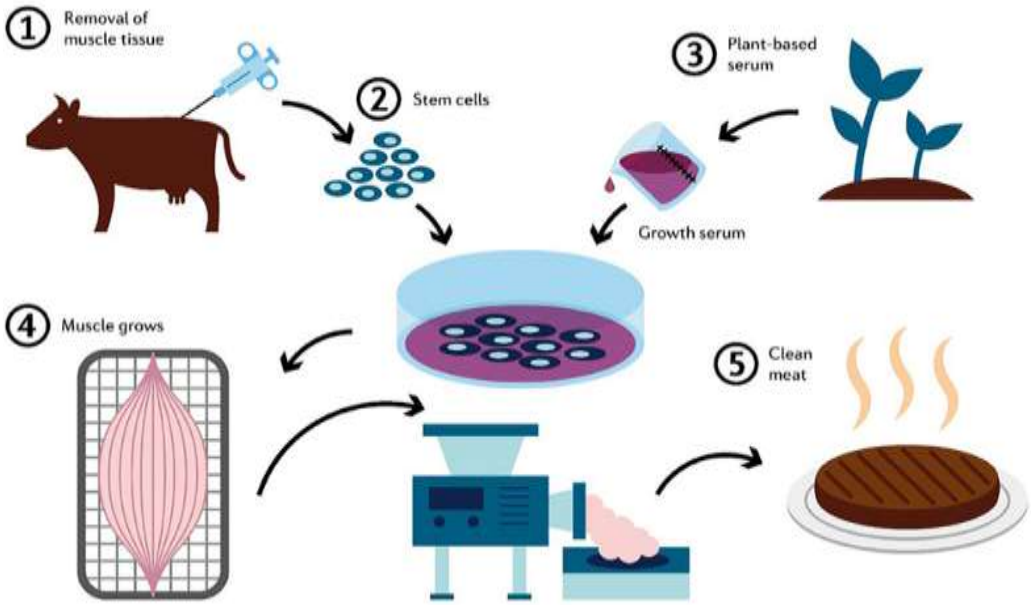

Figure 3. Representation of the meat growing cycle.

In figure 4, the production of unstructured and structured meat products using primary cells of animal origin is represented. In which a skeletal muscle stem cell cell line is established and the cells proliferate in a bioreactor. The cells can then be differentiated in the bioreactor and further processing produces unstructured meat (minced meat). Furthermore, the cells can be co-cultured with other cell types (adipose stem cells) on an edible scaffold to allow differentiation and formation of structured meat products. The formation of structured meat products can also be achieved by bioprinting of muscle and fat cells.

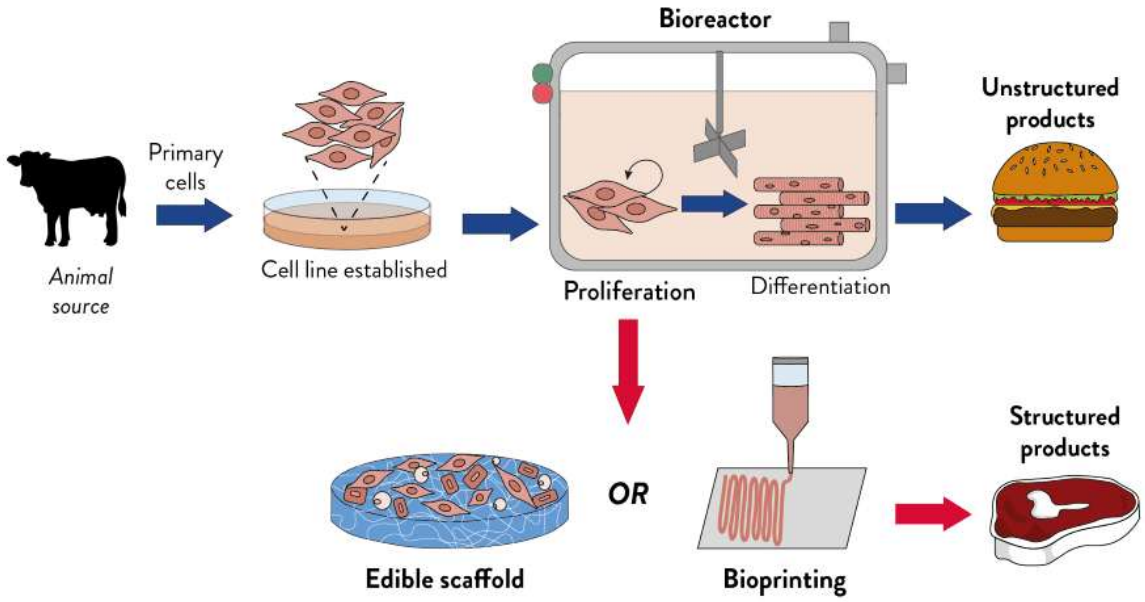

Figure 4. Production of unstructured and structured meat products using primary cells of animal origin.

PRODUCTION PROCESS

The synthetic meat production process involves several fundamental steps that allow animal stem cells to be cultivated and transformed into edible muscle tissue. The main stages of the process are[14-20]:

-Obtaining of stem cells: Stem cell samples are extracted from a living animal through a minimally invasive biopsy. These stem cells are carefully selected to ensure their ability to multiply and differentiate into muscle tissue.

-Cell proliferation: Stem cells are placed in a culture medium that provides essential nutrients, such as amino acids, vitamins and minerals, necessary for their growth. Under these controlled conditions, the stem cells begin to multiply, forming a larger cell population.

-Cell differentiation: Once there is a sufficient number of cells, the differentiation process begins. Stem cells are subjected to specific biochemical and mechanical stimuli so that they develop into specialized muscle cells called myoblasts. These myoblasts fuse with each other and form muscle fibers.

-Electrical stimulation and maturation: In order for the muscle fibers to acquire a texture and consistency similar to those of conventional meat, electrical stimulation is applied to them. This stimulation causes the muscle fibers to contract and strengthen, developing characteristics similar to the muscle tissue of conventionally bred animals.

-Formation of muscle tissue: Muscle fibers are grouped and combined to form three-dimensional muscle tissue. This tissue develops and acquires a structure similar to conventional meat.

-Processing and preparation of meat products: The muscle tissue obtained is processed and molded into different forms of meat products, such as hamburgers, sausages or steaks. During this process, ingredients and spices can be added to enhance the flavor and texture of the synthetic meat.

As research and development in the field of synthetic meat advances, scientists work to improve and optimize each stage of the production process. The objective is to achieve an efficient, scalable and profitable production that allows a greater availability and accessibility of synthetic meat in the market.

Figure 5 represents the general description of a cultured meat production process. Primary cell lines are isolated prior to expansion in a series of bioreactors of increasing size. The cells then differentiate into mature cell types or tissues, often involving the use of biomaterial or hydrogel scaffolds to guide maturation. At the end the mature cells are harvested and assembled into the final product.

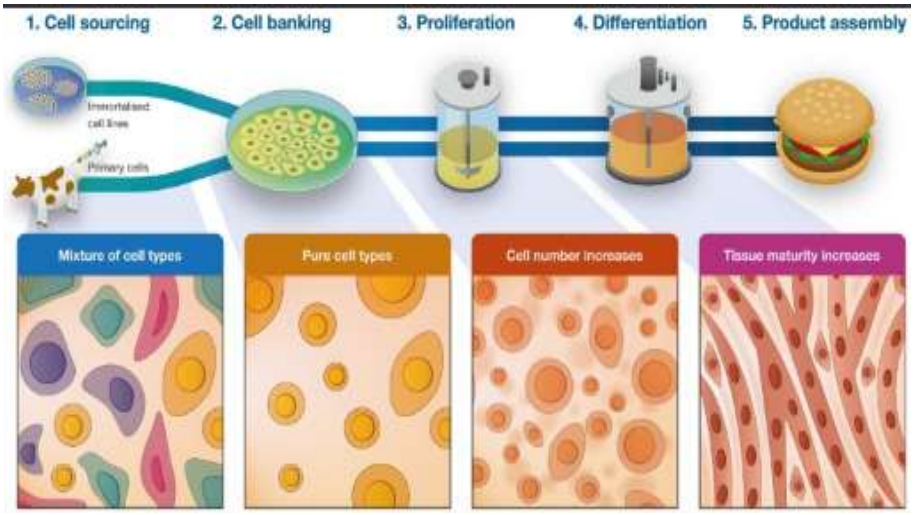

Figure 5. Overview of a cultured meat production process.

In figure 6, the culture process of cultured meat is represented using a scaffold based on vegetable proteins by means of 3D printing technology.

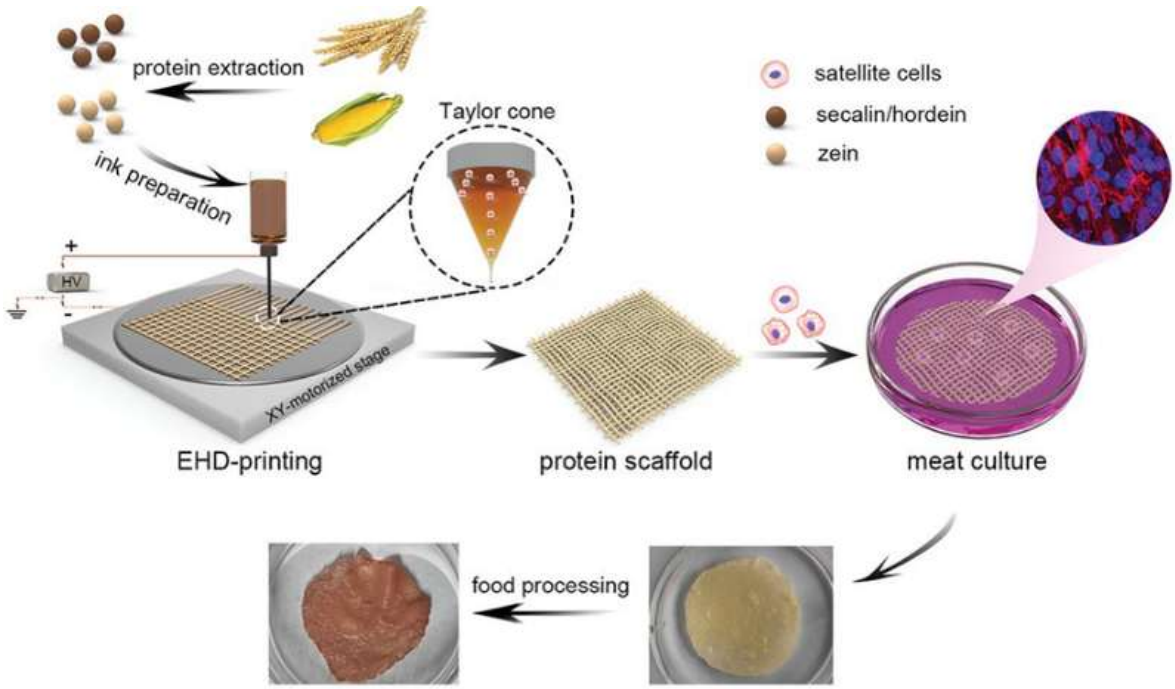

Figure 6. The process of growing cultured meat using a 3D-printed plant protein scaffold.

ADVANTAGES OF SYNTHETIC MEAT

Synthetic meat offers several significant advantages compared to conventional meat. Some of the main advantages are (21-28):

-Environmental sustainability: Conventional meat production has a significant impact on the environment, as it requires large amounts of water, land and feed for livestock, and contributes to deforestation and the emission of greenhouse gases. In contrast, synthetic meat requires fewer natural resources. It is estimated that synthetic meat production can reduce water use by 90%, greenhouse gas emissions by 78%, and land use by 99%.

-Animal welfare: The intensive breeding of animals for meat production implies stressful living conditions and, in many cases, unethical. By sourcing synthetic meat, no animal slaughter is required, eliminating animal welfare issues. Additionally, the synthetic meat is produced in a cruelty-free, controlled environment, ensuring optimal conditions for cell growth.

-Food safety: Synthetic meat is produced in a controlled, disease-free environment, which significantly reduces the risk of contamination by pathogens such as salmonella or E. coli . Additionally, synthetic meat can reduce reliance on antibiotics and hormones used in animal husbandry, contributing to greater food safety.

-Reduction of the impact on biodiversity: The raising of animals for meat is one of the main causes of the loss of biodiversity, since it requires large tracts of land for

grazing and food crops for livestock. By reducing the demand for conventional meat through the production of synthetic meat, the pressure on natural ecosystems can be lessened and biodiversity conserved.

-Customization and reduction of foodborne illness: Synthetic meat is produced from specific stem cells, allowing the possibility of customizing and designing meat products with specific characteristics, such as fat levels, flavor and texture. Also, by avoiding contact with live animals, you reduce the possibility of foodborne illnesses such as bird flu or mad cow disease.

It is important to say that while synthetic meat presents these advantages, there are still challenges to overcome, such as production costs, consumer acceptance and proper regulation. However, with technological advances and growing awareness of sustainability and animal welfare, synthetic meat has great potential to transform the food industry and offer a more sustainable and ethical alternative for the future.[20,23,25]

CHALLENGES AND CONSIDERATIONS

Despite the advantages and potential of synthetic meat, there are also important challenges and considerations that need to be addressed. Some of the main challenges associated with synthetic meat are[29-31]:

-Production costs: Currently, the production of synthetic meat is expensive compared to conventional meat. The high costs of culture media, laboratory facilities, and cell culture equipment are some of the factors that contribute to this challenge. More efficient and scalable production methods need to be developed to reduce costs and make synthetic meat accessible to a wider audience.

-Scalability: The ability to produce synthetic meat on a large scale is essential for it to be a viable alternative to conventional meat. Currently, production is limited to small quantities in laboratories. Further investment in research and development is required to optimize production processes and achieve large-scale production that can meet market demand.

-Consumer Acceptance: Synthetic meat is a relatively new technology and may encounter resistance from consumers. Educating and raising awareness about the benefits and safety of synthetic meat is necessary to gain widespread acceptance. The perception of taste, texture and food safety can influence consumer acceptance and therefore it is essential to continue improving and refining the organoleptic characteristics of synthetic meat.

-Regulations and labeling: Synthetic meat poses regulatory and labeling challenges. It is necessary to establish clear regulations on its production, commercialization and labeling to guarantee safety and transparency for consumers. Regulatory frameworks must address issues such as food safety, proper labeling and the differentiation between synthetic and conventional meat.

-Technological advances: Although synthetic meat production technology has advanced significantly in recent years, improvements are still required in various aspects. Continued research is needed to improve cell culture efficiency, reduce production costs, develop three-dimensional culture methods, and improve the texture and flavor of synthetic meat.

Although synthetic meat presents significant challenges and considerations, its potential to address issues related to environmental sustainability, animal welfare, and food safety is undeniable. As these challenges are overcome and technological advances are made, synthetic meat is likely to become an increasingly viable and widely available option on the market, contributing to a more sustainable and ethical food system.[20]

THE FUTURE OF SYNTHETIC MEAT

The future of synthetic meat is bright and full of possibilities. As technology continues to advance and challenges are overcome, synthetic meat is likely to play an increasingly important role in the food industry. Here are some perspectives on the future of synthetic meat[9,12,17,20]:

-Improvements in production efficiency: Advances in cell culture technology and production methods are expected to enable more efficient and cost-effective production of synthetic meat. This includes optimizing culture media, reducing production costs, and increasing large-scale production capacity. As these improvements are achieved, the price of synthetic meat is expected to decrease and become more accessible to consumers.

-Wide variety of meat products: In addition to hamburgers and sausages, it is expected that synthetic meat can diversify and offer a wide range of meat products, including steaks, chicken, pork and seafood. This would make it possible to satisfy the preferences and demands of consumers seeking alternatives of animal origin in their diet.

-Integration in the food supply chain: As the production of synthetic meat expands, it is likely that it will be integrated into the conventional food supply chain. This means that synthetic meat products could be available in supermarkets, restaurants, and other food establishments. This integration would facilitate access to synthetic meat and increase its availability in the market.

-Contribution to world food security: The growing world population and the demand for animal proteins pose challenges for food security. Synthetic meat offers the possibility of meeting this demand without relying exclusively on intensive animal husbandry. In addition, controlled production in the laboratory reduces the risks of foodborne illnesses and allows for greater traceability and security in the supply chain.

-Innovations in composition and flavor: Scientists and researchers continue to work on improving the composition and flavor of synthetic meat. It is expected that significant advances will be made in the recreation of the muscular structure, the incorporation of fat and other components to achieve a sensory experience closer

to conventional meat. This could increase consumer acceptance and open up new market opportunities.

-Positive environmental impact: One of the main advantages of synthetic meat is its lower environmental impact compared to conventional meat. As synthetic meat production expands, it is expected to contribute to the reduction of deforestation, greenhouse gas emissions and the use of natural resources, which will promote a more sustainable and environmentally friendly food system.

The future of synthetic meat is presented as a promising and sustainable alternative to conventional meat production. As challenges are overcome and technological advances are made, synthetic meat has the potential to transform the food industry, offering more sustainable, ethical, and safer options for consumers.[3,8,14,20]

CONCLUSIONS

Synthetic meat represents an innovative and promising alternative in the food industry. As the demand for animal protein increases and the challenges related to sustainability, animal welfare and food safety become more pressing, synthetic meat offers viable solutions.

The advantages of synthetic meat, such as its lower environmental impact, animal welfare, food safety and the ability to customize, are evident. However, there are still challenges to overcome, such as production costs, consumer acceptance, and proper regulation.

Despite these challenges, the future of synthetic meat is bright. Continued technological advances, ongoing research and development, as well as growing awareness of sustainability and ethics, are driving the evolution of synthetic meat towards a more accessible and market-accepted alternative.

As improvements in production efficiency are achieved and synthetic meat products diversify, we are likely to see a broader integration of synthetic meat into the conventional food supply chain. This will contribute to global food security and provide more sustainable options for consumers.

Therefore, synthetic meat has the potential to transform the way we produce and consume meat, reducing environmental impact, improving animal welfare and offering a safe and nutritious alternative. As we continue to explore and adopt this technology, we will be taking an important step towards a more sustainable and ethical future in food production.

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