IMAGING THE FUTURE: CELLULAR AGRICULTURE

By Henk Hoogenkamp

Part 1

When talking about meat consumption, something has to be done sooner rather than later. For example, let us look at China: In the 1960s, the average Chinese adult person consumed less than 5 kilos of meat annually. Fast forward, in 2020 that number increased to an astounding 63 kilos. In 2021, China will consumer some 28 percent of the world's meat, of which some 51 percent of all pork produced globally.

Another eye-opener: some 60 percent of soy across the world is shipped to China, mainly for animal feed usage.

It is estimated that the demand for crops like the soybean is expected to increase by 80 percent in 2050. About 98 percent of the soybeans are used for animal nutrition. Soy agriculture require large amounts of water and is increasingly associated with driving deforestation, leading to catastrophic environmental damage, including eradication of wildlife habitats.

Looking at these numbers, it is clear that transformative protein selections will become important. Plant meat and plant milk are one of the choices to reduce man-made greenhouse gases (GHG). Applying alternative protein sources from -preferably regional grown plants- as well as cellular agriculture, including molecular farming, will be crucial to meet the strict emission targets over the next decades. China's sign-off on carbon emissions will be essential for global emission reductions. If not, all other attempts will fail.

Bio-Engineering

The future of bio-organism engineering is software and hardware automation. In other words, biology by design will replace much of the legacy technology. This will occur by self-replicating and self-repairing renewable molecular structures that build cultured ingredients or products via fermentation with engineered or modulated yeasts or fungus support. Designer enzymes are an integral part of these bio-industrial applications, ranging from cheese-making to pharmaceuticals, or from textile fabrics to ecologically friendly cleaning agents.

Source:
"Photo courtesy of Honest Burger Restaurant".

Biotechnology is a uniquely powerful technology that can reduce or eliminate the need to grow and manufacture everything. Instead, DNA modification is the new platform which can create cells that use amino acids (the building blocks of protein).

For the food industry, biotechnology has the potential for reducing demand for cattle and meat-producing animals, even as the demand for dairy and meat rises. Cultured milk protein and cultured meat can probably be seen as one of the biggest technological leaps for humanity by using up to 90 percent less land, water, and greenhouse gas emissions rather than conventional dairy and meat production.

Relatively speaking, cellular biotechnology today is still at its very early stages of success. There are clear signs that proteins are poised to become sustainable next-generation ingredients with huge potential for humanity.

Reshape Food for Future Generations

Agricultural civilization came before the technology-driven era by several millennia, but technology-driven inventions have since overpowered agricultural domination. Cellular agriculture has less negative ecological and environmental footprints or side effects compared to traditional farming and intensive animal production for human consumption. Cellular agriculture is a truly groundbreaking entrepreneurial field. However, it is still in its early conceptual phase and in need of additional funding.

Whether explicitly or implicitly, the United Nations Sustainable Developing Goals to turn around world's fortunes by the year 2030, have a strong relation to food. The collective food industry is grappling with the question of how to ensure sufficient nutritious and tasty food for the burgeoning global population, while at the same time reducing reliance on fossil fuels, maintain clean-water status, improve biodiversity and reduce greenhouse gas emissions.

At a closer look, one can say that the animal agriculture sector is the single largest anthropogenic user of land, contributing to reduction of fresh water supplies, soil degradation, and air pollution. To relentlessly increase food production, valuable rainforest is often forcefully converted into farmland and this form of deforestation leads to loss of biodiversity of the most precious natural resources. Yet, with the world population rapidly growing to about 10 billion by 2050, the current food production needs to increase by approximately 50 to 70 percent, while only some 5 percent extra agricultural land is available.

The environmental challenges facing the global agricultural industry are increasing. Alternative and smarter ways to produce foods for the dietary

requirements will alleviate some of these pressures. However, as new cellular agriculture technologies continue to emerge and are nearing commercial introduction, a one-size-fits-all implementation and legislative approach may not work.

The world's future is the (r) evolution of society where animal products are animal-free. In a broader sense, biotechnology is the interface between biology and engineering. "Silicon Valley investors" are attracted to synthetic biotechnology and synthesizing whole genes or genomes, which are now becoming more like the disruptive value propositions that will define technology-driven business models in the future.

Creative Destruction

What the "Silicon Valley high-flying food upstarts" are doing right now is nothing less than creative destruction. Essentially, they are dismantling traditional thinking and rebuilding food science and technology implementations to lay the groundwork for a new sustainable future with affordable, healthy, and manageable food security for the global population. In addition, upcycled side streams are being increasingly used in "green biotechnology" and will be a natural step in the evolution of sustainable products.

Cellular biotechnology has the potential ability to engineer and create hybrid protein versions by using a specific yeast or fungus strain platform. For example, a potato protein isolate can be cultured without the need to separate all building blocks like the starch and fiber of a grown potato. These developments are within reach and will contribute to a strategy readjustment by both legacy and startup protein companies.

The real drivers of biosynthetic technology are the global market potential, and the plummeting cost of DNA synthesis. This has become much more sustainable, precise and faster as it can be repeated in a much shorter time frame. Yeast is the true champion here because it can be seen as a eukaryotic cell –an organism whose cells contain a nucleus- just like the cells of livestock, companion pets, and even humans. Modified yeast strains show how DNA can successfully be manipulated and subsequently applied on a large scale. This is closing the gap between traditional technology and revolutionary disruptive technology.

Biosynthesized: Building Life from Scratch

Biotechnology and bioprocessing focus on the wide range of methods used for transformations like yeasts, enzymes, bacteria, as well as other fungi, plants, and plant cell cultures. These food and agricultural products are described as "green biotechnology".

Biosynthesized technologies will propel the development of sustainable protein cultured through microorganisms. Fungi-induced "brewing" or fermentation offers an excellent nutritional profile, including an amino acid composition similar to animal protein sources like meat, dairy, and eggs.

Moving forward, the possibility of producing proteins from local crops such as cassava, beets, and sugar cane is the main incentive to meet environmentally sustainable proteins that also reduce expensive protein imports in developing or poor countries. Finally, these countries can become self-reliant in their protein needs. Just think about the colossal currency savings if the production of animal-free milk proteins and cell-cultured meat can be done locally by developing countries.

Biosynthesized proteins are still in the experimental stage and expected to reach commercial use in 2022. A few biosynthesized proteins are already commercially available in the US and cleared by the FDA, though in the EU are still subject to regulatory approval such as EFSA Novel Food requirements.

Capital venture investors see DNA modification as the next programmable venture with massive opportunities for the collective food industry, medicine, and biopharmaceuticals, including potent painkillers and cancer medication. The speed of innovation is at times difficult to grasp, but it is evident that the accelerating transformation of the global food system is caused by truly innovative and scientifically driven technologies, combined with improved marketing that will create sustainable and nutritious foods.

Quite a few of these capital venture companies see biotechnology as a scalable innovation with a decent capital to growth ratio, not to mention that having cultured meat, medicine and food security is a good environment to be in.

The huge increase in anticipated food production cannot rely on the traditional or conventional farming practices alone. A fundamental shift in thinking will be needed. Primarily, with the acceptance of new protein sources such as those grown without using valuable land. Instead, they will be created from cellular biotechnology, including heterological protein expression and even single-cell organisms -specifically called hydrogenotrophs, that act like plants in converting carbon dioxide (CO_2) into food. Bacteria assimilate CO_2 directly as a carbon source and will be the first bacterial protein product meant for human consumption.

Carbon transformation technologies are not only suitable for food production. They are also ideal for the conversion of carbon-based materials into biodegradable polymers, as well as converting carbon from the air into bio-stimulants for depleted agricultural soil. In the meantime, more startup companies are developing unique

proprietary processes and are well on their way to enter these potentially lucrative market spaces. Regenerative agriculture will become one of the ways forward to capture the need for increased higher nutritional quality food.

Tissue Engineering: a Disruptive Force

The science of tissue engineering -like growing functional organs for people- is similar to growing or cell-culturing muscle meat or fish tissue. Perhaps the only difference is scale and magnitude of production. It certainly is no coincidence that medical professors and doctors started entrepreneurial cellular biotechnology food companies and now have become the poster child of cellular agriculture.

Tissue engineering is a relatively new science mostly generated from a chronic shortage of human donor organs or tissues for transplantation, a gap that may be filled using re-engineered organs such as skin, cartilage, and other soft tissues like muscle. These applications need to perform and maintain a biological function as they are used in a living person without being rejected.

The technology of regenerated biological material for medical applications is strikingly similar to the one used for the creation of, for example, cultured meat. Actually, the only difference is that synthesized cell-cultured meat needs to duplicate or simulate organoleptic quality such as color, taste, and texture, as well as be similar nutritionally. Examples are companies like Mosa Meat, Just Meat, and Upside Foods.

Cellular agriculture and post-animal cell culturing are emerging together with new technologies like 3D printing, regeneration of human tissue, artificial intelligence, QR (quick response) codes, augmented reality, virtual reality, and robotic interfaces. The use of 3D printing to create highly personalized nutrition is now within reach of commercial introduction. This technology can be applied to both the plant-based and cell-cultured meat sectors, providing nutrient-dense food options not only for those on special diets, but also throughout the entire food supply chain.

Meat in the form of muscle appearance is probably the most complex food product that exists. Not only in its raw form, but certainly also its transition during cooking, creating complex sensorial parameters delivering much-preferred eating experiences. As for cultured meat, it is far more difficult to create a perfect whole-muscle beef steak, than a simple finely ground hamburger. Crucial to creating a cultured steak is the use of multi-material 3D printing technology allowing multiple different meat and fat cells to be layered in one single simultaneous process. This technology uniquely allows to fully replicate appearance, texture and juiciness for cuts such as sirloin and rib-eye steaks. 3D printing is well on its way to become the choice for prototyping or a structured endeavor, enabling unprecedented fast development time at significantly less costs.

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