The Cultured Meat Debut

It is obvious that cultured beef should be considered as a serious alternative in the future. However, many hurdles stand in its way before it arrives onto the consumer's plate.

by Henk Hoogenkamp

Stem cell technology is slowly "growing" out of its role in the clinical armamentarium against disease and ultimately may make its way to our refrigerators and fast food menu boards. Lab-grown meat uses cells harvested from animal tissue that can be cultured, multiplied and turned into edible meat products. Dr. Mark Post, Professor of Physiology at Maastricht University, the Netherlands, is the lead scientist for this futuristic technology. The idea and technology has been lingering around for a while now. However, the recent spike in media coverage seems like a well-orchestrated effort to raise awareness and funding. Sergey Brin, the co-founder of Google, has already invested substantial assets in order to push this stem cell technology to the next stage. Is cultured meat doomed to fail or here to stay?

Meat Duplication

The myosatellite cells – or adult stem cells that are only able to become muscle cells – are programmed to form myofibrils in unison, as they multiply and as such are strikingly similar to skeletal muscle tissue in vivo. The result is biologically similar tissue to the meat from which it was harvested. The technology basically comes down to allow a small sample of muscle tissue to be separated into individual cells that are subsequently placed in a nutrient solution (medium). These cells are then nurtured to allow multiplication to create muscle tissue grown outside the animal. The cells naturally merge and rearrange into small myotubes. These myotubes are grown around gel hubs similar like a doughnut shape, contracting and creating bulk tissue. A single strand can actually multiply to trillions of new strands which –when layered together – replicates meat tissue. About 15,000 strands are needed to make a 100g or 4oz. burger pattie. For now, the most obvious reengineered tissue research is done to duplicate beef. The overriding reason is that beef has a very long outgrow cycle demanding extraordinary amounts of clean fresh water and feed. Generally about 9 kilos of feed and 2,000 liters of water are needed to generate 1 kilo of lean beef.

Professor Mark Post of Maastricht University has hailed as a success the first-ever cooking and tasting of a Cultured Beef burger. The burger was presented to the world at an event in London in August 2013.

Environmental Benefit

In vitro meat production using stem cells, also dubbed "cultured meat," is possibly an ecological and sustainable alternative to the economically inefficient livestock outgrow cycles. Currently, 70% of all agricultural land, corresponding to 30% of the earth's surface, is being used for livestock production in both grazing pastures and securing food stock.

Cultured beef could thus reduce the need for agricultural land and labor-intense feedlots, dedicated to meat harvests and substantially freeing up space to grow crops to be eaten directly by humans, without a transitory transformation. Besides improving upon ethical standing and food security, cultured meat could also help significantly to reduce the risk of animal-borne diseases like salmonella and *E.coli*, or even BSE, which causes mad cow disease. The advantages can even be extended onwards and have indirect implications on human health in general and possibly reduce the risk of cancer, cardiovascular disease and diabetes T2 in particular.

This futuristic option to grow meat could greatly reduce ecological and environmental stress factors such as clean water, energy use, emissions of methane and other forms of greenhouse gases that are some 20 times more potent than carbon dioxide. According the Food and Agriculture Organization of the United Nations, about 18 percent of all greenhouse gas emissions are generated by livestock production, more than all global transportation sectors combined. The anticipated huge increases in world meat demand by the rapidly increasing population, will surely further increase stress levels of greenhouse gas.

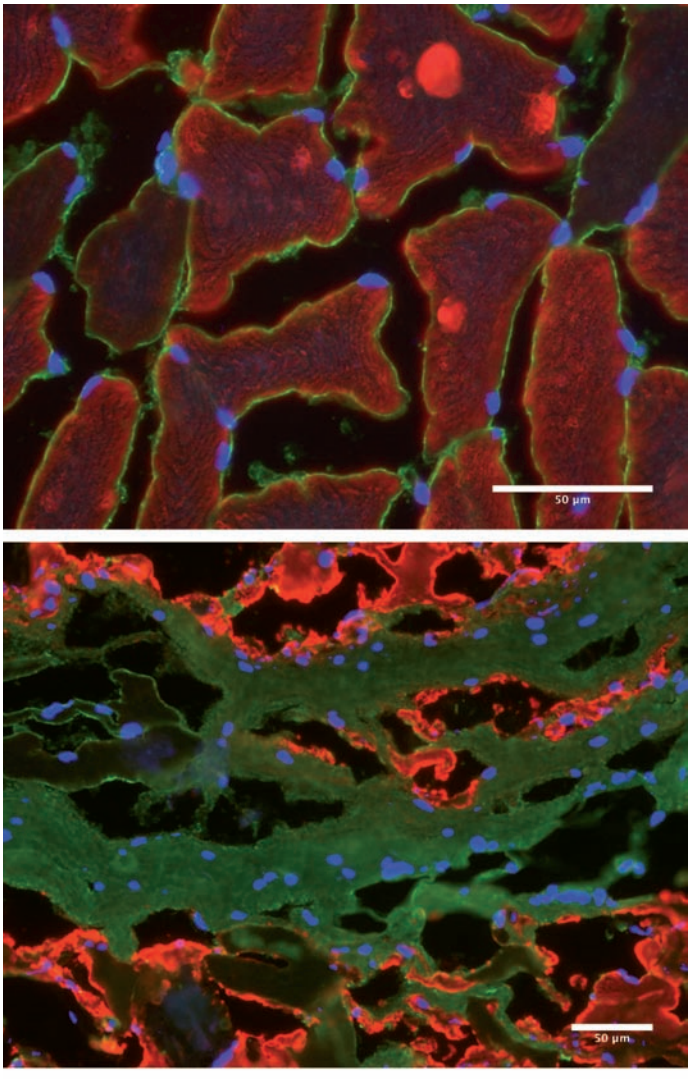
The Hurdles Ahead

It is obvious that cultured beef should be considered as a serious alternative in the future, however, many hurdles stand in its way before it arrives onto the consumer's plate. As previously explained, the technology currently uses myosatellite cells as a basis to grow the meat. However, currently the size and shape to which the muscle pieces can be cultured is limited to 1.5 x 0.5 x 0.15cm. Larger pieces of cultured muscle cannot receive enough nutrients in its core, due to the lack of a vascular system for the transport. Additionally, the *in vitro* proliferative capacity of mysatellite cells is far inferior to embryonic stem cells and thus needs to improve in order to obtain a commercially interesting culture time. Embryonic stem cells (which can form all cell types in the body) are not used

due to the difficulty encountered when trying to direct the cells to make only muscle tissue.

Another important issue is that cultured muscle cells by themselves have not yet resulted in a satisfactory product because of their inability to fully mature to functional muscle which can contract. Biochemical signals can be provided via bioactive proteins called growth factors, in order to help the muscle cells mature and differentiate into functional tissue. However, these growth factors are often isolated from animal sources like fetal calf serum or are made by recombinant DNA technology, subsequently limiting its use in cultured meat technology.

So for now, myosatellite cells are the way to go, and luckily there are some tricks up the researcher's sleeves that might accelerate the growth rate and overall quality of the cultured beef. For example, it is important to mimic the *in vivo* conditions during the culturing to ensure that the formed muscle really resembles the real thing. These conditions may be partially simulated by providing biophysical stimuli in the form of mechanical and electrical contractile stimulation. These methods have proven to be successful in the maturation of the muscle pieces towards functional tissue with native properties. Moreover, the myosatellite cells can be cultured together with other cell types, which help the formation of the extracellular matrix to which the muscle cells can adhere. This so called "co-culturing" of cells ensures that the composition of the cultured muscle is starting to resemble the *in vivo* situation.



Structure of minced beef stained using fluorescent antibodies. In figure A (top), you can clearly see the muscle cells and fibers, where the red (myosin) is surrounded by a green layer (collagen type I). The blue color represents the cell nucleus. In figure B (bottom), the heterogeneity of the minced meat is depicted, where a large piece of connective tissue is clearly present.These pictures show the intricate and complex structure of beef in its natural form. Samples were taken from a commercially available hamburger, 5μm sections were made and subsequently stained with antibodies directed against collagen type I and myosin. Figures A and B were taken at an magnification of 400x and 200x, respectively. bar = 50μm

Perception is Reality

Consumer acceptance and perception is almost even more important than the technological hurdles that have to be taken. In order to gain consumer acceptance the sensory appreciation and quality of the products have to be spot-on. It will be essential to combine cultured beef with other animal tissues such as fat, connective tissue and blood. The red color of meat is created by the proteins hemoglobin and myoglobin. Myoglobin can be found in muscles, and commercially available hemoglobin isolated from red blood cells can be added to the cultured meat products as natural food coloring. In the future, stem cell technology can be used to produce in vitro red blood cells, once again eliminating the need for animal blood. What might prove to be most important feature: flavor, taste and texture organoleptic parameters, will be the fat present in the final product. Let's face it, cultured beef flavor and texture will only be appreciated by consumers, if fat is part of the equation. After all, fat is the carrier of flavor and typically some 20 percent of fat is needed in a hamburger to provide for the highest degree of organoleptic satisfaction. Not surprisingly, the technology to use stem cells to grow fat is already known and like cultured meat, still needs refining before actual mass production can be upscaled. For now, it is expected that science will need at least another 20 years before the first commercial production stem cell based tissues are economically and technically feasible.

Teaming up Proteins

An alternative and much cheaper method to incorporate the much needed fat into a cultured meat hamburger is the use of micro-stabilized vegetable oil globules, by using milk protein or plant protein sources that have microparticulation properties to simulate fat. Actually, it is even possible to prepare a double emulsion in which the inner-layer can contain nutraceuticals, vitamins and minerals, such as iron. This fat-simulation technology is already widely used in many meat and food products and besides improving texture and juiciness, it will significantly reduce the amount of saturated fat. High amounts of naturally occurring saturated fatty acids in meat origin fats are known to significantly increase the risks of heart disease.

The Potential for Insect Protein

Proteins from insects are of high quality and can also be structured to mimic animal tissues. Moreover, insect protein hydrolyzates can be added to vegetable proteins to supplement the essential amino acids. Next to bacteria and fungi, insects are one of the most efficient organisms on this planet, which need little nourishment and energy to flourish. The technology and knowledge behind insect culture has been around for years and will offer many of the same advantages cultured meat does. While these technologies seem to be competitors, they do work towards the same goal of sustainability.

Although still many hurdles need to be taken before commercial introduction is viable, cultured or factory-grown meat should be given serious consideration, especially since current meat production methods cannot sustainably meet future demand. Since more than 50 percent of all beef is eaten as ground meat, it is obvious that hamburger versions will draw most attention and probably are the fastest way forward to bring this technology to market introduction. Here in the ground meat market is where other protein sources can and will excel and gain interest just like the cultured meats. For example, using texturized vegetable proteins to mimic meat structure has recently been introduced and now is being used by world's leading fast food companies as well as organic whole foods companies and subsequently has started to find its way into our everyday food and hybrid meat products. For example, structured and/or textured proteins mimicking chicken, ground beef and fish are used in meatfree or vegetarian products as well as frequently blended with meats to form hybrid products.

More Meat From Less

It is still too early to know for sure, but it is estimated that one single bovine cell sample (taken from the cow's shoulder) could produce 20,000MT of cultured beef. Translated into McDonald's language, this would mean that more than 175 million quarter-pounders hamburgers could be served. Since cultured beef will not appear on the menu boards sooner than 2030, it is safe to assume that by that time these cultured beef burgers are infused with structured plant protein fibers that uniquely mimic organoleptic meat properties including texture, juiciness, flavor and color. Combining premium sources such as soy protein, wheat, and rice bran protein makes these structured plant protein fibers an ideal solution to further stretch cultured meat. By going down this pathway, truly sustainable and cost-efficient hybrid meat products can be produced that will have a very satisfactorily consumer appreciation level. As such it can be assumed that for coarsely ground meat foods, the infusion or blend level will be about 50 percent cultured beef and 50 percent of structured plant-based meat analog fibers that completely match the characteristics of lean meat. Extrapolating the numbers, it would translate to about 350 million burgers or the equivalent of 800,000 cattle. Think about the huge amounts of savings that can be generated, including less intensive livestock farming and of course a much higher standard of animal wellness i.e. no need to slaughter. For now, still many more years will be needed before cultured meat might appear on the menu boards of fast food restaurants. Until then, it will be paramount to engage the consumer in a meaningful dialog to clear the pathway for general acceptance. After all, the highly intense GM-debates and confrontations with special interest groups such as Greenpeace, have shown the food industry how to avoid the pitfalls of groundbreaking technology and its potential consumer impact.♦

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