**New cuisine: A cultured steak tartare by Dutch manufacturer Mosa Meat.**

# New burgers on the plate

**CULTURED MEAT** Factory farming has an enormous impact on the environment. About 14 percent of the worlds greenhouse gas emissions result from producing meat and milk. But an alternative way of producing meat is as close as never before. San Francisco-based biotech Eat Just reveived a market approval for cultured meat in Singapore and started to sell cultured chicken nuggets in a partnering restaurant. It was the first approval worldwide. At the same time start-ups in Europe raise significant funding to scale up their production.

A couple of words made it one of the most iconic moments in the debate on climate change. „How dare you. You have stolen my dreams and my childhood with your empty words." These sentences were adressed to the worlds leaders at the United Nations Climate Action Summit in New York City by Greta Thunberg, at that time 16 year old activist. On 23rd of September 2019 she has put fear and anger of an entire generation into words. The anger that politicians are doing too little to combat climate change. And the fear that it will soon be too late to change anything.

A significant contributor to anthropogenic climate change is mankind's insatiable hunger for meat. More than 50 gigatons of carbon dioxide and carbon dioxide equivalents annually were emitted by humans in the period before the SARS-CoV-2 pandemic. About 15 percent of that was from the production of milk and meat. Global factory farming is thus one of the main drivers of climate change. Against this background, what happened in Singapore in mid-December was a sensational signal. The U.S. start-up Eat Just was the first company in the world to launch cultivated chicken on the market. Singapore had previously been the first country in the world to grant market approval.

Pictures: Mosa Meat

The figures are overwhelming and show that global food production must change radically: According to the Intergovernmental Panel on Climate Change (IPCC), the food sector accounts for between 21 and 37 percent of greenhouse gas (GHG) emissions. Livestock accounts for about 15 percent, according to data from the Food and Agriculture Organization (FAO). Of this share, almost half comes from the production and processing of animal feed, 39 percent from enteric fermentation, what means from the digestive tract of ruminants such as cattle, sheep and goats, and ten percent from storage and processing of manure.

> "You have stolen my dreams and my childhood with your empty words."

All told, livestock production accounts for more than half of the emissions in the food sector. According to the Heinrich Böll Foundation, 70 percent of global agricultural land is used for livestock production. According to this, around 40 percent of arable land is used for the production of fodder.

In 2018, the non-governmental organization GRAIN and the Institute for Agriculture and Trade Policy calculated the emissions of 35 of the world's largest meat and dairy producers. The result: the five large corporations JBS, Tyson, Cargill, Dairy Farmers of America and Fonterra together produce more greenhouse gases than a major oil company such as Exon, Shell or BP. Twenty of these companies together produce more greenhouse gases than Germany, the United Kingdom or France. With Arla, Danish Crown, Lactalis, Nestle, FrieslandCampania and Vion, six of these corporations have their headquarters in Europe. In its Meat Atlas, the Heinrich Böll Foundation outlines four strategies to reduce emissions. First, feed and herd productivity could be increased. This would mean more meat for the same environmental impact. Second, meat consumption could be drastically reduced. Third, the competition between food and feed production could be reduced by processing biomass unsuitable for human consumption, such as crop residues, into animal feed. This could reduce greenhouse gas emissions by up to 50 percent. And fourth, good animal husbandry practices could reduce the carbon footprint. By preventing overgrazing by rotating pastures and eliminating the use of grain feed, for example, 50 percent of emissions could be reduced. But these strategies ignore one aspect: the growing world population is demanding more and more meat. The

globally active management consultancy Kearney assumes that the problems of meat production cannot be solved by just optimizing production processes. In its report "When consumers go vegan, how much meat will be left on the table for agribusiness" it is said: "Major changes in the global meat market will be driven by the development and industrialization of biotechnological processes in the food industry." Accordingly, cultured meat is a key part of the solution.

What ist cultured meat? In brief, cultured meat is genuine animal meat including seafood and organ meats that is produced by cultivating animal cells directly. The manufacturing process begins with acquiring stem cells from an animal. So if the mnufacturer intends to produce beef, stem cells are taken from an adult cow by biopsy which is considered not to be harmful to the animal. These cells are then grown in bioreactors. The cells are fed an oxygen-rich cell culture medium made up of basic nutrients such as amino acids, glucose, vitamins, and inorganic salts, and supplemented with proteins and other growth factors. The cells proliferate. After feeding growth factors ist stopped, the cells start to differentiate into muscle or fat. A scaffold, for example from collagen or polysaccharides, needs to be added. With this structural support, the cells start to form muscle tissue. Layering the muscle fibres and adding fat results in meat.

## Obtaining serum from a fetus

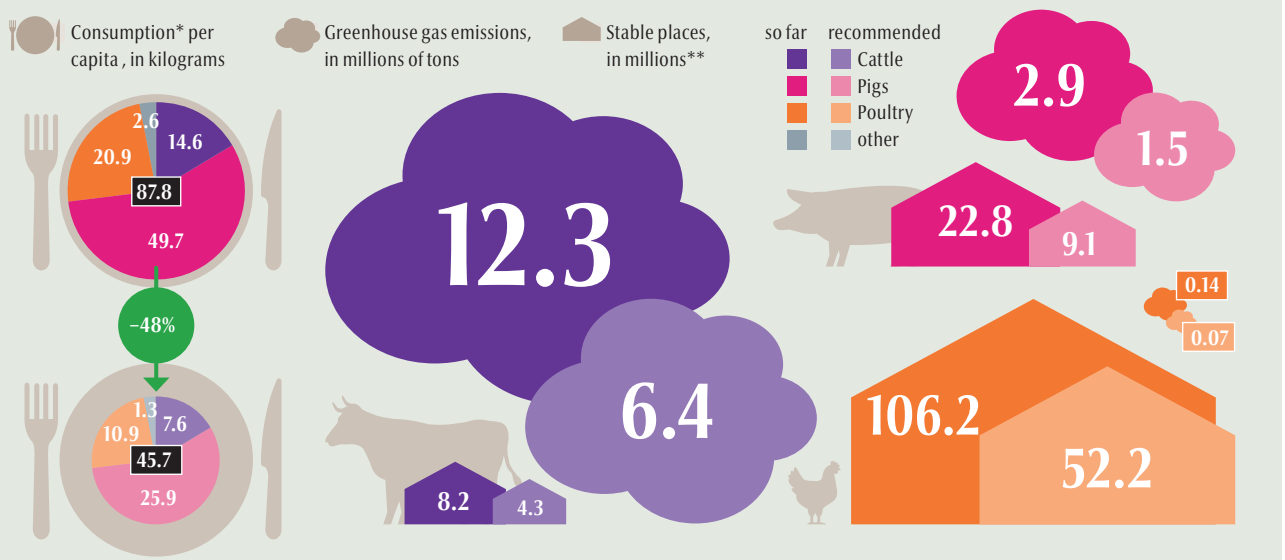
In scientific research often fetal bovine serum (FBS) is used for the growing medium for the cells. After slaughtering a pregnant cow the serum is obtained by inserting a needle to the fetus' heart which is still alive. The fetus is going to die during this procedure. For potential customers of cultured meat who want to reduce the harm to animals this is an unacceptable method. Therefore many manufacturers work on alternatives for their growing medium.

There is no consensus yet how to name the new meat. Depending on the context it is referred to as cultured meat, cultivated meat, safe meat, clean meat, victimless meat, slaughter-free meat, cell based meat, tissue-engineered meat, tubestake, test-tube meat, lab meat, artificial meat, in vitro meat or frankenmeat. And this list is not comprehensive. The labels result from a certain point of view. According to The Good Food Institute (GFI), a nonprofit organization promoting alternative protein innovation, „cultured", for instance, is interpreted by many to mean fermented or aged. And a bioreactor for cell growing appears similar to a fermenter for brewing beer. „Victimless" or „slaughter-free" emphasizes a way of production harmless to animals. „Safe" refers to the elimination of antibiotics, in vitro meat to scientific research which leads to novel food and frankenmeat to skeptisizm towards a seemingly unatural way of producing meat. The GFI prefers the term cultivated meat, whereas cultured meat is already widely in use.

However, cultured meat is no longer science fiction. On December 19, 2020, the private Club 1880 in Singapore served its guests cultivated chicken nuggets for S$23. The nuggets came from the laboratory of the US start-up Eat Just. A few weeks earlier, the Americans had received market approval from the Singapore Food Agency (SFA). „The weekend's transactions were the culmination

**Impact of less meat consumption**

Consequences of a reduction in meat consumption to an average of 600 grams per person per week in accordance with the recommendation of the German Nutrition Society and therefore reduction by 48%, calculated for 2017, Selection




* Consumption: weight before slaughter ** deviating from slaughter figures because production cycles are shorter (pigs, chickens) or longer (cattle) than one year ©Fleischatlas/Öko-Institut

Pictures: xxx

of a nearly 90-year-vision first articulated by British statesman Winston Churchill and pursued for decades by Dutch researcher and entrepreneur Willem van Eelen", Eat Just announced in December. Accordingly, the company acquired van Eelen's patents as part of a broader intellectual portfolio. "This historic step, the first-ever commercial sale of cultured meat, moves us closer to a world where the majority of meat we eat will not require tearing down a single forest, displacing a single animal's habitat or using a single drop of antibiotics", said Josh Tetrick, co-founder and CEO of Eat Just, in late December.

To receive the regulatory approval, Eat Just has demonstrated a consistent manufacturing process of their cultured chicken by running over 20 production runs in 1,200-liter bioreactors. No antibiotics were used, the company annonced. „I'm sure that our regulatory approval for cultured meat will be the first of many in Singapore and in countries around the globe", said Tetrick after receiving the approval. Tetrick said the plan is to make the product available in other restaurants in Singapore this year, and in retail stores by mid- or late-2022, as Singapore-based news network CNA reports. Accordingly, the chicken nuggets are manufactured at the Singapore Polytechnic's Food Innovation and Resource Centre. It takes about two hours to produce 48 nuggets.

Cultured meat is not yet available in Europe. But a vital scene of about 20 startups is working flat out to make it ready for the market. The Dutch company Mosa Meat, for instance, is a pioneer and frontrunner in that field. The Co-founders Mark Post ans Peter Verstrate made headlines with their 250,000-Euro-Burger in 2013. The world's first cultivated beef burger. Mosa Meat seems to be on track to an industrial scale of production. Growth media are still one of the biggest cost drivers in the production process. In last July the company announced a 88x reduction in their medium costs compared to the costs about one year before. And the team had also removed FBS. The same summer, Mosa Meat moved to a new facility, a small-scale pilot factory. CEO Maarten Bosch said in July: "We can achieve our plan to bring cultivated beef to market in 2022."

**Eat Just received market authorization for it's chicken nuggets in Singapore.**

And how far has Mosa Meat come? The company does not show its cards. „One of the main things we are working on in 2021 is scaling up our production and automating our processes to produce more meat. We are aiming to initially role out our burger in higher-end restaurants in the next few years", communication officer Hannah Tait said on request. She also said: "Novel foods in Europe go through a rigorous regulatory process which takes between 1.5 to 2 years. We are ready to begin this process soon."

## Funding of €70m

At least there ist cash to work on scaling up. The company has just completed an impressive Series B financing. This third closing of the quivalent to €8.3m brings the total raised in the round to the equivalent of €70m. Among the investors are Nutreco, a global leader in animal nutrition and aquafeed, and Jitse Groen, CEO of Just Eat Takeaway.com. The Series B funding round is led by Luxembourg-based Blue Horizon Ventures, following a Series A funding in 2018 led by Merck's investment arm M Ventures and Bell Food Group. Other partners are Mitsubishi Corporation, Target Global, ArcTern Ventures, Rubio Impact Ventures and Lower Carbon Capital. Mosa Meat wants to use the funds to extend its current pilot production facility in Maastricht, develop an industrial-sized production line, expand its team, and introduce cultivated beef to consumers. Staff already grew from 40 in spring 2020 to over 70 by now.

A quit young player in cultured meat business ist Swiss-based MIRAI FOODS AG. MIRAI is Japanese and means future. "We thought this fits well with our mission and can also be pronounced well in the western world", co-founder Christoph Mayr told European Biotechnology. MIRAIS mission is to accelerate the world's transition to producing food that is environmentally, ethically and economically sustainable. Its vision is to be a leading household brand for cultivated meat by 2030. The company was founded in 2019 as Swizerlands first and only cultured meat manufacturer. At the end of Januray it raised a funding equivalent to €2m. It was a first tranche of seed financing from backers including the Finland-based food company Paulig Group and German technology investment company Team Europe.

MIRAI's approach is special, according to Mayr. "Most of our competitors manipulate the cells genetically or chemically. We don't do that," he said. Mirai is also working on a serum-free medium. "We started on a small scale with a non-serum free medium to establish a baseline. In the meantime, we have developed several variants, including FBS-free media. In production, of course, we will only use FBS-free media," Mayr said.

Pictures: Eat Just

The production costs are still far too high. What does a kilo of cultured meat currently cost? "As much as a car. But costs are dropping fast", Mayr said. From an investor's perspective Mayr's seven-member team is making good progress. "MIRAI FOODS is a second-generation player in this field and they have been extremely fast. It only took them six months to develop the first prototype and we are very excited to be part of this team's journey," Marika King, Head of Paulig's venture arm PINC, said.

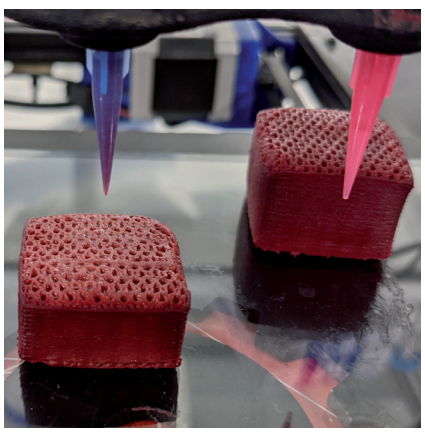
## Affordable for ealy adopters

The company is focusing on markets in Europe and Asia. Market entry is planned for 2022. Mayr is not yet revealing exactly where. By 2024, production should succeed on an industrial scale. And what will the meat cost when it is finally available for purchase? "When it enters the market, it will be in the upper price segment, but in such a way that early adopters can afford it. In the long term, the price should be below that of traditional meat," says Mayr.

Founded in 2018, Spanish start-up Novameat originally focused on producing plant-based meat alternatives. The special thing about Novameat is that the products come out of a 3D printer. In October Founder and CEO Giuseppe Scionti shared plans that his company has protoyped 3D printing hybrid meats that use plant-based ingredients for scaffolding together with cells from cultivated meat. "Our biggest cell-based meat prototypes – or you can call them hybrid meat analogues, as we mix mammalian adipose cells with a biocompatible plant-based scaffold – score at 22500mm³ in volume," Scionti told media publication Green Queen. Accordingly, it was the largest whole cut cultivated meat prototype in the world. Many comapnies are focusing on burgers or minced meat, since it is easier to manufacture than complex structures of whole meat. Novameat chose a different approach. „Whole-cut meats are in the daily diet of most people, so they can be considered essential for people transitioning from an omnivore diet to a flexitarian or vegan diet. The absence of these meat types in the alternative protein companies' portfolio proves that there is a big untapped market", Esther Plans, biotechnologist and scientific researcher leading the cell-based research at Novameat, told European Biotechnology. Novameat does't want to sell cultured meat but considers itself a supplier for scaffolding technology for cultured meat manufacturers, Plans said. From her perspective, the approval of the products could take a few years. „However, we hope it to be approved by 2025", she said. Whereas Novameat's plant-based whole muscle cuts are planned to be available in some selected restaurants already this year and in supermarkets in 2023.

Turkish Biftek Inc., founded in 2018, is focusing on a growth medium. With a seed funding of equivalent to €1.6m the company wants to optimizing it's product for chicken and fish cell lines. „We have tried our solution in mammalian cells so far. We plan to extend the use of our growth medium supplements for fish and chicken cells. We also want to scale up our production capacities", CEO Kerem Erikci told European Biotechnology. Biftek produces a plant and microorganism based growth medium. „FBS is not only unethical. FBS makes almost 90 percent of the costs of the cultured meat today which is more than $2,000 per kilo", Erikci said.

The global market for meat is huge.



**Printed Meat by Spanish manufacturer Novameat**

According to Kearney's report the global value chain is worth around the equivalent to €1,560bn. Just production of feed and meat, excluding wholesale and retail, is equivalent to €823bn. Assuming a growing worl population from 7.6bn in 2018 to 10bn by 2050 the demand for meat will grow. According to Heinrich Böll Foundation, meat consumtion has already more than doubled within the last 20 years to a total amount of 320mmt in 2018. In 2029 it could be already 360mmt.

## Arable land is shrinking

This brings along major challenges. Arable land is shrinking. And so is the supply of fresh water. Resistance to moderne agrochemicals is on the rise and soil compaction and erosion are posing problems. The use of antibiotics triggers antibiotic resistance among humans. Therefore the meat industry became more efficient. But this strategy is not sufficient any more. „The world's multibillion-dollar meat industry is facing disruption – possibly a massive one", the authors oft the Kearney report stated. „Solutions for making conventional meat production more efficient are almost exhausted. New players are entering the market: companies inventing products to replace the meat we have known so far. Among the lternatives are classic vegan meat replacements based on tofu, seitan, mushrooms or jackfruit. Classic vegetarian meat replacements may contain animal-based ingredients, such as egg, in addition to plant-based ingredients. Other replacements are made of insects, rich in proteins. Novel vegan meat replacemnets try to mimic texture and taste of meat. The alternatives mentioned above are altready available to customers. Totally new on the market is cultured meat. „In the long term, cultured meat has great potential because it can also cover the large market of whole cut meat at low prices. Much better than the current plant-based offerings. We estimate that in 20 years it will represent 30 to 40 percent of the global meat market", Carsten Gerhardt told European Bio-

Pictures: Novameat

**European cultured meat companies**

| Company | Location | Focus | Founders | Founded |
|---|---|---|---|---|
| Alife Foods | Leipzig, Germany | Meat production | Steffen Sonnenberg, Dat Tran, Joe Natoli, Bernd Boeck | 2019 |
| Biftek | Gölbaşı, Turkey | Cell culture media, meat production (beef) | Can Akcali, Erdem Erikçi | 2018 |
| Bio Tech Foods | San Sebastián, Spain | Meat production (undisclosed) | Mercedes Vila Juárez | 2017 |
| Biomimetic Solutions | London, United Kingdom, Nova Lima, Brazil | Scaffolding (nanomaterials), part of a larger tissue engineering business | Alana Santos Benz, Lorena Viana Souza, Aline Bruna da Silva, Roberta Ferreira Viana | 2017 |
| Bluu Biosciences | Berlin, Germany | Cultivated seafood (fish) | Sebastian Rakers, Ines Schiller | 2020 |
| Bruno Cell | Trento, Italy | Cultivated Meat | Stefano Lattanzi | 2019 |
| Cellular Agriculture Ltd. | Carmarthenshire, United Kingdom | Meat production (pork), bioreactors (hollow fiber) | Illtud Dunsford, Marianne Ellis | 2016 |
| Core Biogenesis | Paris, France | Cell culture media | Alexandre Reeber, Chouaib Meziadi | 2000 |
| Cubiq Foods | Barcelona, Spain | Meat production (chicken fat) | Andrés Montefeltro, Raquel Revilla | 2018 |
| Cultured Blood | Eindhoven, Netherlands | Cell culture media, bioreactors | Robert ten Hoor | 2019 |
| Gourmey | Paris, France | Meat production (foie gras) | Nicolas Morin-Forest, Antoine Davydoff, Victor Sayous | 2019 |
| HigherSteaks | London, United Kingdom | Meat production (undisclosed) | Benjamina Bollag, Stephanie Wallis | 2018 |
| Hoxton Farms | London, United Kingdom | Cultivated Meat | Max Jamilly, Ed Steele | 2020 |
| Innocent Meat | Rostock, Germany | Meat production | Laura Gertenbach, Philipp Wolters | 2018 |
| Meatable | Leiden, Netherlands | Meat production (pork, beef) | Krijn de Nood, Daan Luining | 2018 |
| Mirai Foods AG | Zürich, Switzerland | Meat production (undisclosed) | Christoph Mayr, Suman Kumar Das | 2019 |
| Mosa Meat | Maastricht, Netherlands | Meat production (beef) | Peter Verstrate, Mark Post | 2015 |
| Multus Media | London, United Kingdom | Cell culture media | Kevin Pan | 2019 |
| Peace of Meat | Antwerpen, Belgium | Meat producer (foie gras, fat) | Dirk von Heinrichshorst, David Brandes, Eva Sommer | 2019 |
| Planetary Foods | Berlin, Germany | Seafood production (undisclosed) | Ines Schiller, Else Wagener | 2019 |

Source: The Good Food Institute

TECHNOLOGY. He is partner at Kearney and one oft he authors of the report. Kearneys projection: In 2040 cultured meat could have reached a share of 35 percent of total meat consumption, novel meat replacements 25 percent whereas conventional meat would have declined to 40 percent. The market (feed and production) will then be about the equivalent of €1580bn. Many costumers might be in favour of cultured meat compared to plant-based alternatives. „It will require fewer additives and binders. Since it is obtained from the cell reproduction of real meat cells, it is much closer to the original meat than vegetable alternatives“, Gerhardt said.

And when will cultured meat be available on the European market? „Following the breakthrough in Singapore, cultured meat components could be on the market as early as the next five years. We expect a broader market entry around 2030, subject to approval by the European Food Safety Authority (EFSA). We estimate the duration of approval procedures to be around two years“, Gerhardt said. Until now no company has handed in an application yet, a EU commission spokesperson said on request.

Investors have taken notice. According to GFIs Cultivated Meat 2019 State of the Industry Report total Venture Capital Investment worldwide between 2016 and 2019 was equivalent to €137m including the equivalent of €63m in 2019. The number of deals was 58 in the same period, including 21 in 2019. The largest investment was equivalent to €17m. GFI data exclude many companies that are involved in meat cultivation but not as their core business. ■

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