

A conversation with Mark Post, March 24, 2015

Participants

- Mark Post, PhD – Professor of Vascular Physiology and Chair of Physiology, Maastricht University
- Lily Kim, PhD – Scientific Advisor, Open Philanthropy Project

Note: These notes were compiled by the Open Philanthropy Project and give an overview of the major points made by Professor Post.

Summary

The Open Philanthropy Project spoke with Professor Post of Maastricht University as part of its investigation into cultured meat development. Conversation topics included current areas of work to make cultured meat commercially viable, funding sources for cultured meat research, potential future areas of research, and a projected timeline for commercial production.

Priority areas of work on cultured meat

Although the technology exists to create cultured meat, preparing the product for commercialization will require a number of improvements. Below are the priority areas of research and development for Professor Post and his team.

Quality improvements

The team is working to enhance the quality of cultured meat, at a small-scale level of production, in two ways:

- Achieving an optimal protein content level by changing the culture and feeding conditions
- Adding fat tissue to the product which would be added to the skeletal muscle tissue to create a true meat “mimic”

Elimination of animal products

The team is attempting to change the culture conditions in the lab to remove all animal products, most significantly fetal bovine serum (FBS). Developing an animal-free medium is very challenging because skeletal muscle and satellite cells are particularly dependent on serum. Professor Post’s team is also working on a synthetic replacement for bovine collagen, another animal product that is important for cell and tissue organization. Removing these products is necessary in order to eventually secure regulatory approval and ensure that the meat can be produced sustainably, without infringing on animal welfare.

The start-up cultured animal tissue company Modern Meadow has also worked on developing an animal-free medium. In addition, other researchers have worked with serum-free media, mainly for embryonic stem (ES) cells or induced pluripotent stem (iPS) cells, but no one else is working on developing serum-free media for skeletal muscle cells.

Scaling cell production

To begin to make its meat product commercially viable, Professor Post's team hopes to scale production to the capacity of a 25,000-liter bioreactor. Producing cells at this scale requires a different culturing technology, using large fermenters similar to those used for bacteria and yeast cultures. In addition, because the muscle stem cells are contact- and surface-dependent, they must be cultured using microcarriers. Microcarriers are small, often bead-like structures that provide a surface to which anchorage-dependent cells can attach when grown suspended in liquid in a large fermenter. Microcarriers have been used to culture stem cells, such as iPS and mesenchymal stem cells), but so far virtually no work has been done on culturing skeletal muscle stem cells on microcarriers.

Scaling production is the most challenging aspect of this research. Within academia, the largest existing bioreactor that also uses microcarriers has a capacity of 5 liters, so a 25,000-liter system would require expanding production by a factor of 5,000, a level previously unimagined. The cost of producing cultured meat must also be drastically lowered to make it resource-efficient and competitive with traditional meat. Currently the cells and culture needed to fill a 25,000-liter bioreactor would be extremely costly. Professor Post is starting a company to achieve scale-up at this level, which would not be possible from within the university.

At the same time, however, scaling up would not require any unpredictable technological leaps in the field, but could be done simply through incremental, linear progress over time, driven by an increase in funding.

Assembling knowledge through conferences

Professor Post is organizing a multidisciplinary scientific conference in October 2015. The aim of the conference is to accelerate progress toward commercially viable cultured meat by bringing together both people who work directly on culturing and those who are not in this field but use technology that could contribute to it. This would include science professionals with knowledge of advanced cell biology and cell culture technologies, as well as experts in psychology who could address strategies for building public acceptance.

The first international conference on this topic was held in 2008 in Norway, and a second was organized in 2011 in Gothenburg, Sweden, by researcher Julie Gold of Chalmers University of Technology. Most of the previous conferences focused on how to secure funding for this work.

Improving public understanding and acceptance of cultured meat

Although it is not a direct subject of his research, Professor Post is also involved in discussions of how to change public perceptions of cultured meat and how best to market it once the product is ready, as well as potential ethical issues and the societal impact of cultured meat. Public acceptance will be essential to cultured meat's success, so continuous interaction with the public is necessary.

Potential areas for further development

Transferability to other animals

Current research on cultured meat largely focuses on beef. This is because raising cows for beef has a greater impact on the environment than producing chicken or pork, as cows are much less efficient than either chickens or pigs at converting vegetable protein into animal protein. Beef is thus a better target for both reducing environmental impact and improving food security. However, if the goal were to improve animal welfare, chicken would be a better target because chickens are slaughtered for food on a much larger scale than any other animal.

Work on cultured meat is relatively easy to transfer from one animal to another. Professor Post's team began with mice before moving to pork and finally beef. The team needed about six months to optimize culture conditions for each new animal.

ES cells

Less progress has been made in using ES cells for culturing meat. A group of researchers who have spent the last 12 years working on porcine and bovine ES cells have so far not succeeded in keeping these cells in an undifferentiated state. ES cell technology does not yet present a viable opportunity for culturing meat, but is still a long-term future prospect.

Genetic engineering

So far Professor Post has not used genetic modification to improve the quality of the meat, to avoid the risk of negative public reception. This is due to his belief that any use of genetic engineering of muscle cells would turn public sentiment against the project.

Producing meat in other forms

No one has yet worked on creating a steak or any other similar "cut" of meat. This would likely be a further step after cultured ground beef is perfected.

Research approach

Research on cultured meat requires a great deal of trial and error. Professor Post's team's current approach is to apply all the serum-free culture media and conditions that have previously been successful to the satellite cells they are using to develop the meat. Because the researchers do not have the resources to design their own culture media, they work with culture media producers to determine an optimal composition, which is a time-consuming process. However, Professor Post believes that given enough time and experimentation, the production of cultured meat will be scalable.

Expected timeline for development

Professor Post believes that cultured meat can be produced commercially at scale in five to seven years. Though the product has not yet been perfected, it would be

marketable within three to four years if production were scaled up to the necessary level. Regulatory approval would take another two to three years.

At that point, the product would still be very expensive. However, after further refinement of the culture conditions, the cost of the product would likely be competitive within another three to five years (i.e., seven to ten years from now).

Challenges to funding and progress

Insufficient interest from the scientific community

Although there is a significant amount of work on tissue engineering in academia, most of it is not directed toward creating cultured meat or other foods. Research into food applications for tissue engineering is not as popular with the scientific community as medical applications.

Risk aversion in the food industry

The food industry is reluctant to embrace or invest in cultured meat because the timeline for commercial production is very long, and the product cannot be tested out on consumers simply by adding it to supermarket shelves. The food industry is also highly image-conscious and hesitant to take any steps that might be seen as radical and would thus diminish their consumers' trust.

Lack of government funding

The Netherlands has one of the few governments that sees the need for alternative proteins and is willing to fund research into them. On the Netherlands' list of funding priorities for alternative protein development, cultured beef ranks fourth, after vegetable proteins, insects, and algae. In Japan, a well-established bioengineer expressed interest in the application of tissue engineering to cultured meat, but said that the Japanese government was extremely unlikely to fund research in this area.

Current costs and sources of funding

Cost model

Based on the time it takes for cells to replicate and the number of cells per milliliter of medium, assuming a 25,000-liter bioreactor, the model used by Professor Post's team estimates a production cost of \$65 per kilogram of cultured beef. Other than the size of the bioreactor, this estimate reflects current numbers. No technological advances would be required to achieve this cost.

Funding

The majority of Professor Post's funding now comes from private philanthropy, as most government organizations have not been very responsive. The grant that Professor Post received from Google co-founder Sergey Brin enabled him to introduce the world's first burger made from cultured beef at an event in August 2013, which helped to build interest from the media and the general public.

With more funding, combined with increased participation from academia and industry, Professor Post believes that the time needed for commercialization could be shortened to three to four years instead of five to seven.

Other actors in the field

Academic research

Currently there is slightly more research being conducted on cultured meat in academia than in industry. Apart from Professor Post's five-person team working on muscle tissue engineering, small research groups throughout the world are working on cultured meat, including a team in Israel that is attempting to develop chicken and another team in Queensland, Australia, that is developing cultured fish. Interest in cultured meat seems to be growing among academic researchers.

There are many researchers working on skeletal muscle tissue engineering generally, and some of their technology could be applied to developing cultured meat. However, the researchers working on tissue engineering may not have the same set of priorities as Professor Post's team, specifically the need for animal-free media and the need to considerably scale up cell production.

Private sector

The largest commercial group currently working on cultured animal products is Modern Meadow. They are also working on producing animal-free leather.

Increasing participation from both academia and industry would help accelerate progress toward commercial feasibility. Industry could play a role by contributing to scale-up efforts, as well as addressing regulatory and legal issues and marketing strategy.

*All Open Philanthropy Project conversations are available at
<http://www.givewell.org/conversations>*