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Sustainable protein alternatives

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ABSTRACT

Background: Fake meat industry is expected to grow and to be worth $140 billion by 2030. **Alternative protein** can be produced by **plant** or **microbe**. Animal-free dairy protein can be produced by **fermentation** in microflora.
Scope and approach: In order to improve the real production, many companies are focusing on **fermentation** for **animal-free meat**, **eggs**, and **dairy** respectively.
Key findings and conclusions: However, their **production capabilities, efficiencies, and costs** are not available in public respectively. This paper reports briefly what is going on in sustainable protein alternatives.

1. Background

Before describing sustainable protein alternatives technology, backgrounds surrounding their technology are addressed from the viewpoint of degradation of environmental protection, deterioration of animal welfare, increase in flexitarianism, and health reasons respectively.

Alternative protein can be produced by plant or microbe where alternative plant-based protein and alternative microbial-based protein issues are discussed respectively in this paper.

Alternative products can be organized in two ways: raw materials and protein production methods. Raw materials include animal cells, plants, fungi, and non-living organisms (e.g., molecules in the air), and methods include cell culture and fermentation. This paper presents products and technologies that provide a solution against the backdrop of the expected increase in demand for meat, and finally argues that parameters such as production costs need to be made available to the public for technological progress. As the World Economic Forum's 2019 white paper lists the only non-plant-based alternative in widespread use as the mycoprotein-based Quorn (WEF, 2019), there are still few alternative products that have reached commercialization and there is little objective comparable information such as market prices.

1.1. Degradation of environmental protection

Animal agriculture emits greenhouse gases such as carbon dioxide, methane and nitrous oxide respectively. Their emissions account for 14.5% of total emissions, including those of other sectors, indicating that animal agriculture is a contributor to global warming (FAO, 2017). There are two main sources of greenhouse gas emissions from livestock farming. The first is the methane produced in the intestines of cattle and other animals, which is emitted in burps. The second is associated with livestock feed. In addition, the expansion of livestock production also consumes water resources. For every kilogram of livestock meat grown, water of 20.7 tones is required for beef, 5.9 tones for pork and 4.5 tones for poultry for every kilogram of feed crops (Oki et al., 2003).

1.2. Deterioration of animal welfare

In order to provide livestock products at low cost, livestock producers have been working to improve productivity (breed improvement, optimal nutritional compound feed, etc.). However, the pursuit of productivity has led to the raising of animals in small spaces, which has been criticized as degrading welfare in light of the concept of animal welfare in Section 9 (Animal Welfare Act, 2006).

1.3. Increase in flexitarianism

A growing number of consumers, known as Flexitarians, are avoiding livestock meat as part of their diet (BBC 2020). For these Flexitarians, meat alternatives are welcome and are playing a role in consumers' selection of protein alternatives.

1.4. Health reasons

In a 2019 survey of consumer attitudes in the US, 23% of all

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consumers reduced the amount of livestock meat they ate in the past year, and about a third (36%) of these consumers said they would eat plant meat instead of livestock meat (MacCarth and Dekoster, 2020). Health was the most common reason for abstaining from livestock meat, surpassing environment and animal welfare.

1.5. Alternative plant-based protein

Flavor, price, and convenience are probably the basic motivations for consumers to purchase food. However, in today's world where many foods satisfy these, consumers cite health as an additional motivation (Szejda et al., 2020). In this regard, plant meat manufacturers promote plant meat as healthy because it does not contain cholesterol. However, plant meat contains approximately the same number of calories and saturated fat as livestock meat, and there is more sodium in plant meat than in livestock meat, which can increase the risk of high blood pressure if consumed in excess (Emily Gelsomin, 2019). Furthermore, many additives may have been added to plant meat to bring its texture and flavor closer to that of livestock meat. These factors make it an issue for plant meat manufacturers to disclose information about the health aspects of their products and to explain them more carefully to consumers.

1.6. Alternative microbial-based protein

The biggest challenges to commercializing microbial-based protein alternatives are cost savings and flavor improvements. The biggest issue for the commercialization of microbial-based meat substitutes is cost reduction. In particular, companies are competing to reduce costs of cell growth factors (serum collected from fetal cattle) used in culture because they are difficult and expensive to obtain in large quantities (Gonzalez & Koltrowitz, 2019; Memphis Meats, 2020, Chase; Purdy, 2020). In addition, microbial-based meat substitutes are derived from the cells of livestock meat and may have a higher added value as a food product that is more similar to livestock meat than plant-based meat substitutes. However, the results so far for microbial-based meat alternatives have been mainly from the culture of muscle cells, and their combination with the culture of fat cells that contribute to meat flavor will be an issue for the future.

1.7. Sustainable protein alternatives

Olive Heffernan introduced sustainable protein alternatives where a variety of protein alternatives are explained (Heffernan, 2017). By 2050, the human population is expected to increase by around 15% to more than 9 billion people so that the global demand for meat is expected to rise by 73% (Thin Lei Win, 2019), and meeting this demand will require an additional 160 million tons of meat per year[1]. In world economic forum, according to Thin Lei Win's talk, 'Fake meat' is going to grow and to be worth $140 billion by 2030 (Thin Lei Win, 2019).

There are two types of fake meat or alternative meat: plant-based meat and microbe-based protein meat. In plant-based protein products, protein is extracted from the plant and combined with other plant-based ingredients which can mimic the product as meaty as possible. Microbe-based protein is called Single cell protein (SCP) which means that microbial cells are grown (cell-cultured) and harvested to accomplish the food requirement of human due to its high protein content.

Plant-based Impossible Burger has 19g of protein and 0mg cholesterol which is made from genetically modified soy, and its characteristic "bleed" comes from soy leghemoglobin (which later turns to heme) that's made from genetically engineered yeast (Amanda Capritto, 2019). Nova Meats is a Spanish company that uses a special 3D printer to produce plant-based steak that can mimic the taste and texture of meat including beef or chicken (Flora Southey 2020). Beyond Meat is a Los Angeles-based producer of plant-based meat substitutes founded in 2009. According to Beyond Meat, Beyond Beef is composed of rice, peas and mung bean and their sausage is made up of peas, as well as fava and rice proteins.

In microbe-based protein production, fermentation plays a key role in producing edible protein. There are three fermentations: traditional fermentation, biomass fermentation, and precision fermentation respectively (Fermentation, 2020). Traditional fermentation is to leverage the power of biology to transform food ingredients. In biomass fermentation, cell culture processes, such as fermentation, capitalize on the fundamental biological property of exponential growth, meaning that every growth cycle can double the available biomass. When performed at the scale of hundreds of thousands of liters, these processes generate tens of metric tons of biomass every hour (Fermentation, 2020). Precision fermentation is to harness microbial hosts as cell factories (Fermentation, 2020). Vitamins including B12 and B2 (riboflavin) are representative examples produced by Precision fermentation.

Nature's Fynd is a company that develops microbe-based proteins for meat substitutes where microbes are found in volcanic hot springs at Yellowstone National Park (Fermentation, 2020).

Perfect day makes animal-free dairy protein, the same nutritious protein found in cow's milk (casein and whey) without cows (Fermentation, 2020). Animal-free dairy protein is made by fermentation in microflora rather than the typical extraction of protein from bovine milk (Fermentation, 2020).

According to Air protein (Airprotein, 2020), the company produces a protein powder which consists only of elements found in the air, specifically carbon dioxide, oxygen and nitrogen, which are then blended with water and mineral nutrients to create a base. Using renewable energy and a probiotic production process (fermentation), Air Protein converts the elements into an edible product (the powder base) with an amino acid profile similar to that of real meat.

Two-stage bioprocessing system was proposed as part of a power-to-protein approach to fix carbon dioxide in a first stage by anaerobic acetogenic bacteria, and grow yeasts or fungi in a second stage under aerobic conditions with acetate as the intermediate metabolite (Molitor B. et al., 2019). The latest bioprocessing system by Solar Foods can produce 1 kg of protein-rich edible powder ("Solein") per day only by solar power electricity (Molitor B. et al., 2019).

In microbe-based protein, companies have their proprietary processes in fermentation which are not disclosed in public. Alternative protein production capabilities, efficiencies, and costs are not available in public respectively so that we cannot compare them. For advancing sciences in alternative protein production, these parameters as open data are needed.

2. Conclusion

Mentioned protein alternatives can be produced by sustainable energy. Sustainable protein alternatives include animal-free meat, eggs, and dairy respectively. Fermentation plays a key role in producing such protein alternatives. Large investments to protein alternatives technology are expected since the fake meat market is worth $140 billion by 2030. Alternative protein production capabilities, efficiencies, and costs are not available in public. These parameters as open data are needed for advancing sciences in alternative protein research. Against the backdrop of an expected increase in demand for meat in the future, "cell-cultured meat" (clean meat), which is not animal-free, should be part of the solution. In addition to the parameters related to the level of achievement mentioned in this paper, technical issues that must be overcome in order to improve from the level of achievement to practical application are also necessary for investment decisions. For each technology, it would be helpful to include the issues that are currently visible.

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Ethical statement

The author has read the manuscript and has approved this submission. Ethical statement is not applicable.

Declaration of competing interest

The authors declare no conflict of interest.

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