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News & Highlights

Customers Start Eating Lab-Grown Meat—With a Side of Uncertainty

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In the summer of 2023, two US restaurants added a novel item to their menus: chicken grown in a lab (Fig. 1) [1,2]. The first to receive regulatory approval for commercial sale, the lab-grown—or "cultivated"—meat starts as a few real chicken cells that are grown in vats of liquid and nutrients until they become pieces large enough to shape into nuggets and strips.

The new offerings—in a San Francisco restaurant and another in Washington, DC—followed the June 2023 approval by the US Department of Agriculture of the production and sale of the lab-grown chicken meat by two US-based companies, GOOD Meat (Alameda, CA, USA) and Upside Foods (Berkeley, CA, USA) [2,3]. The companies and their promoters claim that cell-cultivated meat promises to minimize land use, emissions, pollution, disease spread, and ethical issues associated with livestock farming [2]. Optimistic investors have jumped on board, with industry reports estimating investments in lab-grown meat start-ups to have reached nearly 3 billion USD [3].

"It is hard for people to get a sense of just how early this industry is because there has been so much hype and so much private capital invested," said Elliot Swartz, principal scientist of cultivated meat at the Good Food Institute (GFI) in Washington, DC, USA, a nonprofit research group focused on improving the global food system. "It has led to a lot of inflated expectations around where we are right now and how fast we can move." Swartz added that GFI itself has funded more than 17 million USD in research grants related to alternative proteins, with around a third going to cultivated meat.

Skeptics say that scaling cell culture techniques to the production levels needed to replace any significant amount of current livestock will be difficult, if not impossible, and the cost of producing lab-grown meat may never be low enough to make it an affordable option for most people. One controversial study, published as a preprint in May 2023, concluded that lab-grown beef would have a larger carbon footprint and environmental impact than raising cattle—mostly due to the process of producing and purifying the nutrients and media required to grow the cells [4,5].

Ricardo San Martin, professor of entrepreneurship and innovation and director and co-founder of the Alt: Meat Lab at University of California, Berkeley (Berkeley, CA, USA), cited a 2021 research paper published in *Biotechnology and Bioengineering* that concluded that animal cell cultures simply cannot be grown at the massive sizes some companies are aiming for, due to intrinsic biological limitations [6]. The report points out that very large cell cultures are self-limiting; even with appropriate nutrients, they produce gases that slow or stop their own growth.

"A lot of independent researchers who do not have stakes in these companies agree that scaling cultured meat production up to make it economical is technically unfeasible," said San Martin. "You can always find someone willing to pay five or ten times as much as traditional meat for this niche product, but this is not going to change the world or feed the poor."

Unlike the plant-based meats produced by Impossible Foods Inc. (Redwood City, CA, USA), Beyond Meat (Los Angeles, CA, USA), and others [7], cultivated meat is the same at a cellular and molecular level as the meat butchered from animals. Bioengineers immerse cells acquired from an animal's muscle tissue in bioreactors where they can multiply into millions of cells. But when it comes to the specific cell types to begin with, different companies are taking different approaches, which has included starting with various muscle cells, muscle precursor cells, and muscle stem cells. Moreover, to mimic the texture of unprocessed meat, engineers also must incorporate other cell types, like fats and connective tissues [7]. "There has not been a lot of consolidation

Fig. 1. Commercially approved, lab-grown chicken like that shown here from the Alameda, CA, USA-based company GOOD Meat is being served at only a few upscale restaurants around the world. In San Francisco, a six-course meal including a small serving of the chicken costs 150 USD while in Washington, DC, a serving of cultivated chicken with potatoes costs 70 USD. Credit: GOOD Meat (public domain).

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yet of the exact cell types that people are using and how scalable those will be," said Swartz, who helped author a 2023 report cataloguing the cell lines various companies are currently using [8]. "We still see a pretty big variety."

So far, the bioreactors being used to grow meat commercially are small. An investigation reported in 2023 in the magazine *Wired* found that Upside Foods was using 2 L roller bottles to make a few grams of meat at a time—a tiny portion of a typical 170 g chicken breast—and had not yet gotten their huge steel bioreactors up and running [9]. According to the investigation, both technical hurdles and costs have contributed to the stall in scaling up to larger bioreactors (Fig. 2). Likewise, it is unclear whether GOOD Meat is using its large bioreactors to produce the chicken meat they are selling, but Eat Just, the San Francisco, CA, USA-based parent company of GOOD Meat, claims it is moving ahead with plans for massive bioreactors, although a separate 2023 *Wired* investigation reported financial problems and ongoing lawsuits from suppliers and landlords [10].

Regarding the issue of price, industry proponents argue that fine tuning the media, nutrients, and growth factors used in cell cultures could go a long way toward making lab-grown meat more affordable, which, in turn, could make it more feasible to scale up. The initial techniques used for cultivating cells come from other industries, in which smaller cell cultures were sufficient and food-grade supplies were not required. "The cultivated meat industry is really standing on the shoulders of what has been done in biopharma and cell therapy over the past two decades," said Swartz. "But now the challenge is to build bioreactors in which a complex tissue is the end product rather than a secreted protein or small handful of cells."

Swartz said his tracking of the cost of media used in meat cultivation shows its price is already decreasing. But commercial supplies of the growth factors that are also needed to propagate animal cells can today cost millions of USD per gram because they are produced at pharmaceutical-grade for biological drug production [11]. While cultivated meat only requires these proteins at nanograms per liter of media, experts still hope the cost will decrease. Research is ongoing into how such products can be made more cheaply at food-grade as well as the minimal nutrient requirements for different cell types. "In a lot of media formulations, there are excess nutrients, and the cells are overfed," said Swartz. "With cultivated meat, we cannot afford to have any waste at all—you want to utilize every nutrient you spend money on."

Fig. 2. The large bioreactors at the Alameda, CA, USA-based company GOOD Meat are intended to be capable of producing tonnes of lab-grown meat through precise control of the cells and media contained within massive steel vats, but skeptics say getting them up and running economically will require overcoming substantial technical challenges. Credit: GOOD Meat (public domain).

Investors, of course, are banking on the cost of lab-grown meat decreasing so that the product can be competitive with the huge meat industry, estimated to be worth 228 billion USD in the United States [12]. Armed with hundreds of millions USD in initial venture capital funding and optimistic that their scale-up approaches will be successful, Upside Foods and GOOD Meat are already expanding their production facilities. Upside Foods currently operates a 6500 m^2 facility at its Emeryville, CA, USA production center, which the company claims is currently equipped to produce up to 22 700 kg of cultivated meat a year. Their goal is to expand production at that facility to 180 000 kg a year—still a small percentage of the 2.25×10^{10} kg of chicken produced in the United States each year [1]. In September 2023, the company announced its plans to build a larger-scale, 17 000 m^2 facility near Chicago, IL, USA, which will have the capacity to eventually produce more than 1.3×10^7 kg of cultivated ground meat [2]. Likewise, GOOD Meat already operates a 3000 m^2 production plant in Singapore and a complex at its Alameda, CA, USA headquarter that the company says can ramp up to 1.36×10^7 kg of annual meat production [13]. And, in 2021, the company announced plans to build a larger-scale facility in Doha, Qatar [14].

Ultimately, even if production ramps up, questions remain about who will eat lab-grown meat. A 2023 poll conducted by The Associated Press–National Opinion Research Center found that about half of US adults say that they are unlikely to try meat grown using cells from animals, mostly because they find the concept "weird" [1]. Another concern is that lab-grown meat could harm local economies that rely on livestock. While European Union regulators have not yet approved any lab-grown meat, Italy has already banned the production, sale, and import of cultivated meat or animal feed in a pre-emptive move to protect farmers [15].

While lab-grown meat may be a long way from disrupting conventional livestock food supply chains, most consumers who have tried lab-grown chicken say it tastes "like chicken" [16]. For proponents of cultivated meat, that is perhaps the ultimate praise. "Our first goal, and still our most important goal, is to make people recognize that this is the meat they have always loved for thousands of years," said Uma Valeti, Upside Foods founder and chief executive officer, in a recent interview [16].

If people can be persuaded to eat it—and significant innovation occurs in how to produce it at larger scales and lower prices—there is a path forward for the industry. "We are birthing a whole new industry here and that takes time," said Swartz. "We may not all be eating cultivated meat in five years, but we do expect things to slowly scale up."

References

[1] Aleccia J, Ungar L. US approves chicken made from cultivated cells, the nation's first 'lab-grown' meat [Internet]. New York City: The Associated Press; 2023 Jun 21 [cited 2023 Nov 30]. Available from: https://apnews.com/article/cultivated-meat-lab-grown-cell-based-a88ab8e0241712b501aa191cdbf6b39a.

[2] Carmen T. Lab to table: the promise and the perils of cell-cultured chicken [Internet]. Washington, DC: The Washington Post; 2023 Sep 15 [cited 2023 Nov 30]. Available from: https://www.washingtonpost.com/food/2023/09/15/cell-cultured-chicken-lab-grown-good-meat-upside-foods/.

[3] Jones N. Will cultured meat replace the real thing? Nature 2023;619:22–4.

[4] Quinton A. Lab-grown meat's carbon footprint potentially worse than retail beef [Internet]. Davis: University of California, Davis; 2023 May 22 [cited 2023 Nov 30]. Available from: https://www.ucdavis.edu/food/news/lab-grown-meat-carbon-footprint-worse-beef.

[5] Risner D, Kim Y, Nguyen C, Siegel JB, Spang ES. Environmental impacts of cultured meat: a cradle-to-gate life cycle assessment. 2023. bioRxiv: 2023.04.21.537778.

[6] Humbird D. Scale-up economics for cultured meat. Biotechnol Bioeng 2021;118(8):3239–50.

[7] Palmer C. Engineer dinner—save the environment? Engineering 2020;6(3):213–5.

[8] Ravikumar M, Powell D. Cell line development and utilization trends in the cultivated meat industry. Singapore: Good Food Institute APAC; 2023.
[9] Reynolds M, Fassler J. Insiders reveal major problems at lab-grown-meat startup upside foods [Internet]. San Francisco: Wired; 2023 Sep 15 [cited 2023 Nov 30]. Available from: https://www.wired.com/story/upside-foods-lab-grown-chicken/.
[10] Reynolds M. Insiders say Eat Just is in big financial trouble [Internet]. San Francisco: Wired; 2023 Nov 16 [cited 2023 Nov 30]. Available from: https://www.wired.com/story/eat-just-financial-problems/.
[11] Blois M. Making cultivated meat cheap. Chem Eng News 2023;101(33):18–23.
[12] Douglas L. As lab-grown meat hits menus, the next investor hurdle is scaling [Internet]. Washington, DC: Reuters. 2023 Jul 20 [cited 2023 Nov 30]. Available from: https://www.reuters.com/markets/commodities/cell-cultivated-meat-hits-menus-investors-see-scaling-next-hurdle-2023-07-20/.
[13] GOOD Meat Partners with ABEC [Internet]. San Francisco: Eat Just, Inc.; 2022 May 25 [cited 2023 Nov 30]. Available from: https://www.goodmeat.co/all-news/good-meat-partners-with-industry-leader-to-build-first-large-scale-cultivated-meat-facility.
[14] Eat Just & Qatar Free Zones Authority announce partnership [Internet]. San Francisco: Eat Just, Inc.; 2021 Aug 31 [cited 2023 Nov 30]. Available from: https://www.goodmeat.co/all-news/eat-just-qatar-free-zones-authority-partner.
[15] Kirby P. Italy bans lab-grown meat in nod to farmers [Internet]. London: BBC; 2023 Nov 17 [cited 2023 Nov 30]. Available from: https://www.bbc.com/news/world-europe-67448116.
[16] Lowrey A. Open your mind to unicorn meat [Internet]. Washington, DC: The Atlantic Monthly Group; 2023 Jul 9 [cited 2023 Nov 30]. Available from: https://www.theatlantic.com/ideas/archive/2023/07/plant-based-lab-grown-meat-start-up-investment/674639/.