# Towards a cellular food future: Final recommendations from the Protein 2.0 project to Norwegian policy makers and food system actors

Fish Maw, Avant Meats. Photo: Claire Bomkamp

Mads Dahl Gjefsen[a], Rob Burton[a], Sissel Rønning[b], Christian A. Klöckner[c], Richard Helliwell[a], Klaus Mittenzwei[a], Hugh Campbell[d], Gary Polhill[e], Nick Roxburgh[e], Kenneth Vilhelmsen[c]

[a]Ruralis – Institute for Rural and Regional Research, 7491 Trondheim, Norway
[b]Nofima AS, Pb 210, NO-1431 Ås, Norway
[c]NTNU, Department of Psychology, Dragvoll, 7491 Trondheim, Norway
[d]University of Otago, Dunedin, New Zealand
[e]The James Hutton Institute, United Kingdom

Notat 1/23 – ISSN 2704-0216

## Acknowledgments

The Protein 2.0 project was funded by the Research Council of Norway (project number 294777). We wish to thank all the participants at the project's final conference and participatory workshop in Oslo on December 7, 2022. We would also like to direct a special thanks to Rita Moseng Sivertsvik and Tommy Ruud from Ruralis for organisational support and note taking during the event.

# Innhold

## Introduction: The current state of cellular food technology

When Protein2.0 was funded in 2018 there were 30 startups working on cultivated proteins investing sums of money ranging between tens of thousands and a few hundreds of thousands of U.S. dollars. Now, as we approach the end of 2022, there are hundreds of startups engaged in the development of meat and milk proteins (including some worth over a billion US dollars) and a growing commercial support infrastructure. In Norway, startup companies Foodful aims to develop cultured salmon, while SifoTEK aims to produce milk proteins. In 2021 the cellular protein sector (precision-fermentation and cultivated meat), for the first time, obtained a larger proportion of the alternative protein investment capital than plant-based proteins ($2.07 billion vs $1.93 billion). Meanwhile, as products are finalised, a small – but growing – number of life cycle analyses suggest there may be significant gains in terms of reduced climate gases, land usage, and water usage.

**Fact box: The technologies of cellular agriculture**

Cellular agriculture produces animal-derived agricultural products through processes at the cellular level instead of the whole-organism level, bypassing intensive animal production. There are two kinds of cellular agriculture production systems: The first is fermentation, which produces functional food ingredients by recombinant protein technology using cells as hosts, often termed precision fermentation. In precision fermentation, the process replicates the proteins normally produced in an animal. The cells, however, are not part of the final products; they are "factories" that produce the molecules of interest, such as milk or egg white proteins. Precision fermentation uses microbial expression systems (bacteria, yeasts, plants) for production. Such production has already been in place for a longer time. Already in 1978, scientists produced insulin through bacteria, and this method is now preferred. In 1990, the first genetically engineered bacteria to produce rennet for cheese making was approved. Rennet is a mixture of enzymes necessary to turn milk into cheese, previously collected from the stomach of calves. Recently, the fermentation of animal proteins used directly as food—like milk, gelatin, and egg proteins—is emerging. The second type of technology is cultured meat which involves growing live cells from an animal and then directing and including these cells into a desired product (e.g., sausage, mince patty, meat).

Production of proteins for food, however, such as meat-like and dairy-like products, involves complicated processes reverse-engineering the texture, taste, and nutrients of the food and building them from the molecular components using cells. In modern cellular agriculture, gene editing programs a host microorganism to produce the food macromolecules we want. Although the principal technology is the same as for, e.g., insulin and rennet, it is more challenging to produce large quantities of edible food proteins. Such proteins are also very complex and often require a proper structure to work optimally.

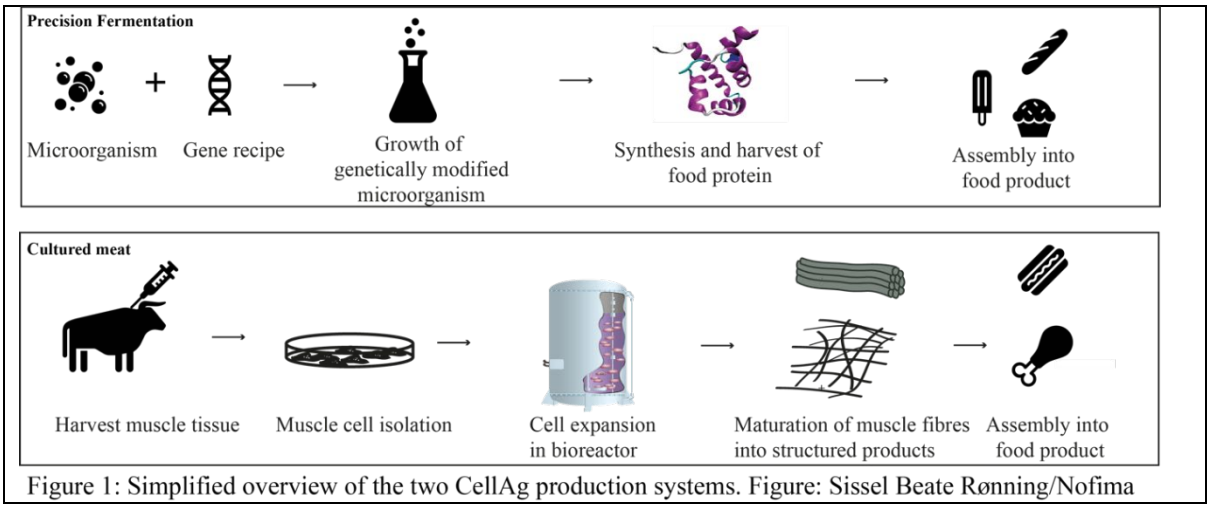

Figure 1: Simplified overview of the two CellAg production systems. Figure: Sissel Beate Rønning/Nofima

Fermentation-based companies already have products on the market in the US. Perfect Day, for example, is manufacturing whey powder for a dozen companies producing products from ice-cream to body-building powders. The price is at a level where the products compete with conventional products at the 'high end' of the market, but the company believes soon the price of their whey powder will be lower than that of conventional whey. Two examples are Israeli company Remilk and U.S. company Change Foods which announced in 2022 they are building factories in Denmark and the U.A.E. producing as much milk as 50,000 and 10,000 cows respectively (whey and casein). Cultivated meat protein, on the other hand, has yet to be made commercially available. Companies Mosa Meat and Eat Just are taking advantage of Singapore's open regulatory system to build small factories in Singapore in the coming years. Although most start-up companies believe the product can be made considerably cheaper, they are unlikely to compete with conventional meat on price in the next few years as technological issues still need to be resolved.

What has become increasingly clear is that a lot of significant new steps in the development of the sector are happening right now. Recently, major food corporations have announced they are developing in-house precision-fermented protein startups (e.g., General Mills and Unilever) or are testing precision-fermented proteins made by external partners (e.g. Nestle and Starbucks). Many start-up companies – precision-fermented and cultivated meat – now have manufacturing, research, or distribution agreements with large companies in the food sector (e.g. Cargill and Tyson). On the regulatory side, the US Food and Drug Administration deemed Upside Foods cultivated meat safe to eat in November 2022 in the first decision of its kind for cultivated meat products. While companies such as Mosa Meat are in talks with the EU, products have yet to be submitted to the EU for approval as a "novel food", meaning it will be at least 2 years before a product is on the market. What these rapid developments are doing is reveal where the next bottlenecks are likely to form: particularly that a key constraining factor will be bioreactor space. Even if it can be produced at the same price as conventional protein, volumes will be very small for the first years.

## About this document

At the conclusion of the Protein 2.0 project in December 2022, actors from Norwegian food production as well as policy members and civil society groups, were invited to a day-long conference showcasing its research findings, discussion with a panel of experts and stakeholders, and concluding with an interactive workshop to enable all participants to submit input to the project's final recommendations. In total, 22 food system actors attended the conference, and 11 of these participated in the workshop.

The day's program is included below, including a link to the conference website which includes all presentations and the conference abstract booklet (see appendix).

This document summarizes the main recommendations, both those deriving from researchers' presentations on the implications of their research for Norway and Norwegian food producers, and those formulated through the stakeholder workshop itself.

As terminology is both a source of confusion and contention in this field, a conceptual clarification is needed: as explained in the foreword, precision fermentation and cell-based meat production are distinct technologies. In this document, unless otherwise specified, terms such as cellular agriculture and cellular food refer to both, and loosely correspond to other terms in public discourse such as cultivated meat, cultivated protein, artificial, lab-based, in-vitro meat, cultured meat or alternative protein (the latter being a broader category that also includes plant-, algae and insect-based protein products).

## Recommendation 1: Don't dismiss but take seriously the implications of cellular foods!

Even though a current lack of regulatory approvals, prohibitive production costs, and doubts about how consumers will respond to cultivated protein, all constitute significant barriers for this emerging industry, there are enough indications of industry progress to warrant serious attention by Norwegian policymakers and food producers.

- Agent-based modeling[1] shows that Norwegian farms that are engaged in livestock or poultry farming will need to focus on productivity or diversify if they are to survive in a market disrupted by a commercially competitive cultivated protein industry. Moreover, the impact of the cultivated protein industry on incumbent industry actors is likely to be spatially uneven, with a complete collapse of farm meat and dairy production possible in certain areas.
- Economic modeling[2] suggests that in Norway, changing consumer preferences for cultivated food may be more important that the price of these products, and if future

[1] Gary Polhill and Nick Roxburgh. 2022. Scenarios of future change in Norway: results of an agent-based model. Protein 2.0 final conference: Anticipating a cellular food future. Oslo: December 7, 2022.
[2] Klaus Mittenzwei. 2022. Effects on Norwegian agriculture. Protein 2.0 final conference: Anticipating a cellular food future. Oslo: December 7, 2022.

feed and food imports rise, cultivated protein will disrupt imports rather than domestic production.

- A narrative analysis[3] of the visions of cellular agriculture shows how synthetic animal protein removes 'nature' as a binding constraint on the production process – threatening the rural base of agriculture. And a historical study of disruptive technology into farming industries in New Zealand[4] provides illustrative examples of how responses to threats from substitutory products can be both slow and follow familiar patterns which tend to maximize imagined benefits and minimize potential risks to established sectors, some of which appear to be playing out in response to cultivated protein now but at significantly faster pace.
- A public survey of consumers (see fact box) suggests the public have a neutral to a slightly positive view of cultivated protein products in the Nordic countries.[5] Yet interviews with Norwegian food producers and policy actors indicate that little systematic attention and strategizing is devoted to cultivated protein by food industries and policy makers.[6]
- The most recent industry developments include several signs that commercial actors are getting closer to the marketplace.[7]

**Fact box: Views of cultivated protein products in the Nordic countries[8]**

Cellular food technology is largely unknown, so attitudes and perspectives are not well-established and might change in the future.

The general attitude to cellular food and willingness to taste/consume it is neutral to slightly positive, with support being higher among younger people, males, more innovative people, and vegetarians/vegans.

Positive factors that impact people's attitudes are reduced environmental impacts, lower price, better health, and nutritional effects than farmed protein. Among the most negative factors are bad smell, taste, less appealing texture, and appearance.

In the beginning of market development, people would be most influenced by their social environment, meaning that as the technology is new and people have no established attitudes, they would look to how others who they trust relate to cellular food.

Based on 3850 respondents in Norway, Denmark and Finland (1207 in Norway).

[3] Richard Helliwell. 2022. Potential implications of cultivated proteins for Norwegian agriculture. Protein 2.0 final conference: Anticipating a cellular food future. Oslo: December 7, 2022.
[4] Hugh Campbell. 2022. Disruptive Technologies in Farming History: Lessons from New Zealand. Protein 2.0 final conference: Anticipating a cellular food future. Oslo: December 7, 2022.
[5] Christian A. Klöckner and Kenneth Vilhelmsen. 2022. Maybe this is something good? Consumer responses to cultured proteins. Protein 2.0 final conference: Anticipating a cellular food future. Oslo: December 7, 2022.
[6] Mads Dahl Gjefsen. 2022. Strategies proposed by Norwegian food producers. Protein 2.0 final conference: Anticipating a cellular food future. Oslo: December 7, 2022.
[7] Rob Burton. 2022. Building a global industry: progress in the cultivated protein sector up to 2022. Protein 2.0 final conference: Anticipating a cellular food future. Oslo: December 7, 2022.
[8] Klöckner, C., Engel, L., Moritz, J., Burton, R., Young, J., Kidmose, U., & Ryynänen, T. (2022). Milk, Meat, and Fish From the Petri Dish—Which Attributes Would Make Cultured Proteins (Un) attractive and for Whom? Results From a Nordic Survey. *Frontiers in sustainable food systems*.

## Recommendation 2: Beware, the ramifications for Norwegian agriculture and society could be significant

Although the exact implications of a future cultivated food industry for Norwegian food production and society are highly uncertain, project findings indicate that they could be dramatic.

- The project's agent-based and economic model both run to 2050. In the agent-based model,[9] agricultural regions with high rates of specialist meat and dairy farming appear especially vulnerable to a commercially competitive cultivated protein industry. In addition to farms, many dairies and slaughterhouses were found to be at risk if overall demand for farm produced animal products falls. Closures of these facilities would have serious knock-on consequences for the farms that depend on them, further accelerating industry decline within their catchment.
- In the economic model,[10] cultivated protein affects the consumption of all food products. Cultivated meat replaces imports, but also domestic production. Milk production is less hit due to incomplete substitution possibilities (and profitability), Producer prices for milk and beef drop because of reduced demand. Milk quota rents disappear, and farm incomes fall by up to 25 per cent. Livestock other than cattle are more affected due to profitability in milk production. Agricultural inputs (land, labour, farms) remains largely unaffected. Furthermore, greenhouse gas emission reductions following from changes in Norwegian food demand, take place in foreign countries.
- The project's qualitative work, and in particular the narrative analysis and interview study, also suggest far-reaching interconnections between changes to food production practices in response to societal uptake of cultivated protein. The interview study[11] points to how changes in the Norwegian food production system might have cascading effects that undermine established distributed rural and coastal settlement policy, as well as how societal receptiveness to cultivated protein reflects detachedness from landscape and changing attitudes to 'naturalness' in food.
- The narrative analysis[12] similarly points to the lack of critical attention to broader ramifications, and raises the question of how to manage a transition to cellular agriculture without eliminating thousands of years of cultural landscapes and ecosystem development associated with agriculture?

[9] Gary Polhill and Nick Roxburgh. 2022. Scenarios of future change in Norway: results of an agent-based model. Protein 2.0 final conference: Anticipating a cellular food future. Oslo: December 7, 2022.
[10] Klaus Mittenzwei. 2022. Effects on Norwegian agriculture. Protein 2.0 final conference: Anticipating a cellular food future. Oslo: December 7, 2022.
[11] Mads Dahl Gjefsen. 2022. How do Norwegian dairy, aquaculture, and meat industry actors view cultivated protein? Findings from an interview study. Protein 2.0 final conference: Anticipating a cellular food future. Oslo: December 7, 2022.
[12] Richard Helliwell. 2022. Potential implications of cultivated proteins for Norwegian agriculture. Protein 2.0 final conference: Anticipating a cellular food future. Oslo: December 7, 2022.

## Recommendation 3: Policy makers should consider starting a Norwegian Alternative Protein strategy process

As cellular foods may have dramatic consequences for the Norwegian food system, food security, and a range of associated socio-environmental implications, a national strategy process may be warranted. Such a process could be coordinated by the Ministry of Agriculture and Food and should include participation from a wide range of actors including food producers, civil society, and research and innovation actors.

- One of the most prominent themes in discussions at the Protein 2.0 final conference and workshops was the need to address a current lack of coherent and systematic thinking about cultivated protein's implications for Norway. Correspondingly, a recommendation from the group work participants was that a Norwegian strategy is needed, either specifically on cellular foods, or around the broader category of alternative protein. Alternative protein encompasses not only cellular foods, but also plant-based, algae, biomass from fermentation, insects, low-trophic species, by-products, and other categories. While these have been outside the scope of Protein 2.0, they are related and should be considered together in a future strategy process.
- Regarding cellular foods, its potentially far-reaching effects for Norwegian society encompass multiple policy sectors and civil society interests and suggest the need for a diverse and inclusive strategy process that examines a range of implications for Norwegian food producers. Ramifications for food producers and associated environmental, economic, and societal aspects of cultivated protein should be addressed, with food security, animal welfare, distributed settlement policy and public health being possible topics of concern.
- Engaging with emerging technology through a politically initiated strategy process is a drastic step, and strategies might quickly become obsolete. As stated above, alternative protein has been outside the scope of Protein 2.0. With regards to cellular foods, a Norwegian strategy process would be warranted given documented advances on one or more of the following developments:
    - Proven development of non-bovine foetal based growth serum
    - Demonstration of sustained production at above pilot project scale
    - US or EU regulatory approval of a cellular product(s)
    - Commercial release of a profit-making cellular meat product
    - Application for construction of production infrastructure in Europe
- The list is not exhaustive and a dedicated effort to identify additional developmental thresholds or stage gates, would be a useful undertaking.
- We recommend the establishment of a monitoring group composed of key Ministries to follow developments and alert the government when a more substantive strategic response is merited, considering the above criteria.

## Recommendation 4: More knowledge is needed in several areas

The project research suggests several areas where additional knowledge is needed.

- The scientific overview[13] shows that the upscaling of the process is considered one of the key limitations of CellAg, begging the question of whether we have the research infrastructure, knowledge, and scientific community to help solve this problem in Norway? Assessment of sector development in the U.S. suggests targeted biotech incubators such as Indiebio and promotional organisations such as New Harvest have played an important role in the development of the sector.[14] Regarding the future implications of the technology, both the economic and the agent-based modeling stressed the significant uncertainty attached to key assumptions. Similarly, qualitative project work identified major unanswered questions about how food production and associated environmental and socio-cultural dynamics might co-evolve with different scenarios for cultivated protein, suggesting a need for continuous monitoring and re-calibration of assumptions about the technology's significance.
- At the final conference, additional knowledge needs and research priorities were also voiced by participants. These included the need for research on the health effects of lab-based proteins in new diets, particularly nutritional value and negative health effects. More research on the sustainability and environmental footprint of cultivated protein products was also requested.

## Additional recommendations, paraphrased from discussions at final conference

Policy makers: *The Food Safety Authority has insufficient resources considering the challenges raised by cultivated protein*

*Consider need for an "Information office for cultivated protein"*

*Policy makers should recognize their important responsibilities in this area*

*Investments are needed in research and innovation and in framework conditions for this emerging area*

Food industry: *Grocery chains should dare to offer new products and give customers time to test new things*

*The food industry has a part to play, and the future will include both traditional and new foods and forms of production. Collaboration is needed to make this a constructive process*

*Collaboration across green and blue sector actors should be supported; there is a tendency to focus only on land-based production*

[13] Sissel Rønning. 2022. The science of cellular agriculture-cultured meat and precision fermentation. Protein 2.0 final conference: Anticipating a cellular food future. Oslo: December 7, 2022.
[14] Rob Burton. 2022. Building a global industry: progress in the cultivated protein sector up to 2022. Protein 2.0 final conference: Anticipating a cellular food future. Oslo: December 7, 2022.

*Develop a culture for alternative proteins*

Researchers: *Be aware of one's own public role. Participate in public debate and dialogue, also in this controversial area with a full knowledge of potential implications*

Educators: *Cultivated protein raises need for new knowledge and competencies*

Farmers: *Farmers and their organizations should take note of the developments around cultivated meat and be aware of associated opportunities for produce inputs to new value chains, opportunities rooted in land ownership, etc.*

*There will be a need for developing farmers' competencies in relation to alternative protein as well*

Consumers: *Consumers should be aware of own influence and foster food diversity*

Civil society: *Civil society organizations should contribute to knowledge development and engagement*

# Appendix: Conference program and link to Abstract booklet

All presentations and the abstract booklet are available on the following website:

https://ruralis.no/aktiviteter/protein-2-0-sluttkonferanse-mot-en-fremtid-med-laboratoriedyrket-mat/ .

### Protein 2.0 final conference: Anticipating a cellular food future // Mot en fremtid med laboratoriedyrket mat?

December 7, 2022, Radisson Blu Scandinavia Hotel, Oslo. Languages: English and Norwegian.

#### 09:00-10:10: Overviews of the topic area

- Welcome, outline of Protein 2.0, practical information, and introduction of panelists - *Rob Burton and Mads Dahl Gjefsen, Ruralis*
- The science of cellular agriculture-cultivated meat and precision fermentation - *Sissel Rønning, Nofima* **Abstract #1**
- Building a global industry: progress in the cultivated protein sector up to 2022 - *Rob Burton, Ruralis* **Abstract #2**

#### 10:10-10:20: Break

#### 10:20-11:30: Project results and reactions from panelists

- Maybe this is something good? Consumer responses to cultivated proteins - *Christian A. Klöckner and Kenneth Vilhelmsen, NTNU* **Abstract #3**
- How do Norwegian dairy, aquaculture, and meat industry actors view cultivated protein? Findings from an interview study - *Mads Dahl Gjefsen, Ruralis* **Abstract #4**
- Comments from panelists (*Sissel Rønning, Nofima; Trond Einar Pedersen, Norges forskningsråd; Anne Cathrine Whist, TINE; Siri Martinsen, NOAH) and* open Q&A

#### 11:30-12:30: Lunch

#### 12:30-14:10: Project results and reactions from panelists

- Disruptive Technologies in Farming History: Lessons from New Zealand - *Hugh Campbell, University of Otago* **Abstract #5**
- Effects on Norwegian agriculture - *Klaus Mittenzwei, Ruralis* **Abstract #6**
- Potential implications of cultivated proteins for Norwegian agriculture - *Richard Helliwell, Ruralis* **Abstract #7**
- Scenarios of future change in Norway: results of an agent-based model - *Gary Polhill and Nick Roxburgh, The James Hutton Institute* **Abstract #8**
- Strategies proposed by Norwegian food producers - *Mads Dahl Gjefsen, Ruralis* **Abstract #4**
- Comments from panelists (*Sissel Rønning, Nofima; Trond Einar Pedersen, Norges forskningsråd; Anne Cathrine Whist, TINE; Siri Martinsen, NOAH) and o*pen Q&A

#### 14:10-14:25: Break

#### 14:25-15:50: Group discussions and workshop: Reactions, needs, and input to strategy and policy recommendations

End by 16:00