Chapter 23

Introduction to Commercial Opportunities, Future Directions, and Novel Approaches to Fermentation

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Abstract

Cellular agriculture has been increasingly touted as a greener alternative to traditional agriculture. Cultivated meat (CM) has attracted significant investments due to its promise to revolutionize the food industry. Still in its infancy, the technology faces several challenges, especially regarding scalability and organoleptic properties of the product. Recent advances in fermentation technology have allowed for the production of a multitude of food products that can transform the alternative protein sector, particularly CM. In this chapter, we examine the ways to reduce or resolve some of the current constraints in CM production by integrating traditional, biomass and precision fermentation.

This chapter will review the current commercial landscape and obstacles that aspiring companies in the field face in launching hybrid products. Quite a few fermentation companies are producing ingredients that can be applied to CM. Research and development in this area will make fermentation more relevant and expand its applications.

Key Words: alternative protein, cell-based meat, cellular agriculture, cultivated meat, cultured meat, fermentation, novel food, scaffolds, serum-free media

Key Objectives

- Describe the positive synergistic benefits that fermentation can bring to cultivated meat (CM) production.
- Examine the four broad areas related to CM production that can potentially be addressed with fermentation: development of serum-free media (SFM); development of scaffolding materials; improvement in the sensorial characteristics of CM; and improvement in the nutritional value of CM.
- Introduce the commercial opportunities within the sector as consumer acceptance of CM is expected to rise with increasingly accommodative regulations worldwide.

1. Introduction

Over the past century, developments in fermentation have allowed it to transcend its traditional role of preservation and flavor enhancement (Vilela, 2019). Its application has been extended to diverse fields. In the alternative protein industry, variations of fermentation have taken three forms: traditional, biomass and precision fermentation. Proteins and food ingredients can be manufactured using microorganisms. Proteins produced by fermentation could reshape the food industry as alternatives to animal-derived proteins that provide the same nutrition and sensory experiences as their animal-derived counterparts. Precision fermentation can use any of a variety of microbes that can use a various sources of feedstock, companies can concoct a circular production plan to produce proteins in a scalable and sustainable manner (Pescuma et al., 2015). Some fermentation produced proteins are evaluated and classified as high-quality proteins based on their protein digestibility-corrected amino acid scores, indicating their potential as protein additives in food (Bashi et al., 2019). As one of the earliest proponents of fermentation technology, the company Quorn used the filamentous fungus *Fusarium venenatum* to manufacture nutritious mycoprotein products (Denny et al., 2008).

The potential of cellular agriculture to be a greener method for producing food compared to traditional agricultural products has been increasingly highlighted in recent years (Eibl et al., 2021). Among the products of interest, cultivated meat (CM) is at the foreground. Substantial investments have been made in CM due to its potential to revolutionize the food industry by increasing the supply of meat-like products while minimizing environmental impacts and potentially eliminating the need for animal slaughter (Handral et al., 2022). However, the challenges remain such as the scalability of production and successfully mimicking the organoleptic properties of traditionally sourced meat created through cultivated means. This chapter discusses how the assimilation of traditional, biomass, and precision fermentation into the CM production process can potentially attenuate or even eradicate some of these challenges. Examples of companies using these techniques can be found in Figure 23.1. The existing commercial landscape and obstacles encountered in this domain will also be analyzed for aspiring companies in the field.

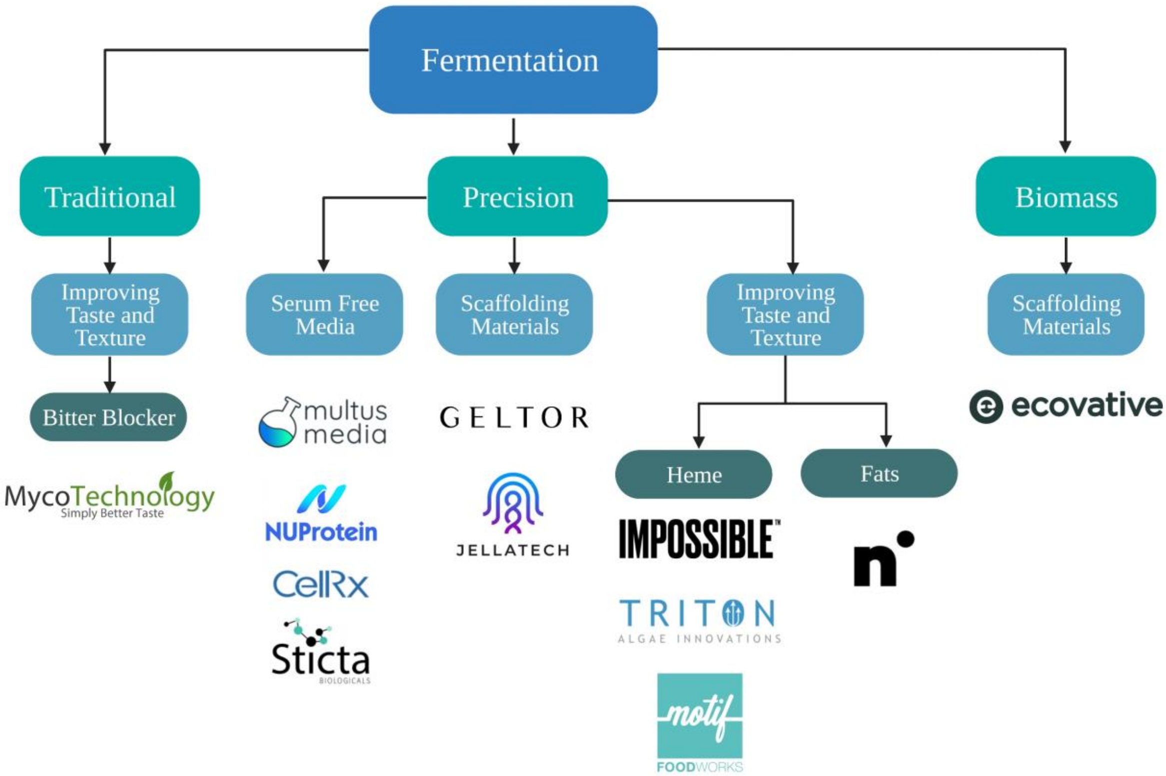

Figure 23.1. Examples of companies that utilize traditional, precision and biomass fermentation to produce serum substitutes, scaffolding materials, and ingredients that modify taste and texture for CM production. This figure was adapted and used with permission from (Singh et al., 2021) and created using BioRender (http://biorender.com/).

2. Fermentation as a solution

Several challenges need to be overcome for CM production to be commercially viable. The following section elaborates on the four broad areas vital to CM production that can be addressed using fermentation: the development of serum-free media (SFM); the development of scaffolding materials; improvements the sensorial characteristics; and improvements in the nutritional value of CM (Fig. 23.2). Integration of fermentation into the CM production process can enhance the scalability and consumer acceptance of CM products, which are essential for their success in the market.

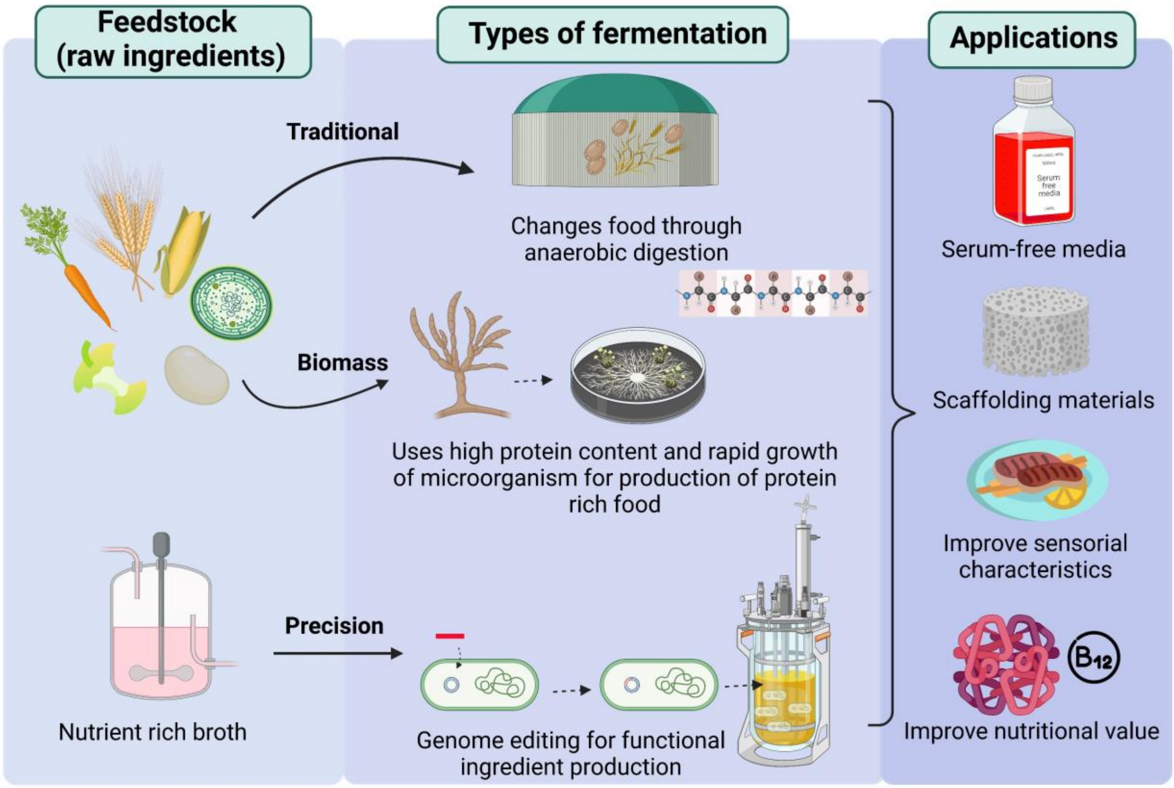

Figure 23.2. An overview of how traditional, biomass, and precision fermentation can help improve the scalability of the CM production process and enhance the organoleptic properties of CM. This figure was adapted and used with permission from (Singh et al., 2021) and created using BioRender (http://biorender.com/).

2.1 Developing serum-free media (SFM)

In the production of CM, cell culture media is crucial since it provides nutrients and growth factors for the cultivation of cells. Traditionally, fetal bovine serum (FBS) has used as the primary source of these essential growth factors (O'Neill et al., 2021). Standard cell culture guidelines have recommended adding 10-20% FBS in the culture media for efficient cell growth of various cell types (e.g., satellite cells) and serum starvation conditions to facilitate myogenic differentiation (Messmer et al., 2022; O'Neill et al., 2021). The use of FBS is unsustainable and inconsistent with the goals of CM production due to the ethical concerns surrounding its harvest from animals, to its large variation from batch to batch, and to its high cost (O'Neill et al., 2021). For CM technologies to become commercially successful, they must overcome their reliance on animal-derived components. This necessitates replacing FBS in the cell culture media with chemically synthesized, animal-free serum alternatives (Stout et al., 2021). Precision fermentation technologies can be used to synthesize various reagents or growth factors that have been identified as potential candidates for serum substitutes.

Insulin-like growth factor (IGF-I) and transferrin are examples of growth factors that have been explored as components in SFM for CM production. Muscle stem cells are known to proliferate and differentiate more quickly when insulin is present (Messmer et al., 2022). Transferrin ensures iron delivery to cells, thus ensuring cell proliferation and function (Finnis et al., 2010). Due to these functionalities, companies and researchers have utilized precision fermentation-based techniques to produce different variations of growth factors to accommodate different culture procedures. CellRX, for instance, manufactures an analog of human IGF-1, Short AE-IGF-1, which has greater efficacy than IGF-1, from cultivated *Escherichia coli* (CellRx, 2023). Importantly, the fermentation produced analog elicits a response in all cells with Type 1 IGF receptors. The cross-reactivity to other species could hence translate into cost savings for organizations dealing with various cell types that share this growth factor (CellRx, 2023). Baker's yeast, *Saccharomyces cerevisiae*, has also been used to produce recombinant transferrin (Finnis et al., 2010). Molecularly engineered yeast strains with elevated yields and productivity were first inserted with recombinant plasmids containing the transferrin gene. They were then cultivated under fed-batch fermentation conditions to encourage the expression of transferrin, followed by harvesting and purification for use (Finnis et al., 2010).

Using microbes that can be grown in large quantities under controlled conditions, precision fermentation will enable the synthesis of these molecules at a greater scale. The process drives down costs for materials, paving the way for the CM manufacturing process to be scalable since culture media currently represents a large portion of CM costs (Specht, 2020). This approach, however, should only be applied if microbes have achieved the qualified presumption of safety (QPS) or generally recognized as safe (GRAS) status so that the production process and, subsequently, the final products are safe (EFSA BIOHAZ Panel et al., 2022; FDA, 2018).

2.2 Developing scaffolding materials

Scaffolds used in CM production are intended to mimic the extracellular matrix (ECM) of muscle and provide physical and biochemical cues for cellular attachment and differentiation. Using scaffolds, structured meat products (e.g., steaks) can be created beyond the existing minced meat products (e.g., meat patties). These scaffolds must be edible, nutritious, and contribute to the overall sensory experience of the CM. Edible scaffolds eliminate the need for scaffold removal processes necessary when inedible scaffolds are used, simplifying the manufacturing process of CM products (Seah et al., 2021). Despite the effectiveness of the animal-derived scaffolds, they are unsuitable for CM applications as their origins go against the slaughter-free intention of the technology (Enrione et al., 2017). However, some plant-based biomaterial scaffolds also have several shortcomings, including the lack of bioactive sites for cell adhesion and unsatisfactory mechanical properties for holding its structure and directing cell behavior (Iravani and Varma, 2019). To address these challenges, fermentation can be used to produce polysaccharides and proteins with desired characteristics to serve as scaffolds.

The development of polysaccharide-based scaffolds (e.g., cellulose (isolated from plants or produced by certain bacteria) (Rybchyn et al., 2021), alginate (from seaweed) (Farshidfar et al., 2023), chitosan (outer skeleton of shellfish) (Rodríguez-Vázquez et al., 2015), and hyaluronan (an ECM polysaccharide) (Flynn et al., 2007)) and protein-based scaffolds (e.g., gelatin (Liu et al., 2022) and collagen (Nagai et al., 2008)) has been extensively investigated in the field of tissue engineering. These biomaterials would need to be obtained in a scalable manner to be realistically applicable for CM. Fermentation is thus being investigated for their production. For instance, certain bacteria can undergo aerobic fermentation to synthesize bacterial cellulose as an alternative to plant cellulose (Lahiri et al., 2021) (also see Chapter 21). To make this production more sustainable, agricultural waste by-products such as grape skin extracts from wine making and spent sulfite liquor from the paper industry, can be used as feedstocks for bacterial cellulose fermentation (Carreira et al., 2011). As scaffolding components, protein-based scaffolds can be beneficial in CM to better mimic conventional meat's cooking and organoleptic characteristics.

Biomass fermentation is used to grow large amounts of microorganisms that are themselves used as ingredients for alternative proteins. Biomass fermentation is also being explored to produce mycelium scaffolds for use in CM due to their biodegradability, affordability, and continuous growth capabilities (Antinori et al., 2021). Various agricultural inputs can be added to edible fungal species to simulate the growth conditions of mycelium and produce feedstock for fermentation (Ahlborn et al., 2019). The mycelium expands continuously under solid-state fermentation and is ultimately harvested as biomass (Khalil et al., 2021). This fibrous and porous biomass can greatly benefit the production of CM since these elements enhance nutrient exchange, cell alignment, and the texture of the final product.

2.3 Improving the sensorial characteristics of CM

Sensorial characteristics, specifically flavor, texture, color, and other visual cues, play an important role in the success of CM products in the marketplace as they can sway consumers' approval. The creation of a commercially viable CM product relies upon the successful reproduction of the distinctive features of conventional meat. For texture, the difficulty resides in creating different types of meat cuts. Besides the alignment of muscle fibers that scaffoldings should address, the CM product should accurately reflect the cellular compositions in the relevant meat cut to emulate the associated sensory experience. For CM to satisfy consumers' taste preferences, the extensive flavor precursors in conventional meat should also be replicated so that the characteristic flavors and 'meaty' aromas can be released upon cooking. It is also important to consider the visual markers traditionally used to assess the quality and freshness of conventional meat such as red color and other visual cues (e.g., marbling) that will apply to CM and ultimately help raise consumer acceptance. Fermentation has tremendous potential to elevate the organoleptic properties of CM by supplying an assortment of additives and components (e.g., fats) to these products. In this section, we will illustrate how fermentation-derived heme and heme analogs, fats, and flavor additives can enhance organoleptic properties of CM.

2.3.1 Biosynthesis of heme and other analogs

The heme-protein, myoglobin, found in conventional meat is indispensable for the color and generation of flavor and aroma compounds while cooking meat. Iron, released from heme during cooking, catalyzes the development of cooked meat's distinct flavor, aroma, and color (Fellet, 2015). As heme is essential to the color and the flavor profile of meat, it should be included in CM products to enhance their organoleptic properties and improve consumer acceptability (Simsa et al., 2019).

Genetically engineered organisms can be used for precision fermentation to increase production and reduce the costs of producing myoglobin. The applicability to CM research was emphasized when the structure of leghemoglobin isoprotein (a form of hemoglobin in legumes) was discovered to be analogous to mammalian myoglobin (Jin et al., 2018), thus suggesting its potential to impart similar taste profiles when cooked. Impossible Foods pioneered the production of soy leghemoglobin using precision fermentation. A yeast host, *Pichia pastoris*, was used to express the leghemoglobin protein that was then extracted and purified for use in their plant-based meat products (Jin et al., 2018). This technology can be used to produce heme-based additives to enhance the organoleptic properties of CM.

2.3.2 Production of fats

Fats in meat affect its flavor, texture, visual presentation, and nutrition. Enhancement of juiciness and tenderness are often synonymous with fat content in meat, implying improved taste perception when fat is present (Savell and Cross, 1988). Currently, CM is primarily composed of animal muscle cells and hence will benefit from the addition of fat constituents into the formulation to enhance its organoleptic properties. Some companies have turned to plant-derived oils (Tayag, 2023; GFI, 2023). Others are investigating the prospects of co-culturing adipogenic cells with muscle cells to obtain a more robust product (Zagury et al., 2022). Both approaches, however, come with their limitations. Plant-derived oils have properties (e.g., cooking behavior, flavors) that are disparate from animal fats (Dohmen et al., 2022). At the same time, the co-culture of myocytes and adipocytes is exceedingly arduous as different cell types require different conditions to grow within a system (Kuppusamy et al., 2021). Despite this, the co-culture method has had some success, albeit not at scale (Zagury et al., 2022).

Incorporating fats into CM products using precision fermentation is thus an alternative strategy currently being pursued by Canberra-based start-up Nourish Ingredients. Fats with molecular structures resembling their animal-derived equivalents were produced by inserting the tailored genes into the unique yeast strands developed by the company and supplying them with the appropriate sugar feedstocks for fermentation (Nourish Ingredients, 2023). The subsequent integration of fermentation-derived fats into CM recreates the familiar sensory experience of conventional meat consumption. As fermentation relies heavily on feedstocks and metabolism of their host cells, alterations in their compositions can result in batch-to-batch variation of the fats' quality and properties (Melt&Marble, 2023). Additionally, the incorporation of fats in CM can conceivably imitate the marbling of specific meat cuts, which are crucial visual markers that can impact consumers' assessment of its quality and, consequently, their willingness purchase the CM product. The partnership between Nourish Ingredients and CM start-up Vow has the potential to symbolize success in the unification of the two technologies of CM production and fermentation produced fats (Lorenzo, 2021).

2.3.3 Production of flavor additives

There is no doubt that flavors tremendously impact consumers' attitudes toward food. Meat, for example, possesses a savory and umami flavor due to a group of small molecules (e.g., glutamic acid) that serve as flavor precursors during the Maillard reaction (Kaczmarska et al., 2021). For CM, artificial flavor additives can be considered for flavor enhancement to increase its appeal. Fermentation is being explored to synthesize flavor additives to improve CM formulations.

Biomass fermentation has been used to generate macrofungal ingredients, which can be used to improve the flavor of CM formulations. During fermentation, the fungal mycelial cells secrete enzymes to digest surrounding resources, absorb nutrients, and build fungal networks (Letti et al., 2018). Ultimately, this produces massive amounts of edible biomass, which will be turned into other products, such as mushroom powders. Due to their high lanthionine and monosodium glutamate content, these powders can be used as natural flavor enhancers to impart distinctive flavors to CM (Pil-Nam et al., 2015).

3. Improving the nutritional value of CM

Conventional meat is a nutritious food with high-quality proteins and a variety of vitamins and minerals. There may be slight variations in their nutrient composition, which can be attributed to differences in the animals' diets. As CM strives to be a replacement for conventional meat, it is imperative that CM has a similar nutritional profile, especially for key micronutrients like vitamin B_{12} and iron. This process will be challenging as the required micronutrients must be synthetically added into the culture media to promote their uptake and accumulation in the cultured cells. Alternatively, these micronutrients can also be supplemented into the final CM formulations.

Precision fermentation can be employed to synthesize some of these vitamins and minerals for supplementation. Meat is rich in heme iron – the more bio-accessible form of iron (West and Oates, 2008). Supplementing the culture media with heme can thus boost the nutritional qualities of CM while enhancing their organoleptic properties. These heme components can be manufactured using precision fermentation techniques described earlier (Jin et al., 2018).

Vitamin B_{12} is another essential micronutrient found in meat. Vitamin B_{12} is originally synthesized by microbes in a ruminant's gut and eventually deposited in its tissues (Watanabe and Bito, 2018). While certain plants and fungi contain minute amounts of Vitamin B_{12} due to parallels in their interactions with microbes, most plants do not. This necessitates humans' intake vitamin B_{12} through animal-based products or supplements to avoid dietary deficiencies. CM production eliminates the interactions between the live animal and microbes and the natural accumulation of vitamin B_{12} cannot transpire. Thus, the process needs to be simulated by supplementing the culture media with vitamin B_{12} produced via precision fermentation to eventually manufacture CM with a similar nutritional composition to conventional meat. Industrially, *Propionibacterium* and *Pseudomonas* species have been used in the precision fermentation process to manufacture vitamin B_{12} (Fang et al., 2017). Additionally, vitamin B_{12} can be synthesized using bacteria, *Propionibacterium freudenreichii*, with wheat bran as feedstock (Xie et al., 2019). The production of micronutrient additives using precision fermentation allows CM manufacturers the possibility to modify the nutritional composition of

CM. This will eventually benefit consumers by introducing meat substitutes into the marketplace that are equally or more nutritious than existing products.

4. Harnessing the full potential of fermentation

Fermentation has also been successfully used in chocolate production. Callus (cells are grown in agar) and suspension (cells are grown in liquid) cell lines were obtained from cacao seeds and cultured in shaker flasks to generate substantial biomass that was processed to produce chocolates (Eibl et al., 2018).

Several start-ups in the cellular agriculture are also adopting fermentation-based approaches to produce animal-free dairy products (e.g., milk proteins, cheese). An example of such a start-up is New Culture, which has developed a method to manufacture casein, the protein responsible for cheese characteristics, using precision fermentation and from that to produce animal-free cheese (New Culture, 2022). Perfect Day has also disrupted the sector by substituting conventional milk proteins with precision fermentation-derived whey proteins to produce animal-free dairy products with comparable mouthfeel and flavor to animal-derived dairy products (Nay, 2021). A series of products, ranging from gelato to smoothies, has been launched through collaborations between Perfect Day and businesses in the food industry (Perfect Day, 2022). Evidently, there is still plenty of potential to maximize fermentation use, especially for creating CM products with greater versatility and diversity using a wider range of fermentation-derived components.

5. Commercial opportunities and landscape

Cellular agriculture has the potential to recreate conventional agricultural products using innovative methods which can bring about an immeasurable impact on our environment and health. Explored in conjunction with the new understanding and application of fermentation, CM has radically changed and advanced the alternative protein sector beyond plant-derived options. Being a sunrise industry, plenty of direct and indirect opportunities exists for stakeholders to get involved. Over the past five years (2017 – 2021), tremendous growth in investments has been observed in both CM and fermentation, where the former more than tripled and the latter almost tripled in market size from 2020 to 2021 alone (Fig. 23.3) (GFI, 2022a; GFI, 2022b).

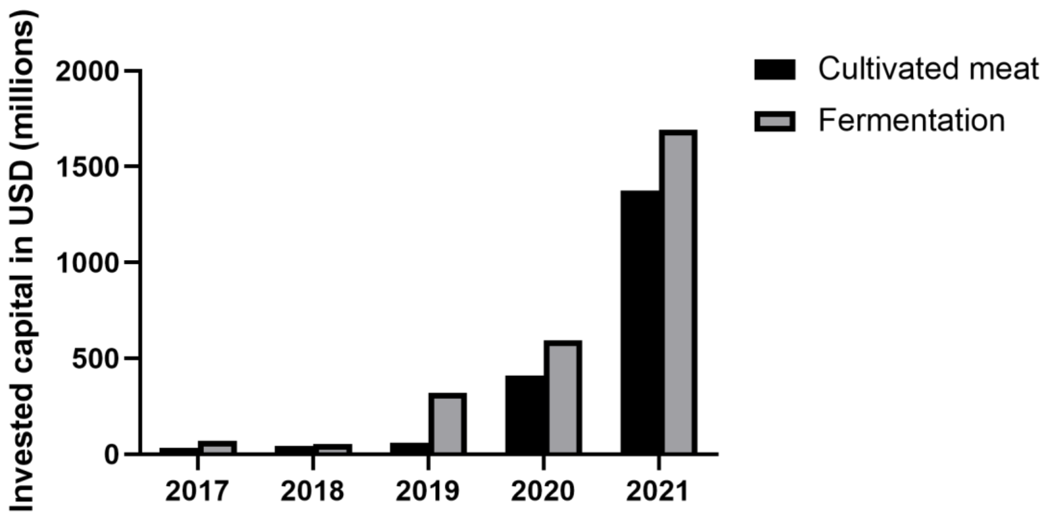

Figure 23.3. Capital invested in CM and fermentation start-ups during the past five years (2017-2021). These data are based on the Good Food Institute's (GFI) analysis of data from PitchBook (GFI, 2022a; GFI, 2022b).

Due to the expected exponential growth in the CM and fermentation markets, legal battles over intellectual property (IP) have emerged in recent years. This highlights two points: recognizing ownership rights is paramount, and industry leaders are looking to seek commercial expansion opportunities through potential market acquisitions. Consequently, to achieve continued and productive growth in this sector, businesses must carefully consider the necessity of IP protection before commercializing their discoveries (Ng et al., 2021).

In the CM industry, many companies are refocusing their efforts from research and development to scaling up. As companies begin to scale, volume and unit cost of production become increasingly important practical considerations for investors. Investors must be strategic about how they proceed and channel their investments to accelerate the development of manufacturing infrastructure for CM, fermentation, or their hybrid products. This will undoubtedly boost competitiveness to accelerate the introduction of new products, which is vital for the sector's growth. Companies have expanded in new markets worldwide as CM and fermentation have both experienced rapid growth in recent years. Geographic expansion is expected to continue, with hybrid product companies likely to follow suit.

Businesses in this space have leveraged business-to-business (B2B) and business-to-consumer (B2C) strategies to drive growth and gain market shares. According to industry experts, B2B strategies will lead to knowledge consolidation, thereby minimizing the possibility of multiple companies solving the same issue (GFI, 2022a). This is advantageous as the industry matures since it could free up resources to pursue other opportunities within the sector. As we move forward, fostering partnerships across the value chain will also play a significant role in achieving the industry's goals and potential. As for companies pursuing B2C strategies, eliminating unnecessary middleman costs streamlines their supply chain and allows them to instead devote more resources to improving consumer acceptance, such as ingredients that can improve the taste, texture, and aroma of CM products, or conducting tasting sessions to help consumers become more familiar with these products.

6. Greatest obstacles for commercialization – regulations and consumer acceptance

Despite the promising potential elaborated above, regulations governing the space and consumer sentiments towards the product are still the greatest obstacles that will define its success. A supportive regulatory environment that nurtures innovation and provides clear directives and high consumer acceptance will help spur developments in the cellular agriculture space and increase the chance of successful commercialization.

6.1 Regulations

The long history of fermentation in food production means that there is a well-defined set of government regulations in place. However, introduced fermentation or fermentation-derived components into CM will still be required to follow a similar set of regulatory standards. As CM is gaining traction in recent years, regulations surrounding this sector are developing globally. CM is presently governed under the wider classification of novel foods in the regulations established by various countries (e.g., Singapore, United States, China, Australia, Israel, Canada etc.) and international organizations (e.g., European Union). These regulations exhibit a high degree of commonality across countries which often articulate the need for extensive pre-market safety assessments before a product can be commercialized for human consumption. That said, the impact of the combinative use of fermentation and CM on regulations remains ambiguous due to lack of precedence. However, we believe that safeguarding the health and safety of consumers is the crux of any regulations and should remain the priority during the development of novel food products for commercialization. In December 2020, Eat Just was granted regulatory approval for their cultivated chicken in Singapore by the Singapore Food Agency (SFA), thereby initiating CM's commercialization (Tan, 2020). To date, Singapore is the only country that has authorized the commercial sale of CM products. However, pressures from market players are intensifying towards regulators of other countries to follow suit. Esco Aster, a contract development and manufacturing organization, was granted a license for manufacturing cultivated animal cells in July 2021 (Ho, 2021). This is a crucial step for furthering developments in the field as CM companies can now engage a regulatory approved manufacturer to produce their products, lowering the barriers to commercialization significantly.

6.2 Consumer Acceptance

Consumer acceptance is instrumental to the success of novel foods. Companies should prioritize understanding and enhancing consumer acceptance when introducing CM products to the market to avoid suffering the same fate (i.e., rejection) as genetically modified organism products. Huge disparities in consumer acceptance of CM exist in society. It is believed to be most heavily influenced by consumers' perceptions, personalities, and awareness of the product (Pakseresht et al., 2022). As fermentation incorporates familiar processes and natural ingredients into the production of CM, it can potentially improve consumer perceptions of the product, especially in environments where strong negative sentiments stem from disgust and food neophobia (Krings et al., 2022).

Cultural and social differences between countries may also shape consumer sentiments. A recent study has revealed that Singaporeans were more accepting of CM than Americans (Chong et al., 2022). This was attributed to ingrained Singaporean traits (i.e., kiasuism, or the taking of extreme measures to achieve success) and the innate craving for social admiration, a characteristic typical of collectivistic countries (Chong et al., 2022). Companies centered around using novel strategies or technologies (e.g., fermentation and CM hybrid products) may want to target launches in collectivistic countries for a better chance of success.

With the advent of more CM companies and growing awareness of environmental benefits, consumers are increasingly open to CM products (Kamalapuram et al., 2021). Further improvements can be anticipated if the media continues to portray CM favorably, as positive framings of CM have been proven to influence consumers' willingness to spend for the product (Kantor and Kantor, 2021; Ong et al., 2020). Many CM companies also adopt similar publicity strategies for that reason. In these circumstances, fermentation will be incorporated into the products to enhance the sensory qualities of CM products.

7. Conclusion

Fermentation transforms or produces useful ingredients by enlisting the help of microbes. Considering the industry's rapid growth, fermentation is a potent tool that can be applied to the production of CM and other cellular agriculture products. By leveraging existing fermentation facilities and processes, natural food-safe ingredients can be manufactured at scale and incorporated in CM to improve their organoleptic properties and nutrition. Nevertheless, consumer acceptance and regulatory approval are vital to accelerating hybrid product launches and should be carefully considered for commercial success. Further research and development in the field of CM will only make fermentation more relevant and consequently expand its potential scope of application.

Recommendations for further reading

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Glossary of Definitions

Traditional fermentation	Microbes digest food under anaerobic conditions to alter their properties (textural, flavor and nutritional profiles).
Biomass fermentation	The production of large quantities of edible protein biomass by utilizing microorganisms that grow rapidly and are high in protein.
Precision fermentation	Precision fermentation produces specific proteins and molecules using microbes as "cell factories".
Cellular agriculture	Cellular agriculture is the production of agricultural products using cell cultures to produce proteins, fats, and tissues. It relies on a combination of biotechnology, tissue engineering, molecular biology, and synthetic biology.
Serum starvation	A sudden decrease in serum concentration of culture media which could direct muscle differentiation.
Novel food	Foods that either do not have a long history of consumption or are produced in a novel way.
Food neophobia	The avoidance of new foods or a reluctance to eat them.
Kiasuism	A mindset that continually compares oneself to others for fear of missing out
Collectivistic countries	Countries with societies that typically prioritize the needs and aspirations of the group over the interests of individuals