Alternative proteins[1]

Alternative protein innovation has the potential to contribute to climate mitigation, relieve food insecurity, and help address malnutrition.

1. Context

The livestock sector is a key driver of climate change. It accounts for two-thirds of annual greenhouse gas emissions from agriculture, and meat products are typically the most emissions-intensive. The largest share of livestock-related emissions today comes from production in upper-middle-income economies, while some high-income countries are large contributors in terms of per capita consumption. While reducing the emissions intensity of the livestock sector is part of the answer, alternative proteins can help by providing a low-emissions substitute for meat.

Climate change threatens agricultural productivity and food security. Crop yields in Africa have stagnated over the last 60 years (1, 2, 3). Climate change is expected to reduce global crop yields for key crops (except rice), even after accounting for adaptation. Climate change may lead to food price increases and food insecurity. Alternative proteins can help relieve food insecurity by reducing the risk of food price spikes from animal feed demands - 37.5 percent of the world's cereals supply was allocated to animal feed in 2020 (1, 2).

Under pessimistic climate-change scenarios, impacts on food production could be severe, creating a high option value of investing now in approaches that could address food security needs if necessary. For example, end-of-century losses for maize yields are 26.1 percent under a high emissions scenario (RCP 8.5, a representative greenhouse gas concentration trajectory adopted by the IPCC) compared to 9.8 percent under a moderate emissions scenario (RCP 4.5). The large costs heavily influence the expected costs of climate change in high-impact but lower-probability scenarios (1, 2). Investing in alternative proteins could help insure against worst-case scenarios by reducing emissions and by providing a climate-resilient source of proteins.

[1] This is a draft document that will be updated periodically until the publication of the Innovation Commission final report

Investing in alternative proteins now could help address malnutrition, a key driver of which is a lack of access to affordable, high-quality proteins. Approximately one billion people, mainly in low- and middle-income countries, have inadequate protein intake. A lack of dietary utilizable protein ("protein quality") and the greater dietary needs resulting from poor living conditions in low- and middle-income countries exacerbate the problem. Insufficient protein intake among children is associated with stunting (1, 2). Increased temperatures are associated with increases in acute childhood malnutrition - projecting forward, global warming would be associated with a 37 percent increase in the prevalence of wasting by 2100 in Western Africa.

2. Alternative proteins

Alternative proteins, which do not rely on conventional animal agriculture, could help address these issues by potentially providing low-cost, reliable sources of high-quality protein.
Alternative protein categories include:

- **Classic plant-based foods**: Examples include legumes and tofu.
- Novel plant-based foods: Examples include "biomimicry" burger products. These plant-based foods aim to be indistinguishable from conventional meat and are often developed using plant protein concentrates.
- **Biomass fermentation**: Examples include meat substitutes made from mycoprotein (fungal protein). Biomass fermentation uses the high-protein content and rapid growth of microorganisms to make large amounts of protein-rich food efficiently.
- **Precision fermentation**: Examples include the heme protein that gives a "meat" taste. Precision fermentation uses microorganisms to produce specific functional ingredients. Precision fermentation enables alternative protein producers to efficiently make specific proteins, enzymes, flavor molecules, vitamins, pigments, and fats.
- **Cultivated meat**: Examples include chicken nuggets in Singapore, though the technology is at an early stage with few commercial products currently available. Cultivated meat involves growing animal cells in a nutrient-rich environment to build muscle and fat.

In low- and middle-income countries, alternative protein technologies have the potential to be a source of low-cost, high-quality proteins. In the near term, plant-based foods could be adapted to meet local tastes and nutritional needs. In the medium term, biomass fermentation has the potential to generate high-quality proteins at a large scale and low cost. It is a flexible process that allows microorganisms to convert agricultural (waste) streams into food-grade proteins in bioreactors in a manufacturing-like setup. Such a setup could also continue manufacturing proteins regardless of climatic conditions.

Specific innovation priorities for advancing biomass fermentation for low- and middle-income country contexts include:

- **Feedstock identification and optimization**: This includes investigating and developing the potential of different raw materials, including local agricultural side (waste) streams as inputs for fermentation.
- **Microbe identification**: This includes screening known microbes for their use in fermentation and bioprospecting for new microbes that may be more suited to local food stocks.

Low-cost alternative proteins could help address malnutrition. They could potentially be incorporated into foods to treat severe wasting (ready-to-use therapeutic food) and moderate acute malnutrition (ready-to-use supplementary food).

Low-cost alternative proteins could also be sold commercially. This market route is important because most underweight and malnourished children in sub-Saharan Africa fall outside the bottom 20 percent of wealth and consumption distributions. Alternative protein products could supplement meals (e.g., bouillons, porridge, or noodles) or be incorporated into prepackaged foods. Consumer demand could emerge if firms develop nutritious products that appeal to local tastes.

In high- and upper-middle-income countries, alternative proteins could reduce greenhouse gas emissions by substituting for conventional meat products if they can compete on taste and price. In the medium term, this would involve further development of novel plant-based foods and fermentation technologies. Specific innovation priorities include optimizing crops and post-harvest ingredients for use in plant-based meats. In the longer term, cultivated meat may offer the potential to replicate conventional meat at a cellular level, which may appeal to consumers with a stronger preference for conventional meat. However, whether this technology will be economically viable at scale is debated. (1, 2). Potential innovation priorities for cultivated meat include:

- **Developing new cell lines (stem cells grown to produce cultivated meat) that can be put in the public domain and used commercially.** These are essential building blocks for cultivated meat. The lack of availability of cell lines is constraining commercial production and holding back innovation in media, scaffolding, and bioreactors.

- **Developing cell culture media (nutrients and growth factors that cells need to grow outside of the body).** Research on cell culture media is central to reducing the costs of cultivated meat (1, 2).

3. Potential impact and cost-effectiveness

Alternative proteins could contribute to climate mitigation in high- and upper-middle-income countries by reducing demand for animal proteins that drive greenhouse gas emissions. One life-cycle assessment suggests a commercially available plant-based burger generates 90 percent fewer emissions than a beef patty (1, 2). Another life-cycle assessment suggests cultivated meat sold in 2030 will have a lower carbon footprint (when using renewable energy) than ambitious carbon footprint targets set for beef and pork, and will be comparable to the targets set for chicken (1, 2). Quorn, a fermented meat substitute in the market today, has lower emissions intensity than typical animal products (1, 2). These emission profiles suggest alternative proteins could make a large contribution to climate mitigation if costs fall and consumers switch to them from emissions-intensive animal proteins.

R&D investments in alternative proteins offer option value under the worst climate change and food security scenarios. Early investments in this area would not be expensive and would accelerate the development of a technology that may be needed in the future. Further investments could be conditional on earlier investments yielding results. Such an approach may offer large benefits if the worst future climate change and food security scenarios materialize: by providing a substitute for animal proteins, alternative proteins decrease demand for animal feed and can reduce the risk of surges in food prices. Lobell et al (2011) found that climate trends between 1980 and 2008 led to a 3% loss in calories, which led to roughly 20% higher commodity prices relative to a counterfactual scenario without warming (1, 2). Price increases would clearly be much greater under the 9 percent (by 2050) and 25 percent (by 2098) yield losses projected in a high emissions scenario (RCP 8.5). Baldi et al 2021 estimate a 4 percent shift to plant-based meats would result in crop prices being 13 to 23 percent lower on average relative to a counterfactual with no plant-based meat.

By providing a substitute for milk proteins, low-cost alternative proteins could potentially reduce the costs of providing therapeutic food to malnourished populations. Milk powder is a key cost driver for ready-to-use therapeutic food (RUTF). UNICEF purchased 50,000 MT of RUTF per year on average between 2019 and 2022, accounting for 75-80 percent of global demand (with much higher purchases in 2022 and 2023). Assuming a price of USD 44 per carton of RUTF, this suggests that UNICEF spent approximately USD 160 million per year on RUTF.[2] Lower cost formulations would allow humanitarian spending to reach more people - UNICEF estimates that 50-75 percent of children suffering from severe wasting do not have access to treatment. Several studies have assessed the cost-effectiveness of changing the RUTF formulation using existing locally sourced or alternative ingredients, with mixed results across different settings (Sierra Leone; Malawi; Malawi; Zambia; Bangladesh). Alternative formulations with (novel) alternative proteins may deliver more promising results as they may have better protein quality and density.

4. Potential pathways to scale

Public and philanthropic money could accelerate the development of low-cost alternative proteins for consumers in low- and middle-income countries. Existing technologies were developed largely to mimic meat for consumers in high-income countries, and will need to be adapted to provide low-cost proteins for low- and middle-income markets. In addition, incorporating low-cost alternative proteins into therapeutic foods would require regulatory approval and therefore large-scale trials.

Public and philanthropic investment in basic research could accelerate innovation in alternative proteins for climate mitigation in high and upper-middle-income countries. Firms will not capture the climate mitigation benefits of such innovations. Some fundamental innovations in this space may be hard to protect with intellectual property or first-mover advantages, which will weaken incentives to innovate. Such market failures justify public and philanthropic funding for basic research such as lab science. Given the likely demand for alternative proteins among high-income consumers, public and philanthropic investments in downstream (product) research should prioritize the needs of low- and middle-income countries.

5. Potential path forward

Greater public and philanthropic R&D funding can fill the gap left by commercial markets. Livestock-related emissions amounted to 3.5 billion CO2 equivalent tonnes in 2018. A one percent reduction in annual livestock emissions would have a social value of approximately USD 6.65 billion using an assigned 2020 social cost of carbon of USD 190. Public funding for R&D in alternative proteins amounted to USD 180 million in 2022, with USD 290 million on

[2] UNICEF indicates 1MT = 72 cartons and an overall price per carton of USD 44.4 in 2022

commercialization, and USD 165 million on initiatives that mixed elements of both R&D and commercialization. Current public investments in R&D for alternative proteins fall short of their potential social value - larger investments by high-income countries in basic R&D would be justified on climate mitigation grounds alone.

Alternative protein innovation focused on the needs of low- and middle-income countries is a neglected area that would benefit from more funding. A USD 10 to 30 million research program could cover biomass fermentation priorities such as feedstock identification and optimization as well as microbe identification in a range of countries.

Donors may wish to consider committing to helping to cover the cost of purchasing low-cost alternative formulations of therapeutic foods (such as ready-to-use therapeutic food and ready-to-use supplementary food) as a way to accelerate innovations in the formulation of therapeutic foods. Donor commitments to subsidize the purchase of low-cost formulations that achieve regulatory approval would help address unpredictable financing and provide incentives for firms to innovate and seek regulatory approval. While alternative proteins are a promising technology for the formulation of therapeutic foods, the commitment should encourage innovation more broadly, and so should be technology-agnostic and open to formulations that do not involve alternative proteins. Given existing levels of expenditure on RUTF, such a commitment could potentially be in the hundreds of millions (see above, UNICEF). [3]

[3] This note draws on contributions from Essential, the Good Food Institute, and the Breakthrough Institute.