

CELLULAR AGRICULTURE

Abstract

Cellular agriculture is a burgeoning field at the forefront of sustainable food production, presenting a revolutionary approach to address the challenges of conventional agriculture. This chapter explores the fundamental concepts of cellular agriculture, delving into its innovative techniques, and the alternative products it offers, the advantages it holds, and the challenges it confronts.

This novel approach eliminates the need for traditional farming practices by cultivating meat, milk, eggs, and other animal-derived items in a laboratory. Techniques, such as cell culture, tissue engineering, and bioreactor technology, play pivotal roles in the efficient and sustainable production of these alternative products, which are, much more environment and consumer friendly.

The chapter explores products of cellular agriculture that are eco-friendly and consumer-friendly such as cultured meat, that can be tailored to be healthier, antibiotic free, and safe from pathogens along with the potential to address animal welfare concerns, offering a more humane and ethical approach to food production.

However, despite the numerous advantages, cellular agriculture faces critical challenges such as upscale and cost reduction of production. Presently, it is expensive, necessitating technological advances to compete with conventional farming.

Keywords: Tissue Culture, Bioreactor, Cell Culture, Genetic modification, Transgenic microorganisms, Cultured meat, Explant Culture.

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I. INTRODUCTION

There is a significant challenge now confronting traditional agriculture. By 2050, the global population is expected to reach 9-11 billion people (Röös *et al.* 2017), this population needs food and other agricultural goods, all while being constrained by limited land and the danger of climate change. A surge in conventional agriculture productivity will soon be required to meet this goal. A potential solution to this problem is the implementation of cellular agriculture, as it emits a smaller amount of greenhouse gases and requires less resources like farmland and water when compared to traditional farming (Rischer, Szilvay, and Oksman-Caldentey 2020).

Cellular agriculture's primary objective is to create agricultural products that, from a molecular perspective, are comparable to those produced by conventional agricultural techniques. Microorganism cultures (such as those of bacteria, yeasts, fungus, and algae) as well as plant and animal cell and tissue cultures can be employed to achieve this goal (Datar and Betti 2010). Resulting products may be a cellular like silk proteins, milk proteins, fats, and egg proteins, they are often created utilizing genetically engineered microbes, or cellular such as plant or animal cells that are living or were once alive (Hoogenkamp 2016) that have not been modified genetically (Rischer, Szilvay, and Oksman-Caldentey 2020) (Eibl *et al.* 2021)

1. Concept of Cellular Agriculture: Cellular agriculture is described here as a set of technologies that use cell-culturing processes to produce animal products (Stephens *et al.* 2018). However, in practice, cellular agriculture may also be employed to produce other animal or plant products (Rischer, Szilvay, and Oksman-Caldentey 2020). Cultured meat is one end product of cellular agriculture and is produced by cultivating animal cells in a nutrient medium in a bioreactor (Post *et al.* 2020). Cultured meat is an example of tissue-based cellular agriculture, whilst another form of production is fermentation-based where no animal cells are used but products are fermented by using bacteria, algae, or yeast (Stephens *et al.* 2018; J. Moritz, Tuomisto, and Ryyänen 2022).

It allows engineers to, essentially generate organic tissue or metabolites outside of an organism by using cellular agriculture. They begin with stem cells which have been safely taken from an animal. Then they culture the cells in a carefully controlled environment that provides a favorable temperature, sufficient oxygen, and plenty of nutrients. The cells proliferate and differentiate, ultimately forming tissue that is similar to tissue obtained from cattle. Professor Mark Post of the University of Maastricht grew the first proof-of-concept hamburger, which was given to tasters in London in 2013 (BBC News 2013). Memphis Meats, a Bay Area start-up, created the world's first cultured meatball in 2016 ("World's First' Lab-Grown Meatball Looks Pretty Damn Tasty | HuffPost Life" n.d.). While technical challenges remain including the fact that, making this meat costs hundreds of dollars each pound., pioneers in the industry believe that it might just be a matter of years before cultured meat can be commercialized (Mattick 2018). Techniques for Cellular Agriculture will be elaborated on in further sections.

2. History: Isha Datar originally used the phrase "cellular agriculture" in 2015 (Stephens and Ellis 2020) however, the early twentieth century is when the field's origins may be found. The discovery of plant cell totipotency (Haberlandt 2003), as well as the ability to

develop animal tissue in a laboratory (Carrel 1912; Gey 1958), created the technological and scientific basis of cellular agriculture. The introduction of sterile fermentation technology (Aiba, Humphrey, and Millis 1965), and the production of recombinant bacterial DNA (Cohen *et al.* 1973) were other major contributions to this field. The key turning points in the evolution of cellular agriculture are shown in Table 1 (Eibl *et al.* 2021).

Table 1: Milestones in the development of Cellular Agriculture (Eibl *et al.* 2021)

1902	Discovery of the totipotency of plant cells
1912	In vitro cultivation of animal cells and tissues
1965	Introduction of sterile fermentation technology
1973	Production of recombinant bacterial DNA
1981	First stable embryonic stem cell lines available
1984	Approval of shikonin
1985	Quorn commercially available in the UK
1988	Plant cell-derived and tissue culture-derived ginsenosides were approved as food additives.
Early 2000's	First research projects on the production of cultivated tissue for food purposes
2004	Foundation of New Harvest by Jason Matheny
2008	Launch of PhytoCellTec <i>Malus domestica</i>
2013	Presentation of the first beef hamburger produced in the lab
2014	SynBio vanillin on the market
2015	First mention of the term cellular agriculture
2016	Veri-te Resveratrol available
2017	Bolt Threads' Microsilk tie sold out and Zoa bioleather exhibited in New York
2019	Prototype of the Moon Parka made of synthetic spider silk on exhibition tour
2020	Perfect Day's Real Dairy Protein available at Smitten Ice Cream

3. Importance and Potential of Cellular Agriculture: By 2050, the world's population is expected to reach 9.5 billion people, posing difficulties for the world's current food production systems (Willett *et al.* 2019). Along with the rising food demand, modern livestock production faces sustainability issues including increased deforestation, climate change, land use, water body pollution, human health concerns, and the morality of raising and eating animals (Poore and Nemecek 2018; Steinfeld, Wassenaar, and Jutzi 2006) (Thornton 2010). Developing only the existing livestock food systems appears insufficient in addressing these global challenges, which has led to the emergence of potential future solutions. Cellular agriculture is one of them, and it refers to a novel sector of food production that uses the post-farm animal bio economy as a framework for arranging its economic activities. (Eibl *et al.* 2021)

The development of cultured meat and other cell-cultured food items has social and technological difficulties, including concerns with scalability of production, currently high production costs, social and cultural difficulties, and consumer acceptability problems (Stephens *et al.* 2018; Post *et al.* 2020). Scientists and engineers have addressed

the challenge of the scalability of culturing meat (M. S. M. Moritz, Verbruggen, and Post 2015). These issues with large-scale manufacturing and the predicted high end-product cost in comparison to conventional meat are still problems that need to be solved (J.-F. Hocquette 2016). According to life cycle assessment studies, producing cultured meat requires significantly more energy than producing conventional meat, but has less of an impact on the environment than producing beef, for example, in terms of water use or climate change. (Tuomisto 2019). A recent study has shown that the production of cultured meat is anticipated to have lower environmental impacts than conventional meat production if sustainable energy sources can be used (Sinke *et al.* 2023). However, the current knowledge of cellular agriculture is fragmented and uncertainties that surround cultured meat are related to social and political acceptance and technical obstacles (J. Moritz, Tuomisto, and Ryyänen 2022).

Many assert that switching from cattle to cellular agriculture would result in significant environmental advantages, such as the reversal of climate change (Cai 2017). Such exaggerated claims, if they portray desired results as automatic and relieve technology developers of the need to seek energy-efficient manufacturing methods, may do more damage than benefit. In reality, however, neither the environment nor human health are guaranteed to gain from a drop in animal output, which may instead result in changes to the energy, agronomic, and chemical systems that sustain meat production. The most appropriate way to put it would be to state that cellular agriculture would provide options for improving the environment – but achieving desirable outcomes will require a realistic understanding of the technology involved as well as a commitment to guiding its development (Mattick 2018).

The conventional idea on how cultured beef affects the environment goes something like this: Lab-grown meat uses up to 99 percent less land, 45 percent less energy, and emits 96% less greenhouse gases than meat derived from animals (Newkirk 2017). A more recent research aimed to comprehend the effects of cultured beef on the environment if it were produced using methods that are presently in use (Mattick *et al.* 2015). High uncertainty was emphasized in the research, which also presented more nuanced and sobering findings. Positively, the research discovered that cultured meat could need far less land than traditional goods - for Poultry, around half as much per unit of meat. However, the research discovered that there may be increased energy needs while making cultured meat – up to 35 percent higher for beef and, for chicken, nearly four times as high as with conventional techniques. The lower land-use estimates are associated with avoided production of animal feed; the relatively high energy requirements are due to the industrial nature of cellular agriculture. (Mattick 2018).

The study's findings on greenhouse gas emissions were conflicting. Cows release the potent greenhouse gas, methane, as a byproduct of digestion. According to the research, it was estimated that cultured meat would reduce greenhouse gas emissions from the creation of methane by around 76% per unit of beef. However, the significant energy consumption associated with cultured meat might result in greenhouse gas emissions that are more than twice as high as those produced by traditional methods in the case of pig and chicken industries (Mattick 2018).

II. CELLULAR AGRICULTURE TECHNIQUES

In every manufacturing process, the initial phase is carried out in a bioreactor, which is a closed, temperature-controlled vessel made of glass, steel, or plastic where cells are combined with nutrients and stirred up and given air. Utilizing parameters that are optimized for productivity is possible with this *in vitro* manufacturing method. However, the entire process must be carried out in an aseptic manner, especially when transferring the carefully chosen production strain or cell line and culture medium into the bioreactor. This is because some production-related organisms grow relatively slowly and could thus be outgrown by contaminating microbes. The bioreactor's contents are extracted after a desired cell biomass concentration or product density is attained, and the target product—such as cells, tissue, proteins, or secondary metabolites—is then separated, purified, and, if necessary, formulated. With complete control over the manufacturing process, this closed production technique provides consistent and repeatable product quality. Additionally, by modifying the metabolism of the producing organism, customized goods may be created. (Eibl *et al.* 2021)

1. Tissue Culture: The growing of organs, tissues, and cells *in vitro* is referred to as tissue culture. The phrase originally included the *in vitro* culture of plant cells as well as animal cells. Organ culture, explant culture, and cell culture are the three main subcategories of tissue culture.

- **Cell Culture:** Cell culture refers to cultures derived from dissociated cells taken from the original tissue ('primary cell culture'). In order to culture cells, they must first be physically and/or enzymatically dispersed into a cell suspension, from which they may either be grown as a monolayer on a solid substrate or as a suspension in the culture medium. These cultures no longer possess their histotypic architecture and often some of the metabolic characteristics that went along with them. They may, however, be replicated and hence enlarged and split to give birth to duplicate cultures. It is possible to characterize cell cultures and freeze a specific population to preserve it. The most apparent benefit of cell culture, and specifically dissociated cell culture, is that it provides access to individual live cells. All things considered, primary dissociated cell cultures are especially well suited to research employing morphological and physiological methods that may be used cell by cell. Because the amount of material that can be obtained from these cultures is often restricted and they include a diverse population of cells, they are clearly less well suited to conventional biochemical methods.

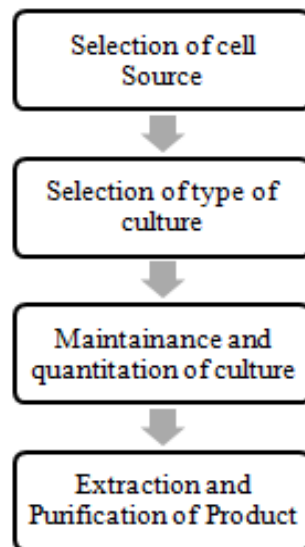
Working with primary cell cultures has one more drawback in that success is not guaranteed. It takes a lot of effort to identify the circumstances that promote healthy cell development and maturation, get culture to grow reproducibly, and document that you have succeeded in all of these goals.

- **Organ Culture:** An organ is defined as a three-dimensional culture of tissue that retains all or part of the histological characteristics of the tissue *in vivo*. The whole organ or a portion of the organ is preserved in a method that permits differentiation and preservation of architecture, often by cultivating the tissue at the liquid-gas interface on a grid or gel. There are disadvantages to organ cultures. It is challenging to evaluate the repeatability of a reaction since organs cannot be reproduced and each

piece of tissue can only be utilized once. And, of course, the particular cells of interest may be very small in number in a given piece of tissue so the response produced may be difficult to detect and quantify. Because the tissue lacks a functional circulatory system, it may be unable to provide enough oxygen and nutrients to all part of it, leading to some cells dying quite quickly. This problem may be ameliorated to some extent by keeping the organ in stirred cultures or in roller bottles which alternately provide air and soluble nutrients.

- **Explant Culture:** Explant culture involves simply allowing tiny fragments of the desired tissue to adhere to an appropriate substrate, often one that has been coated with collagen, and cultivating them in a rich media, typically one containing serum. Following attachment, cell migration is promoted in the plane of the solid substrate. Explants are often kept in Maximov chambers, which are still in use today. In these chambers, cells are grown on coverslips that are sealed over a depression in a thick glass slide. Regular culture plates are now often used, which is considerably more practical since they do not need to be dismantled and rebuilt at every feeding. Immature tissue develops best in dissociated cell culture, and explants are often made from embryonic or neonatal tissue.

Usually, the tissue is simply broken by passing through a nylon mesh or in some cases sliced into slices 0.5 to 1.0 mm thick using scalpels. Thickness is restricted to around a millimetre due to the necessity for diffusion of nutrients and oxygen to the explant's core. Explant cultures may be maintained for months in the hands of experts, and the cells inside the explant continue to grow more or less as expected. One of the primary benefits of this approach is that some features of the tissue's architecture may be retained inside the explant(Unchern 1999).



2. Culturing Cells

- **Step 1: Selection of the Source of Tissue (Adult tissue or embryonic tissue):** Both adult and embryonic tissue may be used to create cultures. Cultures created from embryonic tissue generally survive and grow more effectively than cultures made

from adult tissue. Tissues from almost all parts of the embryo are easy to culture, whereas tissues from adult are often difficult or even impossible to culture. This is thought to be due to the embryo's lower degree of specialization and the existence of replicating precursor or stem cells. Adult tissues often have a more organized extracellular matrix that is less likely to disintegrate and will typically have a lower growth fraction and a higher number of non-replicating specialized cells. Initiation and propagation are more challenging, and the culture's lifetime is often shorter (Unchern 1999). Embryonic or foetal tissue provides numerous practical benefits, but it must be recognized that the cells will be different from adult cells in certain cases, and it cannot be assumed that they will grow into adult-type cells until this is proved by suitable characterization. Commonly utilized embryonic cell lines include MRC-5, other 3T3 lines (mouse embryo fibroblasts), and other human foetal lung fibroblasts.

- **Step 2: Selection of the type of Cell Culture (Organ culture or cell culture):** Preliminary tissue culture efforts were dependent on the explanation of complete tissues or organs that could only be kept in vitro for relatively brief amounts of time. Although it is now more common to create particular cell types from tissues, there are still some circumstances in which it is required to create an entire organ (or a portion of one). The following considerations should be made while embracing a certain culture. After the initial shock of explanation and some core necrosis, organ culture will often stay in a non-growing stable state for a period of many days and even weeks. Organ culture will also sustain cell interaction, retain histological and biochemical differentiation for longer. Due to slight differences in geometry and structure, they are not propagable, usually exhibit larger experimental variation across duplicates, and are typically more challenging to employ for quantitative analyses.
- **Step 3: Maintenance of the Culture:** If a primary culture is not currently intended for use, it may be sub-cultured to produce a cell line before the line's cells become senescent since they may have a relatively short lifespan or have experienced numerous passages. Since they cannot reproduce in vitro, some cells, such as neurons and macrophages, are only helpful in primary cultures.
- **Step 4: Quantification of Cells in Cell Culture:** It could be required to count the number of cells before, after, and even during an experiment in order to execute it effectively. To establish the ideal cell densities for sub-culturing and storage, daily maintenance of cell lines also involves quantitative monitoring of cell development.
- **Step 5: Cell viability Determination:** Before using cells that have just been newly extracted from a tissue or confluent monolayers, the percentage of viable, or alive, cells should be established. This is most often determined by assessment of membrane permeability, under the assumption that a cell with a permeable membrane has suffered severe, irreversible damage. (Unchern 1999)

III. ALTERNATIVE PRODUCTS IN CELLULAR AGRICULTURE

1. **Cell based Fish:** An 80% decline in ocean biomass has been observed, due to fisheries that have been industrialized and fishing due to marine capture (Myers and Worm 2003). Coupled with global warming, these threaten to decimate the ocean wildlife (Funk and Brown 2009). In this state, with the ocean in peril, cell-based seafood provides a new avenue into the sustainability landscape. While the conversation around cell-based cultures is usually on using Mammalian or Avian cell to produce the desired meat this

concept can easily be extended to mollusks, crustaceans, and even fishes. While science and human concerns for cell-based seafood are somewhat similar to those of their land-based counterparts, sustainability is an even more important factor because it may result in more marine ecosystem preservation (Rubio *et al.* 2019).

Procedure:

- **Cell:** Stem cell in form of Myoblasts are harvested from the desired species of fish to act as the base for the desired tissue. In general, the fish is initially sterilized in ethanol, anesthetized, and a tissue sample is removed with a biopsy (Rubio *et al.* 2019).
- **Scaffold Preparation:** The cells require an Extracellular Membrane (ECM) to grow and proliferate outside the body so as not to grow in a random clumpy manner and preserve the texture of the meat as well as prevent the formation of Necrotic centers within the biomass. Since fish protein glycosylation patterns differ from those of mammals, fish cells may need surfaces or scaffolds made of various ECM proteins, such as elastins, collagens, fibronectin, and laminin, as well as fish glycoaminoglycans. (Rubio *et al.* 2019).
- **Media Formulation:** Media used in growth of mammalian cell lines is used such as Eagle's media, Modified Eagle's media (MEM), Medium 1999 (M199) and Leibowitz's 15 (L-15) medium can be used with a couple of additives to boost the cell proliferation rate (Fernandez *et al.* 1993). These include Fetal bovine serum (FBS), fetal calf serum (FCS) (Arora 2013), fibroblast growth factor (FGF2) (Bain *et al.* 2013), Vitamin E and some fatty acids (Scholefield and Schuller 2014).
- **Bioreactors:** Bioreactors provide a sterile, closed environment for the cells to multiply and proliferate. It provides a constant and optimum pH, Temperature, and Osmolarity to the cells to ensure maximum Growth.

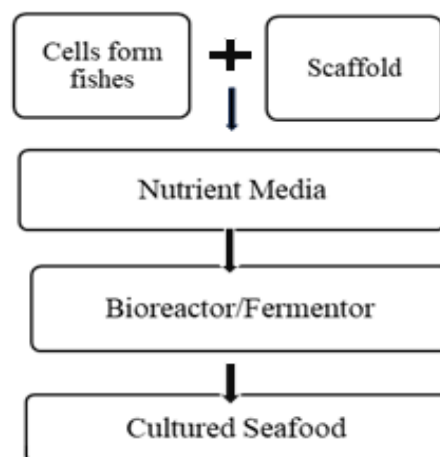


Figure 2: (Edelman *et al.* 2005) Demonstrates the procedure for manufacturing Cell based fish.

2. **Cell Based Milk:** Despite the fact that the procedure is significantly simpler and the technology is older and more established, the production of dairy products without cows attracts much less attention than the production of meat without animals. Currently, only

the United States has a small amount of commercially available fermentation-derived dairy. Despite this limited availability, there are companies building the capacity to bring it to global markets within the next few years, based upon existing industrially scaled food processing infrastructure. Rennet, as a cellular agriculture product, is already produced on an industrial-scale, and there are multiple existing uses for milk solids, regardless of their origin (Mendly-Zambo, Powell, and Newman 2021).

The biggest producer of cultured milk, Perfect Day, Inc. describe their milk as “flora based” as they use transgenic microfauna such as Yeast and/or Bacteria that has been genetically modified to produce Bovine proteins such as casein and whey proteins (alpha-lactalbumin and beta-lactoglobulin) (Compton 2016; Pandya 2014). These are then added with plant fats and water to produce the milk. This milk has been claimed to have a longer shelf life and be more food safe compared to regular milk, with the added benefit of being hormone-, antibiotic-, and lactose-free (“Very Dairy” n.d.).

Cultured milk ensures that everyone gets the benefits of the milk they like, without the ethical implication of cow exploitation.

- 3. Cell Based Leather:** Modern Meadow, an American biotechnology business, has developed a method for producing leather-like fabric without the need of cows or other animals.

But it's about more than just imitation, “We don't want people to just think about it as an ersatz leather,” says chief technology officer of Modern Meadow Dave Williamson. Instead, Modern Meadow may be able to bioengineer the substance to make it more durable, stretchable, or scratch-resistant. With cows no longer limiting them, they may create brand-new textures. (Dance 2017)

- 4. Cell based Meat:** The Huge energy and resource demand of the animal agriculture industry Along with the ethical underpinnings of slaughtering millions of animals for production of meat for consumption is a very concerning issue in the modern world. To combat this issue multiple new avenue are being explored Cellular agriculture being one of them.

Skeletal muscle is the main component of edible meat (Datar and Betti 2010), as well as other cell types, such as red blood cells, adipocytes, fibroblasts, endothelial cells and leukocytes, connective tissue, and blood vessels, which, together, generate the texture, flavor, and, ultimately, the taste experience. Therefore, one of the goal of animal cell and tissue culture-based meat (also known as artificial meat, clean meat, cultured meat, and in vitro meat) is to obtain a sensory and nutritive profile identical to the original packed into a 3D structure. (Eibl *et al.* 2021).

Production procedure is similar to cultured fish.

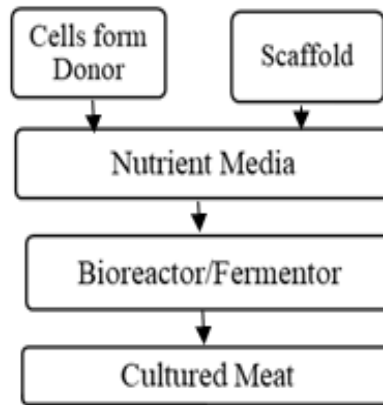


Figure 2: Procedure for production of Cultured Meat(Ong, Choudhury, and Naing 2020)

Given the rapid evolution of this field, regulations and standardization of cell-based meats have not been able to keep up. This has led to a number of difficulties with regard to its nomenclature. Claims that cell-based meats are superior over conventional meats have been challenged by existing meat producers (U.S. Cattlemen’s Association 2018).

Table 2: Common Cellular Agriculture Products and Companies(Eibl et al. 2021)

Product Type	Animal Origin	Company
Cultured meat for human consumption	Beef	Aleph Farms, BioFood Systems, Technologies, Biftek, Future Meat
	Bison	Orbillion Bio
	Chicken	Cubiq Foods , Memphis Meats, Future Meat TechnologiesPet, IntegriCulture, JUST, ClearMeat.
Meat for pet consumption.	Mouse	Wild Earth, Because Animals
Seafood	Crab	Shiok Meats
	Fish Maw	Avan Meats
	Lobster	Shiok Meats
	Salmon	BlueNalu
	Shrimp	Shiok Meat
	Tuna	BlueNalu, Finless Foods
Animal Milk	Goat, Cow milk	BIOMILQ, Turtle Tree Labs

IV. ADVANTAGES OF CULTURED MEAT

- 1. Slaughter-Free Harvest:** Since the only animal-based product, that will be required will be the myoblasts or stem cells from the animals, which can be harmlessly extracted from the animals, Cultures meat will ensure that no animals are slaughtered to feed the human population. While, as of now Foetal Bovine Serum is required in the early steps of the media(Specht 2020) researchers are working on ways to avoid it.

Even in the cases where a biopsy may be required, instead of forcing an immense population in a small area, as is the case in the current industry, only a small herd will be required (Zuhaib F. Bhat *et al.* 2019).

- 2. Exploitation free Milk:** As discussed above, by using bovine transgene expressing microfauna and plant fats, milk can be generated without forcing the cattle exploitation, that is the state of today's dairy industry ("How We Get Microflora to Create Sustainable Protein - Perfect Day" n.d.).
- 3. Environment sustainability Advantages and Urbanization of the Industry:** Conventional meat, dairy, and poultry production usually takes place in rural areas away from the cities due to the sheer scale required for the farms, however cultured meat production can take place in significantly lesser space, as the batteries required can be stacked in a vertical manner this significantly reducing the horizontal area required. Coupled with the fact that the fermenter/Bioreactor will pack the products much more densely, the media effluent treatment area will be the only place occupying extra horizontal space. This will allow for the production to take place near the cities thus cutting down on the transportation cost (Zuhaib F. Bhat *et al.* 2019)

This innovative production system of cellular agriculture may potentially reduce greenhouse gas emissions (GHGs) by 78% to 96%, water use by 82% to 96%, and land use by 99% when compared to conventional meat production, presuming cyanobacteria were employed as the source of energy and nutrients (Tuomisto and Teixeira De Mattos 2011).

- 4. Safe and Nutritionally balanced by Design:** Since all the ingredients are sterile and monitored along with always being in aseptic conditions this will eliminate the chances of any infection, disease, parasites, or chemical contamination in the end product. With more control over the additional substances, cell types, and their differentiation in this system, the generated product's composition can be customized to meet the needs of the market. To enhance the product's nutritional status, omega-3 fatty acids and other elements, including vitamin B12, that can be taken from the environment, could be added. It is also possible to obtain product with specific fatty acid profile or with additional vitamins and minerals, even the ones that are lacking in conventional meat for e.g., Vitamin C by adjusting the composition of the media (Zuhaib F. Bhat *et al.* 2019).
- 5. Rare and Exotic Meats:** Since there is no animal slaughter involved in the production of in vitro meat, Adding a variety of opulent options to the menu, such as exotic wild animals becomes a possibility. This meat may be presented initially in a range of selections including chicken, beef, and shellfish, and later in unusual possibilities like snow leopard burgers and rhino sausages etc. (Zaraska 2013).
- 6. Faster and Efficient:** By cultivating the meat in an artificial environment, production times for meat will be significantly shortened compared to current systems, which require weeks to months for chicken (5 to 7 weeks for broilers and 18 months for layer hens), months for lamb (6 to 8 months) and pork (5 to 6 months), and years for beef (18 months for beef cattle and 4 years for dairy cows) (Aussie Abattoirs 2019).

Also considering the fact that around 75% to 95% of feed given to animals are wasted in metabolism of animals and in development of inedible features such as horns, hooves, hide, bones, hairs etc.(Zuhaib Fayaz Bhat, Kumar, and Fayaz 2015) By growing meat in labs this waste is stopped and the efficiency in usage of feed skyrockets.

- 7. Polar Settlements and Long-Term Space Explorations:** In instances where food production is more cost-effective than transportation, such as polar communities, cultured meat production may offer an alluring alternative to growing fresh food. For permanent space stations and long term space exploration missions, using live creatures as "reactors" to perform life support services, such as algae, bacteria, higher plants, or animals, is seen to be a far more appealing option (Schwartzkopf 1997; Drysdale, Ewert, and Hanford 2003).

V. CHALLENGES IN CELLULAR AGRICULTURE

With all the above stated benefits cellular agriculture still faces a lot of challenges for it to be commonly commercialized, whether it be social, economical or ethical. Some of these are;

- 1. Scalability Issues:** Myoblasts are typically grown in cell culture flasks or Petri dishes, where cells remain attached to the bottom and receive nutrients from the media that surrounds the cells. Like other mesenchymal cells (anchorage-dependent cells), myoblasts can grow and multiply when they come into touch with a surface. These technologies cannot be scaled up to industrial levels for commercial use due to the inadequate surface to volume ratio. Suspension Culture is also considered as one of the possibilities by using suspended beads to act as surfaces for myoblasts to attach to(Zuhaib F. Bhat *et al.* 2019).
- 2. Obtaining the Stem Cells:** The source of the primary cell is one of the most heavily contested topics in this field. Cell lines and induced pluripotent cells are the most promising alternatives to getting stem cells via Biopsies. Cell lines could either be Chemically induced(Ramboer *et al.* 2014), Genetically modified or even Obtained by Spontaneous mutation("Introduction to Cell Culture | Thermo Fisher Scientific - IN" n.d.). Immortalization of cells (via hybridoma technique) can lead to increased differentiation ability and proliferation rate, along with preventing requirement of fresh biopsies. Cell lines do, however, have certain drawbacks, including passaging, subculturing, misidentification, and continuous evolution(Stephens *et al.* 2018). Induced pluripotent cells are another one of the more recent, promising Technique in this field (Genovese *et al.* 2017; Wu and Hochedlinger 2011).
- 3. Resemblance to the Texture and Taste of Conventional Meat:** Cultured meat's commercial viability will depend on how well it imitates the taste and texture qualities of traditional meat and is accessible at a price that is competitive with it. As of right present, no technology is able to create fully structured 3D meat that accurately mimics a steak or a prime rib. It's difficult to replicate the flavors of meat in vitro since it's made up of more than a thousand components that are generated from fat and are water soluble. However, some people contend that because cultured poultry meat does not include off-flavor feed ingredients, its flavor should be superior to that of ordinary poultry meat.

4. **Acceptance among the General Public:** When examining the possibilities of cultured meat in comparison to regular beef(A. Hocquette *et al.* 2015), there were a number of restrictions to be aware of, including social, economic, and technical ones as well as consumer acceptance issues. According to a study(Siegrist, Sütterlin, and Hartmann 2018), the description of this new product has a significant impact on how the participants perceive it. The authors stressed the significance of explaining, labeling, and introducing the cultured meat in a nontechnical manner, placing more emphasis on the product than the production process, in order to promote consumer acceptability of the product.

5. **Availability of Scaffolds and Culture media:** As of Now Culture media is very expensive to produce and thus, is available for research purposes only, since it costs an impractical amount of money to generate culture media for the scale of industrial usage. To combat this issue transgenic Microbes or plants may be used to generate components of the media, and instead of fetal calf serum, serum from mature animals such as Horse serum may be used. Typically, 10% to 20% of growth media is added to the culture media for both stages of skeletal muscle development and with 0.5% to 2% Fetal calf Serum or Horse serum. For long-term cultures, frequent components include antibiotics and antimetotics.

6. **Ethics:** Ironically, animal suffering and slaughter are one of the main ethical concerns related to the current cultured meat manufacturing technology. Current production techniques include collecting biopsies from donor animals for stem cell research and employing media based on fetal calf serum, which uses blood from fetuses collected from slaughtered pregnant cows. Another problem with promoting cultured meat is that it is wrong to do so even if we think it will be produced ethically in the future. While research towards an animal-free growing medium is going forward, the meat created in laboratories and by small firms and start-ups have not yet completely liberated itself from the afflictions of the animal abuse(Zuhaib F. Bhat *et al.* 2019).

Table 3: Cultured Meat: An Overview(Zuhaib F. Bhat *et al.* 2019).

Methods of preparations	Advantages	Challenges
Cell culture	Eco Friendly	Production costs
Tissue Culture	Safe and Customizable according to nutritional requirements	Ethics
Organ Printing	Faster And Efficient	Acceptance among General population
Nanotechnology	Slaughter Free	Availability of Media
Biophotonics	Infection and Antibiotic Free	Resemblance with conventional meat.

VI. CONCLUSION

In conclusion, Cellular Agriculture represents a revolutionary approach to food production that has the potential to reshape the global food system. This chapter has explored

the techniques employed in cellular agriculture, the range of alternative products it offers, its numerous advantages, and the significant challenges it faces. Cellular agriculture enables the production of meat, milk, and other animal-derived items without the need for traditional farming practices, thus providing a much more humane and ethical source. The innovative techniques involved, such as cell culture, tissue engineering, and bioreactor technology, have opened up new avenues for sustainable and ethical food production.

Cellular agriculture has the potential to address pressing environmental concerns, by reducing significant source of greenhouse gas emissions, deforestation, and water pollution in traditional livestock farming. Moreover, the alternative products generated through cellular agriculture offer numerous benefits. Cultured meat, for instance, can be tailored to be healthier, antibiotic free, and pathogen devoid.

Despite its immense potential, cellular agriculture faces formidable challenges. Scaling up production and reducing costs are critical obstacles to overcome as achieving cost parity with conventional farming methods is essential for widespread adoption. Regulatory frameworks surrounding cellular agriculture need to be standardized to ensure food quality and educating consumers and dispelling misconceptions about cultured meat.

Cellular agriculture is a transformational answer to the environmental, ethical, and health issues connected with traditional animal agriculture. While challenges exist, with efforts from the scientific community, regulatory bodies, and consumers alike, cellular agriculture can become an indispensable component of a thriving and sustainable global food system.

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