ESCP
BUSINESS SCHOOL

IT ALL STARTS HERE

BERLIN | LONDON | MADRID | PARIS | TURIN | WARSAW

LIGHTS - Geopolitics

Cultured cuisine: The business of food from the lab

ESCP Impact Paper No.2024-22-EN

Francesco VENUTI
ESCP Business School

Antonio IANNONE
TheFoodCons

ESCP RESEARCH INSTITUTE OF MANAGEMENT (ERIM)

ESCP Impact Paper No.2024-22-EN

Cultured cuisine: The business of food from the lab

Francesco Venuti*
Antonio Iannone**

ESCP Business School

Abstract

Emerging cultured food technologies hold immense potential to revolutionize the food industry, offering sustainable and ethical solutions to feed a growing population. This paper provides an overview of cultured food (from meat to coffee), briefly describing some different technologies, examining 3 cases and highlighting both the exciting opportunities and the significant challenges that need to be addressed for widespread adoption in the near future.

Keywords: cell-based food, cultured meat, cellular agriculture, agrifood systems, lab-grown food

*Associate professor, ESCP Business School

**TheFoodCons

Introduction

The world population is rapidly and continuously growing. It reached 8.0 billion in mid-November 2022 and, according to the UN, it is expected to increase to 9.7 billion in 2050, with a possible peak at nearly 10.4 billion in the mid-2080s. This phenomenon, combined with the wealth of economies and the diet shifts toward higher energy density foods, will result in a growing global demand for food. The demand for food in the world is therefore predicted to double by 2050, and most of this demand will come from developing countries, mainly in Asia and Africa.

Trends in developing economies usually show a shift over time toward a diet with higher percentages of added fat and sugar, more saturated fat intake (mostly from animal sources), and reduced fruit and vegetables consumption (Pullman and Wu, 2021).

According to the WHO, in 2030 the food consumption in terms of Kcal per capita per day will be 30% higher than in 1965 (see table 1).

Table 1 - Global Food Consumption in terms of Kcal per capita per day

Region	1964/1966	2015	2030
World	2,358	2,940	3,050
Developing Countries	2,054	2,850	2,980
Industrialized Countries	2,947	3,440	3,500

(Source: WHO)

The continuous growth of the demand for agricultural products is accompanied by a drop in the production capacity, partially also because of the decreasing amount of productive land still available. Table 2 presents the decline in the global production of major crops from 2010 to 2030, which ranges on average between 10% and 20%.

Table 2 - Decline in the global production of crops from 2010 to 2030 (%)

Rice	Corn	Wheat	Other Crops
-23%	-12%	-13%	-8%

(Source: Farming First - https://farmingfirst.org/)

According to Farming First[1], by 2050 agricultural yields across the world will decrease on average by more than 10% due to climate change. This, and several other factors, poses a significant threat to the sustainability of our current agrifood systems.

In "The State of Food and Agriculture 2023", the FAO explicitly stated that "The unsustainability and lack of resilience of agrifood systems are major concerns, exacerbated by market, institutional and policy failures that generate losses to society and inhibit much-needed transformation towards sustainability" (FAO, 2023)

The sustainability of global food systems is being challenged by a number of issues, in addition to climate change: old and new pandemic and diseases (related to the increasing urbanization of several countries, with higher population density and leading people closer to wild species, combined with the parallel increase in globalization, fast travel, and global

[1] https://farmingfirst.org/

fast transportation), loss of biodiversity, labour and social evolutions, lifestyles, and public health.

Several emerging technologies (from big data analytics to blockchain, from gene modifications to automation, from robotics to cultured food) may potentially help to solve the issues of current global food systems.

One of the key areas of innovation and research driving the development of more sustainable technologies is the search for alternative proteins with desirable nutritional profiles (Wood and Tavan, 2022). Currently, the main options for producing alternative protein sources involve finding a balance between the nutritional needs of these new food products and their ability to improve the sustainability of our food systems. These options include, among others, plant-based products, fermented and cell-cultured products, precision fermentation, insect proteins, and microalgal-based products (Wood and Tavan, 2022).

At the moment, most of these protein products go into pet food or animal feed, but we are already witnessing several cases of products for human consumption that have already been authorized, marketed, and are currently being sold in some countries.

In the following paragraphs, after a brief overview of cultured food, we will detail three cases of different companies already producing different categories of cultured food: meat, milk, and coffee.

Cultured food: an overview

Cell-based. Cultivated food. Lab-Grown. Cultured food. In vitro. Sometimes, improperly and incorrectly, even “artificial food”, “synthetic food” or “clean food”[2]. These are all nearly synonymous terms, some more accurate than others, indicating a set of technologies shaping the future of food.

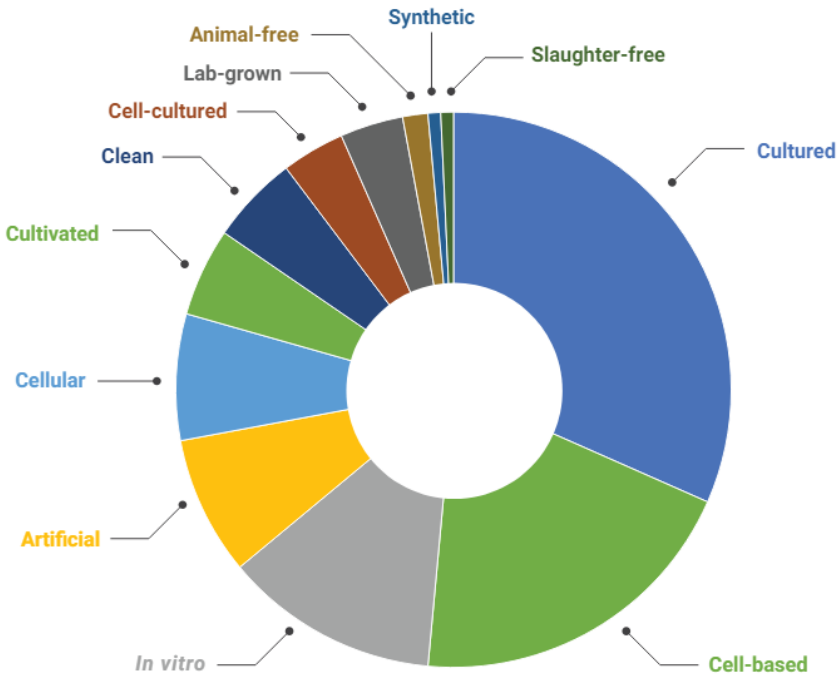
Even within the scientific community, there is no consensus regarding terminology, and a broad range of different terms are currently used. Most of them reflect their first use and the choice reflects the way mass-media presented these technologies at the beginning. For example, in 2013, one of the first products was described as a “lab-grown” beef burger at a press conference in London and then popularized by BBC News (FAO & WHO, 2023). More recently, in December 2020, chicken nuggets (actually resulting from a blend of cultured chicken and plant-based ingredients) represented the first product of this kind launched on the market after the official approval in Singapore. The media reporting this event called this innovative product as “No-kill, lab-grown meat” and “cultured meat” (Carrington, 2020).

The FAO and WHO report (FAO & WHO, 2023), concluded that ““cell-based”, “cultivated” and “cultured” are the three major terminologies used or preferred by consumers, industry and the authorities. These terms are also commonly used in scientific publications, but a broader range of terms can also be found in many cases in science, including the terms “in vitro”, “artificial” and “clean” that were used more frequently in the early days of the technology developments. However, industry actors prefer to use “cultured”, “cultivated” or cell-based”, while the media use a more diverse array of terms including, but not limited to, “cultured”, “lab-grown”, “fake”, “clean”, “cultivated”, or “cell-based” (FAO & WHO, 2023).

[2] For a broader discussion over the different terminology, see FAO & WHO, 2023.

In this paper we will therefore privilege “cultured food”, which is the most common terminology in scientific publications (see figure 1), but also largely adopted by consumers, industries, and authorities.

Figure 1 - Relative share of the synonyms of “cell-based” food in the scientific literature



(Source: FAO & WHO, 2023)

As the food of the future, of course, also reliably contributing to crafting a better food system, cultured food perfectly aligns with the goals of Agenda 2030. This agenda 2030 emphasizes reducing reliance on water and land usage, as well as animal exploitation. Technologies will definitely play an ever-more central and important role in achieving these goals, and cellular agriculture can be considered the perfect synthesis of all that.

Sinke et al. (2023) showed that the use of renewable energy to produce cell-based meat could reduce carbon emissions by 93%, soil usage by 95%, and water usage by 78%.

The anticipated arrival of this disruptive technology has predictably triggered a tangle of contrasting reactions, with a clear division between proponents and opponents. Among the latter are several farmers' associations around the world, particularly in Italy, France, and the US (Florida), as well as more conservative areas, that see laboratory food as a severe danger to tradition and even a potential threat in terms of health security. In some cases, such as in Italy ("Il Bel Paese"), a law was even passed to ban any business related to lab-grown food, even if this law has been severely questioned by the European Union in terms of legitimacy. On the opposite side, a large part of the global foodtech ecosystem, startups, researchers worldwide, and many governments have instead embraced the rise of this technology. Currently, countries like Singapore, the USA, and Israel have already authorized some companies to sell cellular agricultural products. The major reasons provided by those who support these technologies are related to the sustainability impact (in terms of use of natural resources such as land, feeds, water, land, impact on the environment, wastes, pollution, biodiversity, etc...), but also animal well-being, and higher safety for human consumption (for example, these products will be free from hormones, antibiotics, pesticides, etc...).

It's important to remember that cultured food represents a category of the so-called “novel food” and therefore it is subject to specific regulatory approval from each country's relevant authorities (such as the EFSA in Europe, the FDA in the US, etc...). The first cell-based products were approved in Singapore in 2020 when Eat Just started selling cultured chicken nuggets in a single restaurant (Wood and Tavan, 2022). Actually, the first cell-culture-based beef burger was produced a long time before, in 2013, by a Dutch scientist, Mark Post, at the cost of $330,000 (Post, 2014).

Despite the complicated road to market, investments haven't stopped. According to the Good Food Institute, in the past 10 years, cell-based startups have collectively raised more than 3 billion dollars. Notably, some of these investors are even meat industry giants.

How is cultured food produced?

In the production of cultured food we can identify three main elements:

- The cells
- The growth media
- The bioreactor
- The cells can be considered the "starting point." The technology requires stem cells that can be obtained from two primary sources:
- Directly from the food to be replicated, such as beef tissue, duck liver, a fish fillet, or a coffee bean. This method is completely safe for the animals and does not create any damage to them.
- Secondary sources, such as cryopreserved cell cultures.

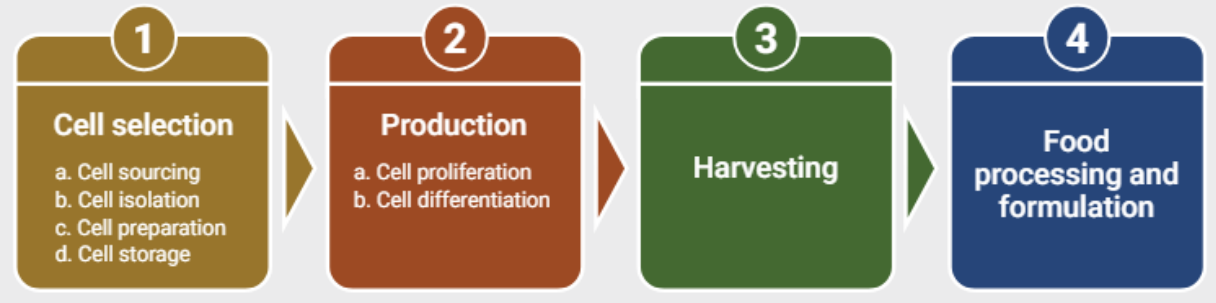
Cells are then inserted into a growth medium, in a sterile environment. The growth medium is probably the most controversial aspect of cell-based food, still subject to smear campaigns by various farmers' associations. We must consider that in the first lab-grown meat prototypes and experiments, fetal bovine serum (FBS), a by-product of the meat industry, was used as the growth medium. However, FBS has been progressively abandoned due to ethical, sustainability, and economic concerns. The cellular agriculture industry is now transitioning to FBS-free alternatives.

The growth medium with the cells is then placed in a bioreactor, where the cells multiply through a process similar to tissue engineering (fermentation process). The output of this process can be a beef steak, a pork chop, a fish fillet, a glass of milk, or a coffee or cocoa bean or powder.

In synthesis, cell-based food production's four main phases could be described as follows (FAO & WHO, 2023):

1. cell selection;
2. cell growth and production;
3. cell harvesting;
4. food processing.

Figure 2 - A generic overview of the cell-based food production process



(Source: FAO, 2022, Thinking about the future of food safety - A foresight report, Rome - www.fao.org/3/cb8667en/cb8667en.pdf)

Undoubtedly, such a complex technology presents many critical points, the first and most obvious being scalability, which justifies the huge amount of money invested to date. Other challenges, now almost solved, are represented by the "mouthfeel" and "texture" of the product (for example of a beef steak), which is not only a group of cells, but also needs to have a specific structure and texture.

Two specific aspects, among several, are usually presented as the major challenges in this field: consumer acceptance (from different perspectives, from the taste and organoleptic features to the psychological barriers) and the potential issues in terms of food safety and security.

Regarding the taste and organoleptic features of cultured food, the most recent techniques have improved a lot and are now able to replicate quite well not only the cells (which are identical to the "natural" ones), but also the texture, mouthfeel, firmness, and smoothness.

Regarding safety and food security, the FAO and WHO report[3] examined case studies (mainly from Israel, Qatar, and Singapore) and their respective regulatory frameworks. The document covers all aspects related to cultured food, from production techniques to terminology, stating that "*currently a limited amount of information and data on the food safety aspects of cell-based foods to support regulators in making informed decisions*". The report highlighted that "*experts agreed that while many hazards are already well known and existing equally as well in conventionally produced food, the focus may need to be put on the specific materials, inputs, ingredients (including potential allergens), and equipment that are more unique to cell-based food production. While the list of hazards identified forms a strong basis for the next steps, more data generation and sharing at the global level are essential to create an atmosphere of openness and trust that will enable the positive engagement of all stakeholders*" (FAO & WHO, 2023).

Cases

The number of startups and research groups that are successfully developing, implementing, and improving the technologies to produce cell-based food (not only meat, but also fish, vegetables, and other products such as milk or oil) is literally booming.

As soon as the first governmental authorization appeared, the run to be "the first in the market" began. Cell-Based, a division of FoodBev.com, has created an international award. On November 9th, 2023, the first edition of the World Cell-based Innovation Awards took

[3] FAO & WHO, (2023) available at (last accessed May 2024): https://openknowledge.fao.org/server/api/core/bitstreams/4594c44d-213d-48e9-83b2-a2cd8a37ed92/content

place and the winners of the 2023 competition, divided by category, are presented in table 3. It can easily be seen that cultured food technologies are now being applied successfully to several different categories of food. While originally and still today largely associated with meat production, cellular agriculture now covers a broad range of food products: meat, fish, vegetables, and more.

Table 3 - Winners of the 2023 World Cell-based Innovation Awards

Category	Company	Product / Area
Cell-based Drink	Senara	Milk
Cultivated Meat	TissenBioFarm	Whole-cut cultivated beef with marbling
Cultivated Dairy Product	BIOMILQ	Cell-cultured human milk
Cell-based Seafood	Umami Bioworks	Cultivated grouper fillet
Cell-based Ingredient	C16 Biosciences	Palmless palm oil
Technology Innovation	The Cultivated B	AUXO V bioreactors
Cell-based Business	BioBetter	BioBov

(Source: https://www.thecellbase.com/posts/winners-announced-world-cell-based-innovation-awards - Last accessed April 2024)

All these categories and these examples represent the variety, the dynamic growth, and the success of research and development in cultured food technologies. In the following paragraphs 3 cases are briefly presented. They cover three different products: meat, milk, and coffee. They represent examples of applications of these technologies to different categories of food, contrasting with the widespread public opinion that mainly associates cultured food with meat production only, and provide deeper evidence of different techniques in the field.

1/ Mosa Meat: producing cell-cultured meat

Mosa Meat is a food company, founded in 2016 and currently headquartered in Maastricht, Netherlands, producing cultured meat.

Among many, one definition of “cultured meat” could be the following, synthesizing all its major characteristics: “cultured meat is meat grown from animal muscle cells in isolation without the need to raise animals” (Wilks and Phillips, 2017).

The story of Mosa Meat started in 2006 when the scientist Mark Post and the food technician Peter Verstrate met for the first time, thanks to a government-funded program for exploring the opportunities of cultured meat. After the program ended, Mark and Peter continued their research activity until 2013 when they unveiled the world’s first cultured beef burger at a packed press conference in London. This first burger required several years of research and cost almost €250,000 to make. Following these initial successes, in 2016 Mosa Meat was incorporated and the team of scientists and engineers started to grow. Crucial technical milestones were reached, like adding fat, removing animal components from the production process, and reducing the cost.

On April 16th, 2024 Mosa Meat announced that it has successfully collected €40M in new capital to finance their next phases: further scale up the production processes, drive down the cost of production, and prepare for market entry. This capital increase was led by big investors such as Lowercarbon Capital, M Ventures, Invest-NL (the Dutch state-owned impact investor, partly with coverage by InvestEU, the European Commission program supporting initiatives that align with EU policy priorities).

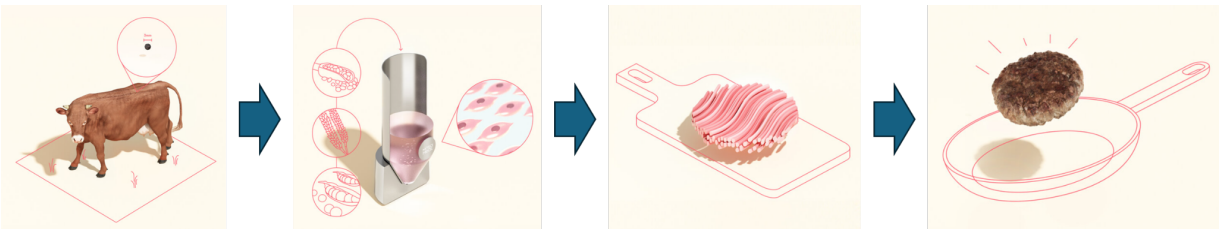
Their activity, mission and values are described on their website as follow [4] : *"We're making the beef burgers of the future. They don't taste 'just like' meat. They are real meat. Real beef that oozes and sizzles with real fats and juices. We're making these burgers so people can make a positive impact on the planet, simply by swapping delicious beef... with delicious beef.*

We want to serve you a burger that's just like a regular burger. Mouth-wateringly moist and packed full of flavour, and that looks, smells, and tastes just as good — with the big difference, that no animals were harmed in the making.

The four main phases of the production process are described by Mosa Meat as follows[5]:

1. Just like a farmer chooses the best steers for the butcher, the healthiest cows and the best cells are selected to grow the meat. Instead of being butchered and sent to the, the cows are free to roam the fields once the sample of cells is collected. The sample is the size of a peppercorn: 0,5 gr. sample taken under anesthesia with a standardized veterinary procedure. The sample leads to the selection of 33.000 myosatellite cells, to produce 80,000 burgers from one sample.
2. In the lab, the cells collected from the sample are "nurtured" with nutrients, vitamins, a comfy climate and fresh air, replicating a natural environment. In this way they "proliferate", multiplying into trillions of cells. In the lab the production takes place in an oxygen-rich environment with controlled temperature. This phase of cell growth is completely free of any animal components
3. By allowing nature to take its course, the cells become fully fledged muscle and fat, just like they would inside a cow. Muscle cells merge naturally and 0.3mm long primitive fibers form (myotubes), placed in a gel that is 99% water. Fibers from one sample grow to 800 million strands of tissue.
4. Muscle tissue reaches maturity and, in combination with fat tissue, they could be prepared for cooking

Figure 3 - Schematic representation of the production of cultivated meat



(Source: Mosa Meat - https://mosameat.com/ - last accessed April 2024)

[4] https://mosameat.com/ - last accessed April 2024
[5] https://mosameat.com/ - last accessed April 2024

On its website, Mosa Meat clearly stated what they think are the major benefit and opportunities of their business activity:

1. being kinder to consumers, as the product (the burger) is “cleaner” and the company is fully accountable for “every cell” produced, which makes the product safer and better for human health (free from any type of “contamination”).
2. being kinder to society worldwide, as the product could be easily accessible to everyone in the world, everyone should have the right to eat good quality, nutritious food.
3. being kinder to cows and other animals, because to make ten thousands burgers only a small cell sample from a single cow is needed. Cows are not killed, they do not suffer, no slaughter is required and much fewer cows are needed. By reducing the number of cows needed for meat production, there is less need of space and no need to take away any other animals from their own habitats.
4. being kinder to the planet, as these techniques require much less water; less land (and therefore less deforestation to create pasture and animal feed), less chemicals and a similar amount of energy.

2/ Remilk: precision fermentation for milk and dairy products

Remilk is an Israeli startup founded in 2019 by Aviv Wolff, an experienced entrepreneur, and Ori Cohavi, PhD in biochemistry, who has worked in R&D for different biotech firms. This startup has revolutionized the dairy industry with an innovative approach to producing lab-grown milk using precision fermentation (PF) technology. This sophisticated technique leverages the power of microorganisms, such as yeast, to produce proteins identical to those found in cow's milk. This process involves inserting genes encoding the desired milk proteins into the microorganisms, which then produce these proteins during fermentation. Regarding funding, Remilk completed an $11.3 million dollars Series A at a $30 million valuation in December 2020, followed in 2022 by a $120 million dollars Series B, led by NY-based Hanaco Ventures together with a lot of other big international investment funds[6].

Additionally, in June 2023, Remilk announced that three top managers from world-renowned food & beverage companies were appointed to the Board of Directors: Alicia Enciso (recent CMO of Nestle USA), Floris Wesseling (recent President of Danone Europe) and Pedro Padierna (former CEO and Chairman of PepsiCo Mexico)[7].

Remilk's commitment to bringing its products to consumers worldwide is evident in its strategic market expansion efforts. In early 2024, Remilk received a "No Questions Letter" from Health Canada, the governmental department in charge of food safety. This opens the North American market not only to their milk but also to all their synthetic dairy products made using the beta-lactoglobulin protein (Blg), produced through precision fermentation without animals but entirely equivalent to its bovine counterpart. Their product range also includes lactose-free, cholesterol-free, and growth hormone-free ice cream, yogurt, and cream cheese.

This is the fourth market outside the European Union to open up to synthetic milk. In February 2023, Remilk received the “green light” from the US Food and Drug Administration

[6]https://www.calcalistech.com/ctech/articles/0,7340,L-3926451,00.html - last access: April 2024; and https://www.remilk.com/newsroom/remilk-tm-raises-120-million-in-series-b-funding-signaling-animal-free-dairy-at-scale-is-closer-than-ever - last accessed: April 2024

[7] https://www.dairyreporter.com/Article/2023/06/22/Remilk-attracts-former-Nestle-Danone-and-PepsiCo-execs-to-Board-of-Directors and https://www.remilk.com/newsroom/remilk-attracts-top-food-beverage-execs-from-danone-pepsico-and-nestle-to-board-of-directors - Last accessed: April 2024

(FDA), a recognition of their product's safety for human consumption and legal entry into the US market. This was followed by approval from the Singapore Food Agency and, shortly after, also from Israel, with Prime Minister Benjamin Netanyahu himself visiting their facility and commenting on the country's leading role in food-tech research and development. Remilk also signed a major commercial agreement in 2023 with Central Bottling Company (CBC Group), the exclusive Israeli affiliate of Coca-Cola, to launch a range of milk-based beverages, cheeses, and yogurts made with their proteins upon receiving the necessary approvals.

Although nearly identical in its structure and ingredients, milk varies dramatically between mammals in its composition[8], see Figure 4.

Figure 4 - Major Constituents of Milk from Different Species (% values)

Major Constituents of Milk from Different Species
(Values expressed in %)

Habitat		The Arctic		Desert & dry conditions		Domestic Herbivores		Domestic Predators	Savana Herbivores	
Species										
Water	87.8	49.2	30.8	90.8	86.1	82.5	87.4	76.2-78.8	81.1	77.4
Fat	3.8	35.1	53.2	0.6	4.5	7.4	3.7	8.3	9.3	12.5
Lactose	7.0	3.9	5.5	6.1	5.0	5.5	4.8	4.1	3.7	3.4
Proteins	1.2	10.6	9.7	2.1	3.7	3.8	3.4	7.5-10.1	5.1	5.8
Ash (minerals)	0.2	1.2	0.86	0.4	0.7	0.8	0.7	1.3	0.73	0.9

(Source: Elemental Composition Of Human And Animal Milk, A Review by G.V. Iyengar. A report prepared under the auspices of the IAEA in collaboration with the World Health Organization, Vienna, 1982 - www.remilk.com)

Among all these differences in milk, Remilk products are declared to be “identical to the perfectly balanced cow-milk protein[9]”. Even the name “Remilk” is the acronym of “real milk” (their slogan is “Real Milk/Dairy, no cows”).

These synthetic dairy products are made by inserting genes for the desired protein molecules into yeast, which then produces them during fermentation in an incubator. Once the protein solution is obtained, it undergoes dehydration to create a highly versatile powder. Remilk's milk proteins are produced through a fermentation process using engineered yeast, making them "chemically identical" to those of cow's milk. According to the company, the resulting product is indistinguishable from "traditional" milk in terms of taste and functionality, "but with the advantage of being free of lactose, cholesterol, antibiotics, and growth hormones." The startup guarantees a 100% resemblance to "real" milk and declares its products "indistinguishable from old-fashioned dairy”[10].

According to what they declare, these technologies require only 1% of the land, 4% of the feedstock, and 10% of the water to produce comparable products in traditional dairy

[8] https://www.remilk.com/newsroom/how-we-turned-milk-into-a-better-version-of-itself - last accessed: April 2024
[9] https://www.remilk.com/newsroom/how-we-turned-milk-into-a-better-version-of-itself - last accessed: April 2024
[10] https://www.remilk.com - last accessed: April 2024

systems. Overall, they declare to consume only 5% of the resources needed for traditional dairy production and to produce only 1% of waste[11].

A report by Research and Markets predicts that the dairy alternatives market will grow to $21.34 billion in 2028 at a compound annual growth rate of 8.8% (up from around $13 billion in 2023)[12]. Remilk positions itself as an alternative to plant-based products, but distinguishes itself by using precision fermentation to replicate cow milk proteins at the molecular level, making them chemically identical to those in "original" milk. Remilk estimates that its sales will reach $600 million USD by 2026[13].

Remilk's entry into the Canadian market clearly presents a challenge to the traditional dairy industry. While the company's carbon footprint needs further clarification and careful evaluation, it aims to capture significant market share with innovative products that could forever change how we consume milk and its derivatives. Precision fermentation-based dairy products offer several advantages over traditional dairy, including being lactose-free, cholesterol-free, and free of antibiotics and growth hormones.

Remilk is not the only startup of this kind, especially in Israel, where the government declared FoodTech as one of five new national investment priorities for the next five years. The Israel Innovation Authority (IAA) announced in 2023 the allocation of 50 million shekels (equivalent to 12.5 million Euro) to build a research and development center focused on advanced fermentation of microorganisms like yeast or fungi to produce alternative proteins on a large scale and maintain Israel's advantage in this sector. Over the past decade, the IAA has allocated 230 million shekels in subsidies to FoodTech, with over 140 million shekels dedicated solely to alternative proteins.

Numerous other companies are already operating in the field of alternative dairy proteins using similar technologies, such as the Israeli startup Imagindairy, which produces whey proteins and casein that they declare to be completely identical (at least from a purely “chemical” point of view) to animal-based products, likely for use in other dairy products.

3/ Stem: coffee powder from the lab

STEM is a Paris-based startup, founded in 2022 by Tom Clark (a specialist coffee roaster and wholesaler), Henri Kunz (biotech IP specialist), and Chahan Yeretzian (analytical chemist). STEM has developed a cellular agriculture solution to produce coffee from Arabica coffee plant cells.

The production process begins with undifferentiated coffee cell materials from selected varieties. These are propagated in a liquid suspension using a plant growth medium before being upscaled in a bioreactor through a fermentation process[14].

STEM has also developed an innovative and specific natural flavor engineering technique sourced exclusively from coffee by-products. This technology can enhance the sensory experience by extracting various precursors from different parts of the coffee cherry, leaves, green coffee beans, and spent grounds. The process is very similar to the one for lab-grown meat, except that here the process is obviously entirely plant-based, with no animals involved.

---

[11] https://startupitalia.eu/startup/non-solo-carne-remilk-e-la-startup-del-latte-sintetico - last accessed: April 2024 and https://www.calcalistech.com/ctech/articles/0,7340,L-3926451,00.html - last accessed: April 2024

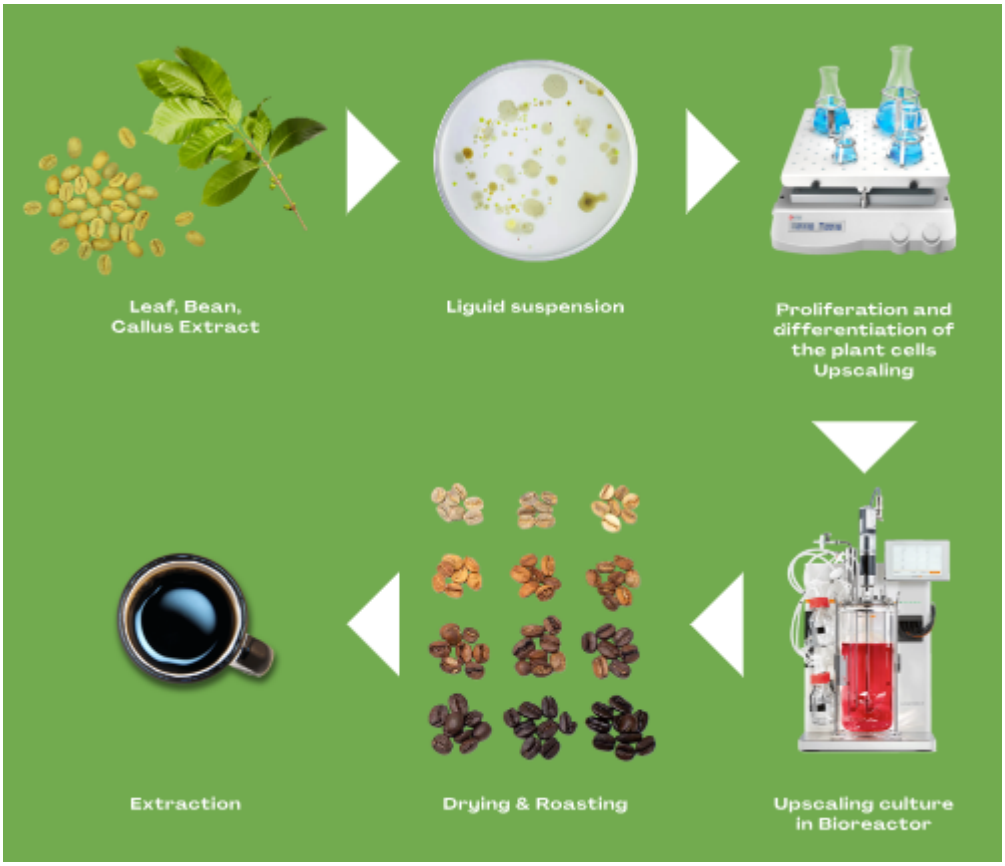
[12] Research and Markets, Dairy Alternatives Global Market Report 2024

[13] https://www.calcalistech.com/ctech/articles/0,7340,L-3926451,00.html - last accessed: April 2024

[14] https://s-tem.fr/#technology - Last accessed: April 2024, https://s-tem.eu/)

The product is a green coffee powder and not beans, because it would require extra energy, efforts, processes and would not add much value. This powder is then dried and roasted just like regular coffee beans. The roasted coffee powder is then ready for extraction using various popular methods. Once roasted, the granular size of this powder is very close to what you want for filter coffee without grinding. Initially, the STEM product is suitable for brewing as filter coffee. In a second step, they will also target the espresso market.

Figure 5 - The production process of coffee with STEM technology



(Source: STEM® - https://s-tem.fr/#technology – last accessed April 2024)

Of the two coffee varieties, Arabica and Robusta, Stem is targeting Arabica because Robusta is much more prolific, stronger, and more resistant, while Arabica is more sensitive and therefore its future is more uncertain.

Also in the case of coffee, climate change represents a significant threat to the future of the coffee market, for several reasons. The amount of land suitable for growing coffee, particularly the well-known and most popular Arabica variety, is shrinking. Arabica is very fragile as it is very sensitive both to temperature and to diseases. In fact, Arabica variety thrives in specific temperature ranges, which are shifting upwards due to global warming. Additionally, its genetics makes it highly susceptible to pests and diseases, a weakness exacerbated even more by climate change.

By 2050, projections indicate a 50% reduction in land suitable for Arabica cultivation. While moving coffee plants to higher altitudes is a potential solution, it comes with the unfortunate consequences of increasing deforestation, declining crop yields (soils at higher altitude are usually less productive and more costly), and with negative impacts on various environmental aspects like biodiversity.

On the other hand, global coffee demand continues to rise. Coffee is the third most consumed beverage in the world, after water and tea. Some studies predict that coffee consumption might triple by 2050. China and India, two of the world's most populous nations, are experiencing a significant increase in coffee consumption. This surge in demand from such massive populations fundamentally alters the landscape of coffee production and necessitates innovative solutions.

Additionally, in this landscape of divergence between the natural production capacity and the global demand, alternative solutions should take into account that coffee consumers are particularly sensitive to the quality, taste, aroma, and all the organoleptic characteristics of the product.

The development of techniques such as the one implemented by STEM could contribute to mitigate this divergence, by preserving the taste and the aroma, and potentially controlling also other elements, such as the level of caffeine. Clearly it will never be a complete replacement for agriculture coffee and especially for premium quality coffee, but it should probably be seen as a good complement for the production.

Looking ahead

From a business perspective, two main trends will shape the near future of cultured food:

1. Market consolidation: We will likely see a significant consolidation within the industry, with many startups and companies shutting down, primarily due to the scalability challenges mentioned earlier.
2. Expansion of the Pro-Nations: More countries are expected to follow the lead of Singapore, the USA, and Israel and approve the sale of cellular agricultural products. As of today, potential candidates include Switzerland, the UK, and Canada.

In the medium to long term, surviving companies will likely engage in extensive marketing efforts to raise public awareness and stimulate debate. This is crucial to create a market that currently remains largely nonexistent.

On May 15, 2024 Good Meat announced that its cultured chicken was now sold by a retailer in Singapore and was priced at 7.20 SGD (around 5 Euro) for a 120 g. package[15]. This is the first time that cultured chicken meat is sold at retailers allowing customers to buy it and cook at home.

The combined effect of the aforementioned challenges and the absence of a fully established market makes reliable predictions difficult. Therefore, forecasts from general market research companies should be viewed with caution.

A valuable resource to understand better possible future trends is the report "Food for Thought: The Protein Transformation," published in March 2021 by the Boston Consulting Group (BCG) and alternative protein investor Blue Horizon[16]. This report, considered a benchmark within the food technology sector, estimates that cell-based proteins could achieve cost parity by 2032. Additionally, this report also demonstrates how in the next decade cell-based protein production will register a higher growth rate (CAGR) compared to other alternative protein sources (plant-based and microorganisms-based).

[15] https://www.goodmeat.co/all-news/good-meat-begins-the-worlds-first-retail-sales-of-cultivated-chicken (last accessed: May 20, 2024)
[16] https://bluehorizon.com/insight/food-for-thought-the-protein-transformation/

Conclusions

Looking at the market data and some successful stories, we could definitely state that we are witnessing the rise of something with a positive impact that could change our lives, impacting the food on our tables, and the environment. However, the path is still long, with several challenges still unsolved, clear evidence on several aspects still required, and therefore we will probably need a couple of generations, or maybe more, for a full acceptance and a significant market presence of these products.

Furthermore, a significant amount of scientific research still needs to be done. Many challenges in terms of techniques, data analysis, differences in the quality of proteins, etc. are still open and need to be addressed with more consistent data and research. However, the sector is definitely promising, and the trajectory seems to be quite clear.

Another interesting question would be to see if the introduction of these new products and techniques will significantly impact consumers' behaviours (for example, in terms of lower meat consumption). Even if there is not clear evidence, probably consumers will slowly adapt their habits to the new products offered in the market, even if consumer acceptance cannot be taken for granted (Rosenfeld and Tomiyama, 2022). Disgust toward cultured food is still a strong potential barrier to consumer acceptance, mainly due to its perceived unnaturalness (Rosenfeld and Tomiyama, 2022).

These new processes deeply impact the “emotional side” of food consumption, which is an “experience” that strongly affects the emotional (and the unconscious/irrational side) of human beings. This will imply a significant increase in consumer knowledge, more awareness, and education about these new products and techniques, with a collaborative mindset, free of ideological prejudices. This means that cultured food and traditional food could not be presented as opponents, but as valuable allies for better human nutrition and a more sustainable planet.

The traditional meat industry's large investment in alternative protein producers is a clear sign of the potential for synergies and alliances between the two. On the other hand, caution is inevitable as evidenced by the case of plant-based alternatives such as Beyond Meat and Oatly having lost over 60% of their market value in the last year when they failed to meet the financial market expectations.

References

Carrington, D. P. (2020), No-kill, lab-grown meat to go on sale for first time, *The Guardian*, www.theguardian.com/environment/2020/dec/02/no-kill-lab-grown-meat-to-go-on-sale-for-first-time (last access: May 2024)

FAO, (2023), The State of Food and Agriculture 2023

FAO & WHO, (2023), Food safety aspects of cell-based food, Rome, https://doi.org/10.4060/cc4855en

Rosenfeld, D.L., Tomiyama, A.J. (2022), Would you eat a burger made in a petri dish? Why people feel disgusted by cultured meat, *Journal of Environmental Psychology*, Vol. 80, 101758, ISSN 0272-4944, https://doi.org/10.1016/j.jenvp.2022.101758

Sinke, P., Swartz, E., Sanctorum, H. et al., (2023), Ex-ante life cycle assessment of commercial-scale cultivated meat production in 2030. *The International Journal of Life Cycle Assessment*, 28, pp. 234–254 (2023). https://doi.org/10.1007/s11367-022-02128-8

Post M.J. (2014), Cultured beef: medical technology to produce food, *Journal of the Science of Food and Agriculture*, 94, pp. 1039-1041, https://doi.org/10.1002/jsfa.6474

Pullman M., Wu Z. (2021), Food Supply Chain Management. Building a Sustainable Future, Routledge

Wilks M, Phillips CJC (2017), Attitudes to in vitro meat: A survey of potential consumers in the United States, PLoS ONE 12(2): e0171904. https://doi.org/10.1371/journal.pone.0171904

Wood P., Tavan M, (2022), A review of the alternative protein industry, *Current Opinion in Food Science,* Vol. 47, ISSN 2214-7993, https://doi.org/10.1016/j.cofs.2022.100869 (access from https://www.sciencedirect.com/science/article/pii/S2214799322000716)