**Cellular Agriculture**

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**Abstract**

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

 The techniques employed in cellular agriculture involve harnessing biotechnology and tissue engineering to cultivate animal-based products from cell cultures. This novel approach eliminates the need for traditional farming practices by cultivating meat, milk, eggs, and other animal-derived items in controlled laboratory settings. Key techniques, such as cell culture, tissue engineering, and bioreactor technology, play pivotal roles in the efficient and sustainable production of these alternative products.

 Among the many advantages of cellular agriculture, its potential to address pressing environmental concerns is paramount. Conventional livestock farming has been a major driver of greenhouse gas emissions, deforestation, and water pollution. Through a significant reduction in land usage and resource consumption, cellular agriculture presents a viable solution for combating climate change and promoting environmental conservation.

 Moreover, cellular agriculture offers a range of alternative products that provide various benefits to both consumers and the environment. Cultured meat, for example, can be tailored to be healthier, free of antibiotics, and safer from foodborne pathogens. These products also have the potential to address animal welfare concerns, as they eliminate the necessity for intensive farming practices and slaughterhouses, offering a more humane and ethical approach to food production.

 However, despite the numerous advantages, cellular agriculture faces critical challenges that must be addressed for successful integration into the mainstream food industry. Chief among these challenges is the scale-up and cost reduction of production. Presently, cellular agriculture remains relatively expensive, necessitating advancements in technology and infrastructure to achieve cost competitiveness with conventional farming methods.

 Another pressing challenge lies in regulatory frameworks and consumer acceptance. Developing standardized regulations that ensure food safety, quality, and transparent labeling is crucial to instill consumer confidence and facilitate market expansion. Moreover, public perception and understanding of cellular agriculture must be improved to overcome skepticism and foster broader acceptance of these innovative products.

**I. Introduction**

Traditional agriculture is currently facing an enormous challenge. The world population, is set to reach 9–11 billion people by 2050 (1) and needs to be supplied with food and other agricultural products, all while under the pressure of limited land and the threat 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 fewer greenhouse gases and requires less land and water than traditional farming methods(2) .

 The main goal of cellular agriculture 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 (3). Resulting products may be acellular like milk proteins, silk proteins, egg proteins, and fats, and tend to be produced using genetically modified microorganisms, or cellular such as living or formerly living plant or animal cells (4) that tend not to be genetically modified (2) (5)

**A. Concept of Cellular Agriculture**

 Cellular agriculture is defined here as a selection of technologies to manufacture livestock products with cell-culturing techniques (6), although in practice, cellular agriculture can also be used for the production of other livestock products (2). Cultured meat is one end product of cellular agriculture and is produced by cultivating animal cells in a nutrient medium in a bioreactor(7). 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 (6,8).

 It allows engineers to, essentially generate organic tissue or metabolites outside of an organism by using cellular agriculture. They start with stem cells that can be extracted harmlessly 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 grow and divide, and eventually differentiate into tissue that is identical to tissue harvested from livestock. The first proof of concept hamburger was grown by University of Maastricht Professor Mark Post and served to tasters in London in 2013 (9). In 2016, Bay Area start-up Memphis Meats produced the world’s first cultured meatball (10). While technical challenges remain including the fact that, the meat costs thousands of dollars per pound to make, pioneers in the industry believe that cultured meat will be commercialized within a matter of years (11).

 Techniques for Cellular Agriculture will be elaborated on in further sections.

**B. History**

 The term cellular agriculture was first coined by Isha Datar in 2015 (12) but, the field’s roots go back as far as the early twentieth century. The discovery of plant cell totipotency (13), as well as the ability to develop animal cells and tissue in a laboratory (14,15), created the scientific and technological basis of cellular agriculture. The introduction of sterile fermentation technology (16), and the production of recombinant bacterial DNA (17) were other major contributions to this field. Table 1 depicts the major milestones in the development of Cellular Agriculture (5).

|  |  |
| --- | --- |
| 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 | Approval of plant cell–derived and tissue culture–derived ginsenosides 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 Malus domestica |
| 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 |

Table 1. Milestones in the development of Cellular Agriculture (5)

**C. 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 (18). Along with the rising demand for food, 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 (19,20)(21)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 bioeconomy as a framework for arranging its economic activities.(5)

 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 (6,7). Scientists and engineers have addressed the challenge of the scalability of culturing meat (22). 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 (23). 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. (24). 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 (25). 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 (8).

 Some people also claim that replacing livestock with cellular agriculture will usher in dramatic improvements in the environment, such as a reversal of climate change (26). Such hyperbolic promises, if they present desirable outcomes as automatic and absolve technology developers of the need to pursue energy efficient production processes, may do more harm than good. In reality, while a decline in livestock production may lead to shifts in the energy, land, and chemical systems that support the production of meat, neither environmental nor health benefits are guaranteed. It might be most accurate to say that cellular agriculture will present opportunities for environmental improvement – but achieving desirable outcomes will require a realistic understanding of the technology involved as well as a commitment to guiding its development(11).

 Conventional wisdom regarding the environmental impact of cultured meat goes something like this: Compared to animal-derived meat, lab-grown meat requires up to 99 percent less land and 45 percent less energy, and produces 96 percent fewer greenhouse gas emissions (27). A more recent study attempted to understand the environmental impacts of cultured meat if it were produced with techniques already in common use (28). The new study emphasized high uncertainty and reported more complicated – and cautionary – results. On a positive note, the study found that cultured meat could require substantially less land than is required for conventional products – for poultry, roughly half as much per unit of meat. On the other hand, the study found that the energy requirements for producing cultured meat might be higher – 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.(11)

 The study’s results regarding greenhouse gas emissions were mixed. As a by-product of digestion, cows produce methane, a powerful greenhouse gas. The study estimated that cultured meat, by avoiding methane production, would produce about 76 percent fewer greenhouse gas emissions per unit of beef. But where pork and poultry are concerned, the high energy consumption associated with cultured meat could result in greenhouse gas emissions more than twice as high as conventional techniques produce(11).

**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. This in vitro production approach permits using parameters optimized for productivity. However, it is necessary to ensure that the entire operation is conducted aseptically, especially during the transfer of the carefully chosen production strain or cell line and culture medium into the bioreactor, as some organisms used for production grow comparatively slowly and thus may be outgrown by contaminating microbes. Once a desirable cell biomass concentration or product titer is reached, the bioreactor content is harvested and the target product, e.g., cells, tissue, protein, or secondary metabolite, is separated, purified, and, if required, formulated. This closed production method ensures full control over the production process and hence constant and reproducible product quality. In addition, tailor-made products can be designed by influencing the metabolism of the production organism.(5)

**A. 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.

**1. 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. However, they can be propagated and hence expanded and divided to give rise to replicate cultures. Cell cultures can be characterized and a defined population can be preserved by freezing. The most obvious advantage of cell culture, and of dissociated cell culture in particular, is that it makes individual living cells accessible. All in all, primary dissociated cell cultures are particularly amenable to study using morphological and physiological techniques, which can be applied on a cell-by-cell basis. They are obviously less well suited to traditional biochemical approaches because the quantity of material obtainable from these cultures is usually limited and they contain a heterogeneous population of cells.

 Working with primary cell cultures has one more disadvantage 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.

**2. 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 part of the organ is maintained in a way that allows differentiation and preservation of architecture, usually by culturing 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. It may not be possible to supply adequate oxygen and nutrients throughout the tissue because of the absence of a functioning vascular system, so necrosis of some cells occurs fairly rapidly. 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.

**3. 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. More recently, it has become common to use regular culture dishes, which are much more convenient since they do not need to be disassembled and reassembled at each feeding. As with dissociated cell culture, immature tissue grows best, and explants are generally prepared from embryonic or neonatal tissue. Typically, the tissue is cut with scalpels into slices 0.5 to 1.0 mm thick, but in some cases, it is simply fragmented by passing through a nylon mesh. The need for diffusion of nutrients and oxygen to the center of the explant limits thickness to about a millimeter. In experienced hands, explant cultures can be maintained for months, and cells within the explant continue their development more or less appropriately. One of the principal advantages of this method is that some aspects of the tissue's architecture can be preserved within the explant (29).

**Culturing cells**

Figure . Procedure of Tissue Culture

**Step 1. Selecting sources of tissue for culture (Adult or embryonic tissue)**

Both adult and embryonic tissue may be used to create cultures. Generally, cultures made from embryonic tissue survive and develop more successfully than those 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 presumably reflects the lower level of specialization and presence of replicating precursor or stem cells in the embryo. Adult tissues often have a more organised extracellular matrix that is less likely to disintegrate and will typically have a lower growth fraction and a higher number of non-replicating specialised cells. Initiation and propagation are more difficult, and the lifespan of the culture is often shorter.(29)

 Embryonic or fetal tissue has many practical advantages, but it must always be remembered that in some instances the cells will be different from adult cells and it cannot be assumed that they will mature into adult-type cells unless this can be confirmed by appropriate characterization.

 MRC-5, various 3T3 lines (mouse embryo fibroblasts), and other human fetal lung fibroblasts are examples of widely used embryonic cell lines.

**Step 2. Selecting types of animal cell culture (Organ culture or cell culture**)

 Early attempts at tissue culture relied on the explantation of complete tissues or organs that could only be kept in vitro for relatively brief periods 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).

 In adopting a particular type of culture, the following points should be taken into account. Organ culture will preserve cell interaction, retain histological and biochemical differentiation for longer, and, after the initial trauma of explantation and some central necrosis will generally remain in a non-growing steady state for a period of several days and even weeks. 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. Maintaining 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 macrophages and neurons, are only helpful in primary cultures.

**Step 4. Quantitation of cells in cell culture**

 For properly run experiments, it may be necessary to count the cell numbers before, after and even during the experiment. Day to day maintenance of cell lines also requires quantitative assessment of cell growth so that optimum cell densities for sub-culturing and storing can be determined.

**Step 5. Cell viability determination**

 When cells are freshly isolated from a tissue or confluent monolayers are subcultured, the proportion of living, or viable, cells should be determined before they are used. 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.(29)

**III. Alternative Products in Cellular Agriculture**

**1. Cell based Fish.**

An 80% decline in ocean biomass has been observed, due to industrialized fisheries and fishing due to marine capture (30). Coupled with global warming, these threaten to decimate the ocean wildlife (31). 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 (32).

**Procedure**

 Figure 2 (33) Demonstrates the procedure for manufacturing Cell based fish.

Figure Procedure for manufacture of cultured fish.

**(i) Cell harvest:** 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(32).

**(ii) Scaffold preparation:** The cells require an Extracellular Membrane (ECM) to grow and proliferate outside the body so a not to grow in a random clumpy manner and preserve the texture of the meat ass 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.(32).

**(iii) Media Formulation:** Media used in growth of mammalian cell lines is used such as Eagle’s media, Modifies Eagle’s media(MEM), Medium 1999(M199) and Leibowitz’s 15 (L-15) medium can used with a couple of additives to boost the cell proliferation rate (34). These include Fetal bovine serum (FBS), fetal calf serum (FCS) (35), fibroblast growth factor (FGF2)(36), Vitamin E and some fatty acids(37).

**(iv) Bioreactors:** Bioreactors provide a sterile, closed environment the cells to multiply and proliferate. It provides an constant and optimum pH, Temperature, and Osmolarity to the cells to ensure maximum Growth.

**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(38).

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) (39,40). These are then added with plant fats and water to produce the milk. This milk as 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 (41).

 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 company has found a way to produce leather-like fabric without cows or other animals.

But it’s about more than mimicry. “We don’t want people to just think about it as an ersatz leather,” says chief technology officer 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.(42)

**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.

 Edible meat consists primarily of skeletal muscle (3), 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. Animal cell and tissue culture–based meat (also known as artificial meat, clean meat, cultured meat, and in vitro meat) aims to achieve a sensory and nutrient profile similar to the original packed into a 3D structure (5).

 Production procedure is similar to cultured fish.



Figure 3. Procedure for production of Cultured Meat (43)

 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 (44).

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

*Table 2. Common Cellular Agriculture Products and Companies(5)*

**IV. Advantages of Cultured Meat**

**A. 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 (45) 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(46).

**B. 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(47).

**C. 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(46)

 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 if cyanobacteria were employed as the source of energy and nutrients(48).

**D. 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(46).

**E. Rare and exotic meats.**

Since there is no animal slaughter involved in the production of in vitro meat, it is possible to add a variety of opulent options to the menu, such as exotic wild animals. 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.(49).

**G. 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)(50).

 Also considering the fact that around 75% to 95% of feed given to animals are wasted in metabolism of animals and in growth of inedible parts such as horns, hooves, hide, bones, hairs etc.(51) By growing meat in labs this waste is stopped and the efficiency in usage of feed skyrockets.

**H. 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 living organisms, such as algae, bacteria, higher plants, or animals as the “reactors” to provide life support functions is considered an much more attractive avenue(52,53)

**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, weather it be social, economical or ethical. Some of these are;

**A. 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 (46).

**B. 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(54), Genetically modified or even Obtained by Spontaneous mutation(55). 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(6). Induced pluripotent cells are another one of the more recent, promising Technique in this field (56,57).

**C. 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.

**D. Acceptance among the General Public**

When examining the possibilities of cultured meat in comparison to regular beef(58), 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(59), the description of this new product has a significant impact on how the participants perceive it. The authors stressed the significance of explaining, labelling, 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.

**E. 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 antimitotics.

**F. Ethics**

Ironically, animal suffering and death 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 strangled 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 produced in labs and by start-up businesses has not yet completely liberated itself from the afflictions of the animal abuse(46).

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| --- |
| Table 3. Cultured Meat: An Overview(46). |
| 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 leverages biotechnology and tissue engineering to cultivate animal-based products from cell cultures, enabling the production of meat, milk, and other animal-derived items without the need for traditional farming practices. The innovative techniques involved, such as cell culture, tissue engineering, and bioreactor technology, have opened up new avenues for sustainable and ethical food production.

 One of the most significant advantages of cellular agriculture is its potential to address pressing environmental concerns. A significant source of greenhouse gas emissions, deforestation, and water pollution is traditional livestock farming. By circumventing the need for vast expanses of land and reducing the environmental impact, cellular agriculture can play a crucial role in mitigating climate change and conserving natural resources.

 Moreover, the alternative products generated through cellular agriculture offer numerous benefits. Cultured meat, for instance, can be tailored to be healthier, free of antibiotics, and devoid of harmful pathogens. Additionally, it can provide a more consistent and safe food supply, reducing the risk of foodborne illnesses.

 Furthermore, cellular agriculture has the potential to improve animal welfare. By eliminating the necessity for intensive farming practices and slaughterhouses, it offers a humane and compassionate approach to food production, resonating with the growing consumer demand for ethically sourced products.

 However, despite its immense potential, cellular agriculture faces formidable challenges that must be addressed to ensure its successful integration into the mainstream food industry. First and foremost, scaling up production and reducing costs are critical obstacles to overcome. Currently, the technology remains expensive, and achieving cost parity with conventional farming methods is essential for widespread adoption.

 Additionally, regulatory frameworks surrounding cellular agriculture need to be developed and standardized to ensure food safety, quality, and labeling transparency. Public acceptance and perception of cultured products also play a pivotal role in shaping the market's trajectory, underscoring the importance of educating consumers and dispelling misconceptions.

 In conclusion, cellular agriculture holds immense promise as a transformative solution to the environmental, ethical, and health challenges associated with conventional animal agriculture. By harnessing cutting-edge technologies and embracing a sustainable approach, it has the potential to revolutionize the food industry and pave the way for a more sustainable and compassionate future. While challenges exist, with concerted 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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