CULTURED MEAT: NO MORE SLAUGHTERING

Meat without animals is the new notion of cellular biotechnology using stem cells and bioreactors as the basic platform to "brew" healthy and nutritious clean meat.

By Henk Hoogenkamp

Cultured Meat Going Forward

To bring these cultured meat products to the market successfully, it will be essential to aggressively lower production costs in order to meet traditional food store fresh meat prices. Theoretically, cultivating meat should have high startup costs, but low operational costs. The main factor governing costs is the nutrient-rich medium (broth) in which the cells grow.

The 2018 and beyond, FAO statistics clearly show that protein consumption is growing around the world. People have an appetite for protein, whether it's animal-based or plant-based protein. There is a tendency, however, that in affluent societies plant-based protein is growing a little faster than animal-based protein consumption. All signs are clear that "protein migration" is here to stay. Meat is very complex and culturally ingrained; hence, plant-meat products will never be the whole answer.

Cultured meat production differentiates itself from conventional farm-raised and harvested meat in that it minimizes environmental degradation and is able to harness the ever-present risks of fecal contamination, such as those caused by E.coli and salmonella. Because cultured meat is free from spoiling bacteria, the meat will have a much longer shelf life. In fact, exposure to light and not bacteria is the limiting factor for cultured meat.

In the future, cultured meat should be entirely made in an enclosed clean sterile environment of a bioreactor with no use of harsh chemicals or growth promoting hormones or antibiotics, so there won't be any concern about drug resistance development in humans. However, the cultured meat technology is still partially dependent on the use of the above at this point in time. The risk of trying to grow one single type of cell generally means that methods need to be employed to prevent the growth of unwanted organisms. The larger the scale of growth, the larger the risk of contamination, ergo, the more stakes (read: money) involved in a failed batch. This may incentivize companies to keep on using chemicals and antibiotics until suitable alternatives can be found.

Health, Wellness & Sustainability

The environmental challenges facing the global agricultural industry are increasing. As meat demand soars, rainforest gets destroyed to grow animal feed, and fresh-water sources are diverted from drought-prone regions. Alternative and smarter ways to produce food and meat to be included into the daily diet will alleviate some of these pressures.

Human civilization was largely enabled by the domestication of livestock animals. In the future, cellular biotechnology is going to be the second domestication. Not only to produce huge quantities of cellular or clean meat, but also everything from growing leather, silk, perfumes, vaccines and organs.

In the future, the words "meat" and "animal" will be decoupled. Meat without animals is the new notion of cellular biotechnology using stem cells and bioreactors as the basic platform to "brew" healthy and nutritious clean meat. Making meat without the animals is rapidly emerging new concept. The ultimate goal is to remove the animal from the meat production. "It is time that the world moves past needing to kill animals and ruin the environment for food."

In Basic Terms

By relying less on an inefficient traditional meat protein-delivery system, people should instead utilize the nutritive value of the world's five major commodity crops – rice, corn, wheat, soy, and potatoes - as well as embrace cellular agriculture which can be further explored for the production of meat and animal-free dairy that could fundamentally reshape our food supply.

Put simply, the process of cultivating clean meat involves feeding the cells the correct nutrients to produce muscle and fat, as it would ordinarily happen were they grow inside the animal's body.

Cultured clean meat will be hugely beneficial in reducing the environmental impact that industrial farming has, as well as reducing the spread of food-borne illnesses, especially in light of salmonella contamination, and the fast-developing antibiotic resistance.

The major hurdles to cross are both in terms of the core science of growing

meat, and developing a manufacturing process that will enable "clean meat farms" to scale and at a cost that can compete with animal-reared meat. Also of importance is resonating with consumers about its name, quality and organoleptic performance.

Meat Minus Slaughter

Meat minus slaughter equals meat without animals. The "next-gen meat" will be produced with no traditional animal agriculture, no animal raising or slaughter. Clean meat is produced using cell cultures and these "slaughter-free" cells are cultured to become the constituent parts like mycocytes (=muscle), chrondrocytes (=connective tissue), and adipocytes (=fat). All these components are assembled and will ultimately provide the structural integrity of the product.

Cultured meat, also termed clean meat, is biologically identical to conventional slaughtered meat. All of this progress is possible due to advancements in chemical engineering, genetics, stem cell biology and regeneration. This method is a better way of bringing meat for human consumption with a very transparent production process signaling an inevitable shift towards an ecologically sustainable food system.

Cultured meat is a significant and huge technological leap for humanity, as well as an incredible business opportunity to transition a huge global legacy industry while solving some of the most urgent sustainability issues of our time, with significant reduction of greenhouse gases and feed-to-meat conversion inefficiencies. It is the new way forward to feed the world.

Post-animal Cellular Agriculture

The finite amount of agricultural land and the availability of clean water combined with resource depletion will force government policy makers to rebalance diets towards more plant-based foods. In other words, they will accept the need to reduce the consumption of foods with a higher environmental impact like slaughtered animals for meat consumption and using dairy cows for milk production, while increasing lower-impact foods like cultured cellular meat to enrich the diet with plant proteins derived from cereal grains, legumes, potatoes, vegetables, and fruits. Considering cellular agriculture like the emerging animal protein sources is vital to create cultured meat, natural cultured dairy foods, insects and other post-animal biotechnology and bioeconomy developments to boost food security and affordability.

Riding the Revolution

(Partly) replacing or reducing conventionally-killed animals for meat supply with cultured meat

Plant - based burger

can significantly reduce land, water, and crops needed to feed animals, while benefitting people's health and reducing outbreaks of diseases. For the next generation, sustainability of food security will be a major challenge. Besides the fundamental economic and technological challenges, the biggest hurdle is how to convince consumers to try the plant-based equivalent and the food "harvested" from cell cultures instead of the "real or original" food.

When exponential technologies stride forward, consumers have the tendency to become suspicious. The question is, if consumers will embrace cellular bioengineered foods like animal-free milk supplanting traditional cow's milk. This question is difficult to answer, but the fact remains that the world population is growing at unprecedented pace and innovation will be the essential key to provide every citizen great tasting healthy foods now and in the future.

Stem Cell Science

Cultured meat directly originated from cell and gene therapy, a science that is increasingly used in the field of regenerative medicine. Cultured meat is meat grown from animal cell in culture and the first step is to make it grow in a cell proliferation bioreactor where a nutrient solution or medium allows the cells to quickly grow and multiply. The isolated animal cells regenerate with external support like oxygen and nutrient-rich broth that enables the cells to grow and multiply. This process is followed by scaffolding, which actually provides a support structure for cellular adherence, and develops –if needed- into the various component cells of the integral meat composition.

Stem cells are undifferentiated cells that can become different types of tissue as they mature (and can form healthy new muscle to replace what has been lost). The muscle-forming cells will join together in long chains and become multicellular myotubes. Since these myotubes are living tissues, at some point they will start spontaneously contracting.

Scaffolding is an essential part of the cultured meat process because it provides heterogeneity structures that influence variables like texture. At this point, variables come into play so it might best to use plant fat rich in mono- and polyunsaturated fatty acids, instead of cultured animal fat, with increased levels of Omega 3 and 6 or a different vitamin/mineral profile.

Compared to conventional animals, there are fewer concerns regarding the environment, animal welfare, and human health. Animal agriculture is the largest single source of greenhouse gas emissions globally. These emissions will only grow further now that developing countries are rapidly increasing meat consumption for which billions of additional slaughter animals are needed annually. Another point of concern is the increasing frequency of human health concerns associated with meat consumption and its supply industry. Some risks need to be considered like antibiotic resistance, disease and viral outbreaks, as well as microbial food contamination, which can be managed by reduction or elimination.

Ready to Roll

The current economics of cell-cultured meat is a long way from competing with the current intense-harvests of animals. However, going forward, it is expected that cultured meat can be cost-competitive with conventional raised meat. All signs are clear that the first bioreactors for commercially sold clean meat will be ready sometime in 2022 or slightly thereafter.

Even tough clean meat is some years away from large commercial introduction, it is likely that cultured meat will eventually be cheaper than ranch-grown meat. Looking in the future, it is not unthinkable that traditional cattle ranchers will go out of business because of competition from meat grown via cell culture. Traditional ranchers might arrive in a disadvantageous position because of the long outgrow cycle of beef and everything else that is associated with bringing traditional meat to the table.

The world's overreliance on factory-raised livestock to feed the burgeoning demand for protein will be ecologically and environmentally difficult to sustain. Add to that the misery of highly intensively industrial meat production often associated with the use of chemical fertilizer, hormones, antibiotics, energy, land and water required to keep the outgrow cycle of animals at pace for an early arrival at the slaughterhouse.

There is Logic in "Brewing" Meat"

All of these variables remain mostly invisible for consumers when selecting their beautifully shrink-wrapped meat cuts at the meat case in the supermarket or when served as a center-of-the-plate choice in a restaurant.

The younger generation of customers – millennials born between 1982 and 2004 - increasingly take more responsibility for the "invisible animals" that end up in a slaughterhouse, where it will be stunned, skinned, eviscerated and processed.

The large legacy food and meat companies owe it to their shareholders and stakeholders to have a contingency plan in place to –at the very minimum- profit from a plant-based protein market with special focus on meat substitutes, including hybrid meat and plant connotations. There will be no other choice as soon as intensive livestock production will reach peak levels of greenhouse gas emissions and

pollution, not to mention the growing health concerns of some degenerative diseases affecting the aging population which will likely cripple the quality of health services and living standards.

There are also calls to reverse high meat consumption in the affluent world by –much like sugar and tobacco- implementing a red meat tax to forcefully tackle the environmental impact of beef and pork production.

In terms of protein quality, there is nothing wrong with eating animal-derived meat protein as a healthy dietary source. However, eating factory-raised animals is quite another thing and a topic that is increasingly subject of controversial and heated discussions. That is why cultured meat is such a welcome and wonderful new technology, which not only eliminates the friction of the different mindsets, but also allows diversification of the global protein supply.

Cultured meat started out its journey as "laboratory-grown", but it will be essential to coin a descriptive name that resonates with consumers and is indicative of its origin. There is nothing unreal about cultured meat, which some industry insiders now refer to as "clean meat". "Clean meat" is analogous to "clean energy" and will help the food industry avoid ballooning costs of grain, water and waste-disposal associated with livestock. The product is most certainly not "fake meat", but rather real meat made from real cells from real animals.

The point in case is that cultured meat allows manufacturing of wholesome high-quality protein creation without the need to feed, raise and slaughter the animals. All of these variables are a much better way forward for the environment, the animals and humanity.

Cultured meat –which is part of the new cellular agriculture movement- requires up to 90 percent fewer greenhouse gas emissions, while using much less water and habitable land compared to the traditional or conventional intensive animal farming systems. Traditional animal agriculture and intensive raising of animals for slaughter –especially beef- requires huge amounts of fresh water of which availability is increasingly affected by the human interaction and needs for a growing demand for food security, like growing vegetables and fruits and securing sufficient high quality protein sources.

Leading up to 2020, there are currently some 20 universities and upstart

companies conducting cultured meat research. There are several cultured meat upstart companies that prefer to stay in the stealth-mode and, for the time being, do not seek publicity to share its work and research.

From Idea to Reality

The road to successful large-scale industrial cultured meat is still quite long. However, looking at the large pressure on natural resources in the coming decades, the world has no other choice but to embrace this new biotechnology, which can become an integral strategy as part of combining it with plant meat formulated products. The tandem or hybrid of an integrated animal-free cultured meat and plant protein derived diet is probably the most logic way forward.

For example, Memphis Meat, San Leandro, Silicon Valley California debuted in March 2017, the world's first chicken strip from animal cells, following the animal-free meatball introduction in 2016. In a nutshell: using animal cells, and infusing grow cultures ultimately transitions in a few weeks to clean and nutritious food to make the cells grow into muscle. This whole process from start to finish takes about four to six weeks, depending on the organoleptic parameters. Memphis Meat has successfully created cultured beef, chicken- and duck meat. Duck meat might sound weird at first, but it is popular in China, which consumes more of it than the rest of the world combined.

Memphis Meat has received financial backing from Cargill and household-name individuals like Sir Richard Branson and Bill Gates. Memphis Meat mission is bringing cultured meat to the plate in a more sustainable, affordable and delicious way. Meat is still universally enjoyed in many of the world cultures and traditions, though it is time to switch from conventional slaughtered meat that creates challenges for the environment to a humane and clean method of meat production.

To turbo-charge change and disruption of the status quo, capital venture companies which include Horizons Ventures, DFJ, Temasek Singapore, Viking Global Investors, Khosla Ventures, PHW Germany, Stray Dog Capital, New Crop Capital, and Kleiner Perkins provide assistance and strategic advice to entrepreneurs working on these breakthrough technologies. Also legacy companies, such as Tyson Foods and Cargill, have started to take part-ownership in "disrupting companies" like Beyond Meat and Memphis Meat.

More to the point, most new technology introductions are taken with skepticism and often driven by a "can't do" attitude. It is precisely the entrepreneurial spirits of many of the capital venture companies that are uniquely able to select the true innovators and provide the financial means to make their dream come true. With this is mind; it seems to be easier to fund a disruptive plant protein startup than to find capital support for an animal protein startup company.

Capital Venture:
The Drivers of Change

Company	Country
* Mosa Meat	Netherlands
* Super Meat	Israel
* Aleph Farms	Israel
* Memphis Meat	USA
* Modern Meadow	USA
* Finless Foods	USA
* Just	USA
* Integriculture	Japan

Pushback

Like with any other disrupting innovation, there is usually a pushback from the legacy meat industry for fear that their "monopoly" business model might

Some universities and upstart companies are conducting cultured meat research

be threatened. Instead of embracing new science and looking how to incorporate new learning's, there are reports of orchestrated attempts to sabotage or greatly slow down the speed of progress.

It is not a bad thing to take a step back to view these changes in light of the greater good, a changing ethical and moral landscape, acknowledgement of knowledge gaps, implications on a larger time scale, unforeseen effects on ecosystems, and much more.

Ultimately, implementation of new technology will win due to the numerous inherent socioeconomic, health and food security issues the global market will eventually need. History has always shown that progress can be temporarily slowed down, but ultimately it will succeed. Hence, the big-name traditional meat processors will ultimately embrace the emerging cultured meat technology, whether as acquirers, licensees, customers or investors.

More than One Option

An alternative option is to use bovine serum from unborn calves' blood. This method might not bode well will animal rights activists. Then there are also the so-called "immortal" cells, which are genetically modified to grow on a continuous basis. Rapid DNA sequencing allows radically faster and cheaper to program yeast cells to manufacture protein. Going forward, additional cell-harvest methods will become available which will likely drastically cut manufacturing costs.

Cells from a certain starter culture are typically brought together on a scaffold to grow in conjunction with serum in an environment (=bioreactor also known as a fermentation tank) that promotes growth. In living bodies, blood vessels assure transport of nutrients to and remove waste from tissues. Because of the lack of vessels in cultured meat, the tissues can only reach a length of about 0.5 mm thickness. This feature explains why all initial groundbreaking research focuses on ground meat appearance, such as that used in hamburger patties and meatballs, rather than a whole-muscle steak.

New Learning's

There are currently a few different methods researched to optimize the most efficient method to regenerate meat. Technology allows a transformation of adult livestock cells into a pluripotent state and this advanced knowledge of stem cell technology allows scientists and engineers to develop a self-renewing skeletal muscle progenitor for cultured or clean meat and other livestock products. Stem cells from larger animals have traditionally been difficult to generate. Skeletal muscle can be efficiently generated from induced pluripotent stem cells (piPSC in vitro). This emerging technology provides a versatile platform for applications ranging from regenerative medicine, skin crafting to the cultivation of meat.

There is also cultured lean beef made from using cells extracted from a live cow (biopsy) and grown into tissues and small actomyosin muscle. A small biopsy sample is taken from the animal, segregated it into cells that proliferate in culture and, subsequently, grown into true lean tissue.

The method can be described as separating muscle tissue cells and fat, after which the individual cells start to self-renew and multiply. Once this process is underway, the growing cells merge into a myotube of about 0.3mm. These small cell muscles have the tendency to contract and grow into small pieces of lean meat strands of about 3mm length. When all these grown strands are layered together, lean meat is recreated right back to the starting cell. Actually, 1 starting cell can transform into more than 1 trillion muscle strands.

3D

3D technology has now entered the cultured or clean meat vocabulary and specifically it allows growing all the cells that make up traditional meat simultaneously –the muscle fibers, the fat, the blood vessels and connective tissue (collagen). Blood vessels have an important role to play in replicating the structure of the grown meat, which impacts its texture. Using the four different cell types found in traditional cuts of meat creates a holistically grown three dimensional meat product that is much closer to the meat that people recognize and crave. Tyson Ventures has teamed up with Israeli biotechnology company Future Meat Technology to speed up the clean meat movement.

The Analogy of a Car

The proliferation (growth and multiplication) of animal cells in vitro brings a couple of large challenges regarding what type of external support and triggers they require. The simplest requirement is that the basic physiochemical properties are similar to that of the animals' body e.g., oxygen, temperature, pH, moisture and pressure. Adequate supply of animal-free nutrients like amino acids, sugars, vitamins, trace elements and such is still fairly straightforward. Think of this as putting gasoline in a car. However, the successful growth of animal cells in vitro also requires one to determine how far the gas pedal is pushed, apply breaks when needed, and steer the vehicle in the right direction. In this case, variables are in play like the use of growth medium, growth factors, cytokines and more, which are currently either derived from animal by-products (blood plasma, interstitial fluids and more) or genetically-modified single-celled organisms (yeast, fungi and bacteria).

Last but not least, varying factors like mechanical strain, oxygen levels, concentration of metabolic by-products (e.g. urea, lactic acid) can also have significant effects on the cells. If the factors mentioned above are not balanced or applied correctly, the car might not move at all, run at the right speed or, worst of all, not drive in the right direction.

This analogy tries to explain complex cellular processes where the proliferation of a muscle cell does not matter if it does not stay a muscle cell. This is because, arguably, cells have the potential to transform into another cell type. For example, cells making up muscle tissue can, under certain circumstances, turn into fibrous connective tissue or even calcified bone tissue. This process is called differentiation in which it is paramount to be able to control the mechanisms.

Clean & Natural

Cultured meat –in vitro- is composed of a tissue or collection of tissues, not an organism. This fact will probably allow avoiding the dreaded GMO discussions. The in-vitro grown cells are carefully controlled in an enclosed environment. In a very special way, the technology can be compared to hydroponic vegetable growing methods.

In principle, all types of meat can be cultured: beef, pork, turkey, chicken and fish. As a matter of fact, once the cultured meat science and engineering technology is ready for large up-scaling, there will come a time when cost efficiencies are economically competitive allowing mass-production of a nutritionally-superior lean and tasty protein source. Large-scale tissue engineering technology will allow also manufacturing delicacy foods like "clean foie gras" products. Much of meat's flavor comes from the breakdown of collagen, therefore, it will be necessary to cultivate different types of cells to truly simulate the desired meat flavor profiles.

This process is healthier, safer, and more sustainable than conventional animal agriculture, not to mention the environmental benefits like significant lower water consumption, lower surface footprint, and possibly no antibiotics and hormone usage during the outgrow cycle. Since cultured meat is largely bacteria-free, there is less need to store it at the same low temperatures as traditional slaughtered meat.

The future is approaching faster than many people like to think. Cellular agriculture products like cultured meat, dairy and eggs have significantly less environmental and ecological stress factors, not to mention that the foods can be enhanced by stripping unwanted compounds, such as saturated fat or lactose and create lactose-free milk or cholesterol-free eggs.

Name Calling Anyone?

Come to think of it, the terms "cultured" or "clean-grown" meat can put people off the revolutionary animal protein product. A new terminology of this new concept of tissue engineering is necessary for consumers to clearly understand that –for example- a description like "clean meat" is a more accurate way of communicating real meat grown without animal slaughter while highlighting its environmental sustainability and the decrease in food-borne pathogens and drug residues. "Clean meat" is better for people and the planet.

After everything is said and done, cultured meat needs to stay away from the negative perception of synthetic manufactured foods. The mind of the consumer will not probably grasp words like "lab-grown", "cultured meat" or "clean meat". After all, the opposite of clean meat is "not-clean". It really doesn't matter whether this

Cultured meat - invitro

Impact Score Overview:

- About 25% of Earth's ice-free surface is taken for livestock farming. This surface area is about 70% of all land used for agriculture.
- Approximately 45% of the earth's total land is covered by classical animal agriculture.
- Some 55% of water consumed in the US is for animal agriculture.
- About 30% of the fresh water footprint is used for the production of animal-derived products, including meat, dairy, and eggs.
- Greenhouse gas emissions generated by livestock farming (18%) is higher than global transportation (12%).
- The huge amounts of antibiotics given to livestock cause major implications to human antibiotic resistance.
- Most of bacterial contamination induced foodborne illnesses, such as E.coli and salmonella, arise from livestock farming, including waste dispersion to grow plants.
- The huge increase in global demand for animal-based food -66bn land animals slaughtered in 2017 and growing to 100bn+ in 2050- will put major strain on animal welfare, including challenges at factory farms, intense confinement and imperfect slaughter conditions

logic is right or wrong, as consumers usually attach symbolic meanings to certain words, even though they do not understand these words. For example, meat grown from stem cells, rather than traditional meat, can be considered less natural and perhaps more risky.

It is clearly a huge problem that "laboratory-grown" meat is still struggling with its own descriptive name. As it stands now, cultured meat is known by many names: cellular meat, clean meat, synthetic meat, fake meat and "in-vitro meat". These are just different names for basically trying to say: "Cell cultures instead of animals".

Societal-wide acceptance of "clean meat" may take a generational change –young people will be more open- though clean meat will ultimately be cheaper than conventionally farmed meat, which suffers from notoriously low resource efficiency like feed, land, and water costs.

Although the scientists frequently use the name "cultured meat", the description "clean meat" is trending and might be a better strategy to attract the interest of the consumer. But then again, there is still the very influential political lobby of the traditional meat industry and, no doubt, heavy pushback will happen. If "clean meat" is going to be the marketing name going forward, in the mind of the consumer, all other traditional or conventional meat will be considered "unclean".

One of the regulatory issues that still need to be solved are the standards and definitions. For the US, this means that the FDA and not the USDA will likely be given the authority to decide on issues like labeling, since no life animals are involved.

The Verdict

Symbolic meanings and interpretations often override issues like environment-friendly as well as better treatment and less suffering of animals. Other examples are the terms "sugar" and "fruit sugar". In the symbolic interpretation by the consumer, sugar is bad and fruit sugar is healthy, although both are chemically identical. In psychology, these behavioral characteristics are described as the halo effect. The verdict is still out on how cultured meat needs to be marketed to be successful.

Initially, only a subset of affluent consumers will be willing to pay premium prices for cultured or clean meat, marketed as environmentally sound and sustainably produced, as well as cruelty-free.

Perhaps an agreeable description could be "natural meat analog". Over time, the consumers have gotten used to these innovative foods and cultured meat eases into the supply chain without any further identification necessary.

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