WHITE PAPER

Meat Replacement Products and Process Safety

Author: Arturo Trujillo, Global Director of Process Safety Consulting, DEKRA Service Division Consulting

Biomanufacturing is a promising technology that is rapidly becoming mainstream. It is used, among other things, to create meat replacement products that promise an ample supply of high-quality protein without the ill effects associated with raising and slaughtering livestock. It is important to recognize, however, that biomanufacturing might give rise to new risks. Fortunately, humankind has successfully addressed the challenges posed by unfamiliar hazards before and, with process safety, has developed a robust framework suited to tackling any risks that emerge from biomanufacturing.

Biomanufacturing: doing better than Soylent Green

The 1973 thriller *Soylent Green*[1] presents a dystopian future (set in the year 2022), where the combined effects of overpopulation, pollution and a climate catastrophe have had devastating consequences for humankind. The vast majority of New York City's 40 million citizens have been forced to give up natural food and replace it with the three varieties (red, yellow and green) of the synthetic food supplied by the Soylent Corporation. Allegedly, it is manufactured from soy, lentils and sea algae[2].

As we approach the year in which the movie is set, we can see once again, that reality outpaces fiction—at least in part. Today, companies like Impossible Foods and Beyond Meat have developed striking imitations of real meat manufactured in a chemical reactor from vegetable-based raw materials — and they are enjoying rising popularity. As a matter of fact, a recent Nielsen survey reported that in the nine weeks ending on May 2, sales of alternative meat products in grocery stores went up 264 percent.[3] Today, products like The Impossible Burger and Beyond Meat's substitutes are

1 Directed by Richard Fleischer; starring Charlton Heston, Leigh Taylor-Young and Edward G. Robinson, in his very last appearance on screen.

2 Spoiler alert! At the end of the movie we discover that Soylent green is made with recycled human bodies.

3 Jacob Bunge and Heather Haddon. "Coronavirus Meat Shortages Have Plant-Based Food Makers' Mouths Watering." The Wall Street Journal, May 13, 2020.

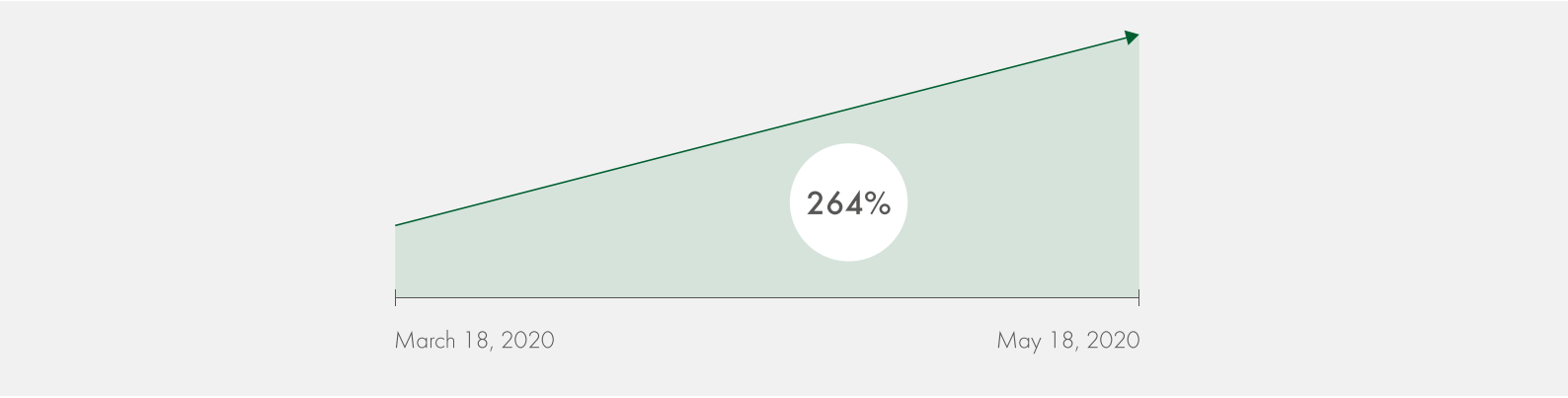

Figure 1. Sales of altenative meat products in grocery stores.

available in mainstream chains like Burger King, Carl's Jr. and Del Taco, as well as in grocery stores throughout the United States.

One of the drivers for this growth has been the COVID-19 pandemic. Providing humans with animal protein involves long and convoluted supply chains including many middlemen, which has made traditional meat production vulnerable to the virus. The working conditions at meatpacking facilities have resulted in a number of outbreaks in the US, turning the factories into COVID-19 hotspots. When these plants consequently shut down, farmers were left without buyers for their livestock. Paradoxically, farmers in the Midwest had to destroy animals just as meat was becoming scarce in supermarkets nationwide. [4]

This, of course, is not good news for the environment, as even under "normal" conditions, food waste accounts for 6% of total greenhouse gas emissions.[5] "Cellular agriculture," on the other hand, has been hailed as a revolution in food production that will not only reduce the carbon footprint associated with conventional meat production, but also improve animal welfare and enhance human health.[6] Indeed, a number of the most successful meat replacement products are cultured in biological reactors, far more efficient than Mother Nature herself in transforming energy, carbon and water into high quality protein (for example, a burger patty).

Perceiving risk with the process safety framework: "No such thing as a free lunch"

The American economist Milton Friedman used this popular saying as the title of a rather famous book. [7] In the world of process safety, the same sentiment might be phrased thus: "Be aware; whenever there's a new solution to a problem, it is likely to be accompanied by new process safety hazards." For instance, the chemical industry has given us a seemingly endless cornucopia of products to support our lifestyles and well-being, from plastics and biocides to medicines — yet it has also given us disasters like Bhopal.

Cellular agriculture certainly has the potential to initiate a new era of abundant "animal" protein, much the same way the Green Revolution of the 1950s and 60s changed the global agricultural landscape. It is likely that when this technology is fully developed, humans will have better access to nutritional protein than ever

4 Matt Simon. "Coronavirus: Accelerating the rise of imitation meat?" Bulletin of the Atomic Scientists, May 26, 2020.
5 Hannah Ritchie. "Food waste is responsible for 6% of global greenhouse gas emissions." Our World in Data, March 18, 2020.
6 Carolyn S. Mattick (2018) "Cellular agriculture: The coming revolution in food production." Bulletin of the Atomic Scientists, 74:1, 32-35.
7 Friedman, Milton, There's No Such Thing as a Free Lunch, Open Court Publishing Company, 1975.

before in history. But we have to ask: what will the consequences be in terms of process safety?

New risks stemming from any sort of unfamiliar technology are difficult to predict. After all, who thought that an incident like Chernobyl could occur when the first civil nuclear reactors were being designed? Humans are probably predisposed by some innate bias to feel excitement over the potential benefits of a new product or discovery while overlooking drawbacks and risks. It does indeed require a disciplined effort to detect potential hazards and manage the corresponding risks. So, we must ask ourselves: do we have the required discipline to look at novel food sources and identify the new hazards that may arise? History provides instructive examples of what happens when we do not, and now, as we use technology to feed our rapidly growing population, we must learn from the past and commit to doing better this time.

Managing risk with vigilance and the process safety toolbox

In previous papers,[8] we pointed out that using genetically engineered micro-organisms as "manufacturers" has a potential that we have only begun to envision; yet, these processes also carry the risk of generating a catastrophe of unprecedented scale. In those papers, we proposed recycling a robust, pre-existing framework to analyze the emerging risks caused by biomanufacturing: process safety. Process safety, with its expansive toolbox, is where we find the required discipline to look at new food sources and identify their potential hazards.

We must keep in mind that while meat replacement products may be launching a revolution in our food supply, they might also be the source of risks yet unknown. There are a number of well-documented incidents caused by loss of containment of micro--organisms from laboratories, and biomanufacturing utilizes engineered micro-organisms to make products such as meat replacements.

However, this is no reason not to embrace the promise of meat replacement products. Humans have faced entirely new risks before, and have done so successfully. We firmly believe that process safety constitutes a sound framework for analyzing and mitigating any risks linked to this new and auspicious technology.

DR. ARTURO TRUJILLO

Dr. Arturo Trujillo is Global Director of Process Safety Consulting. His main areas of expertise are diverse types of process hazard analysis (HAZOP, What-if, HAZID), consequence analysis and quantitative risk analysis. He has been involved in many projects over the last 25 years, especially in the oil & gas, energy, chemicals and pharmaceutical industries.

8 Arturo Trujillo. "Do We Need to Re-Define Process Safety?" DEKRA Process Safety & Chemical Safety https://www.dekra.com/en/process-safety-solutions/, June 2020 and "Re-defining process safety to accommodate biomanufacturing risks" Process Industry Informer, June 2020.

DEKRA Process Safety and Chemical Safety

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> Audit existing PSM Programmes, comparing with best practices around the world
> Correct and improve deficient Programmes

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> Thermal instability (DSC, DTA, and powder specific tests)
> Energetic materials, explosives, propellants, pyrotechnics to DOT, UN, etc. protocols
> Regulatory testing: REACH, UN, CLP, ADR, OSHA, DOT
> Electrostatic testing for powders, liquids, process equipment, liners, shoes, FIBCs

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> Electrostatic hazards, problems, and applications
> Reactive chemical, self-heating, and thermal instability hazards
> Hazardous area classification
> Mechanical equipment ignition risk assessment
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