Opportunities and challenges of new disruptive food production methods in Finland

Qualitative analysis carried out by a Finnish network of experts

Contents

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Summary

The aim of this report was to identify and analyse Finland's opportunities for new food production technologies and measures that are needed to promote these technologies. The study has been carried out as part of the Food without Fields research project, within the Catch the Carbon research and innovation programme of the Ministry of Agriculture and Forestry of Finland, and examines the possibilities of new disruptive cellular agriculture and plant production technologies as part of the achievement of the carbon neutrality targets set for Finland. Information for the report was collected through an online survey and through an expert and stakeholder workshop. The results of the survey and the workshop were compiled and complemented with expert knowledge. On the basis of this information, measures to promote the introduction of new production methods were defined.

In many of the identified opportunities and challenges, coherence was found between plant production and cellular agriculture methods. Funding was identified as one of the main obstacles and enablers. It was hoped that the new technologies would receive versatile and sufficient funding for both research and development activities and for the commercialisation and scaling of solutions. Competence development was another clear entity where the respondents hoped for more advice and practical teaching projects and experiments, including the construction of test platforms and training that emphasises the multidisciplinary and new types of competence that are needed in these production methods.

The respondents hoped to see active cooperation between various operators from researchers to entrepreneurs and industry sectors in order to enhance the exchange of information and create new innovations through the collision of various competence areas. The importance of monitoring international operators was emphasised so that Finnish industry/society have up-to-date information on production methods. It was hoped that new production methods would be actively communicated to the public. Information should be targeted at both business operators and consumers as well as decision-makers. In consumer communications, it is important to ensure the communication method and content will enable the society and consumers to accept new production methods, and that production methods do not cause unjustified concern or suspicion in consumers.

Legislative perspectives were highlighted as an important entity. The introduction of new production methods could probably be promoted by facilitating the novel food authorisation process through cooperation and advice, in particular in cellular agriculture, and by reforming support and industrial policies concerning the food sector.

Value chains and operating models related to new production methods must be actively developed. In particular, the benefits and disadvantages of locating production facilities in different areas must be investigated in order to ensure continuous and profitable production. It is also important to assess, develop and test the potential of combining different operations to circular systems, such as plant production and cellular agriculture processes. In order to verify the actual effectiveness of new production processes, particular attention must be paid to objective, peer-reviewed profitability and environmental impact calculations.

In general, although the impact of the new production methods is seen mainly in the long term, they were found to have substantial potential. However, work must be carried out in many areas and by means of joint efforts to translate the identified challenges into opportunities and to bring production methods to the market extensively.

Summary of results and proposed measures

OBJECTIVE

To define opportunities and challenges of new food production methods, cellular agriculture and plant production in controlled conditions in Finland

Qualitative analysis carried out by a Finnish network of experts

METHODOLOGY

Data collection through an online survey and via an expert and stakeholder workshop

Collection of results, qualitative analysis and complementing data with expert knowledge

RESULTS

Development needs for the new production methods and proposed measures related to them

COMPETENCE DEVELOPMENT

- Training and guidance
- Testing, cooperation and teaching platforms
- Education programmes

ACCELERATING COOPERATION

- Cooperation platforms and models between companies, research and education, also across scientific and administrative branches

DEVELOPMENT OF VALUE CHAINS

- Development of operating models for new value chains
- Both scenario analysis and testing for new value chains

INCREASED FUNDING

- Basic research and RDI activities
- Support for commercialisation and investment, including for start-ups

STRATEGIC DECISION-MAKING

- Facilitating the novel food authorisation process, reform of GMO legislation
- Reforming agricultural subsidies policies

RAISING AWARENESS

- Fact-based dissemination
- Confidence-building consumer communication
- Product branding

FURTHER INFORMATION

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Preface

In addition to reducing fossil emissions, achieving Finland's carbon neutrality target set for 2035 requires reducing emissions from agriculture and agricultural land use as well as strengthening carbon sinks and stocks. The Food without Fields research project examines the possibilities of new cellular agriculture and plant production technologies as part of the achievement of the set carbon neutrality targets.

The project is part of the Ministry of Agriculture and Forestry's Catch the Carbon research and innovation programme, which supports climate-sustainable land use solutions. The name of the project, Food without Fields refers to food production solutions independent of agricultural land, and the project focuses in particular on production methods related to safeguarding protein self-sufficiency. The studied production methods include: 1) cellular agriculture, i.e. the use of microbes and plant cells to produce feed and food, and 2) plant production solutions based on controlled conditions (incl. greenhouses, vertical farming environments) for producing protein-rich crops in our cool climate.

The project examines how new technologies will be integrated into the current food system, and will work closely with regional operators and various stakeholders. One of the objectives is to analyse the business potential and sustainability of new production solutions, focusing on greenhouse gas emissions and land use. In piloting new production technologies, the aim is to take into account regional perspectives and, for example, the possibilities of using un-utilised side streams as production inputs.

The Food without Fields project runs from 2021 to 2023 and its total budget is EUR 1.45 million. In particular, the project combines the cross-disciplinary expertise of VTT and Natural Resources Institute Finland (Luke) in agriculture, biotechnology and food technology as well as sustainability assessment and ecosystem work. The project's research partners are VTT, Luke and eniferBio. Business partners include Fazer, Solar Foods and Valio.

This report compiles the views of the network of experts on the opportunities and challenges of cellular agriculture and plant production technologies, as well as what kinds of solutions can be found to solve these challenges, and in particular what are the most essential measures (implementation steps?) for new food production technologies in Finland. The material has been collected through an online survey and workshops, and worked and complemented after that with the help of a project expert group.

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AUTHORS

Background and objectives

Background

Cell agriculture is a new way of producing food and feed, and so far there is a limited amount of information on its impact potential in Finland. In addition, technological solutions for plant production in controlled conditions, such as greenhouses and vertical farming environments, are constantly evolving. Both controlled plant production and cellular agriculture are expected to enable efficient, year-round food and feed production, including in northern conditions in northern conditions. These promising future production methods can contribute to the achievement of Finland's carbon neutrality target set for 2035, especially through land use changes. As cellular agriculture and vertical farming are relatively new production methods, there is currently little research on these from the Finnish perspective and there are open questions related to their introduction. In order for these new production methods to become more common in Finland, production methods must be developed and the preconditions for operating in Finland in a competitively must be assessed in a versatile manner.

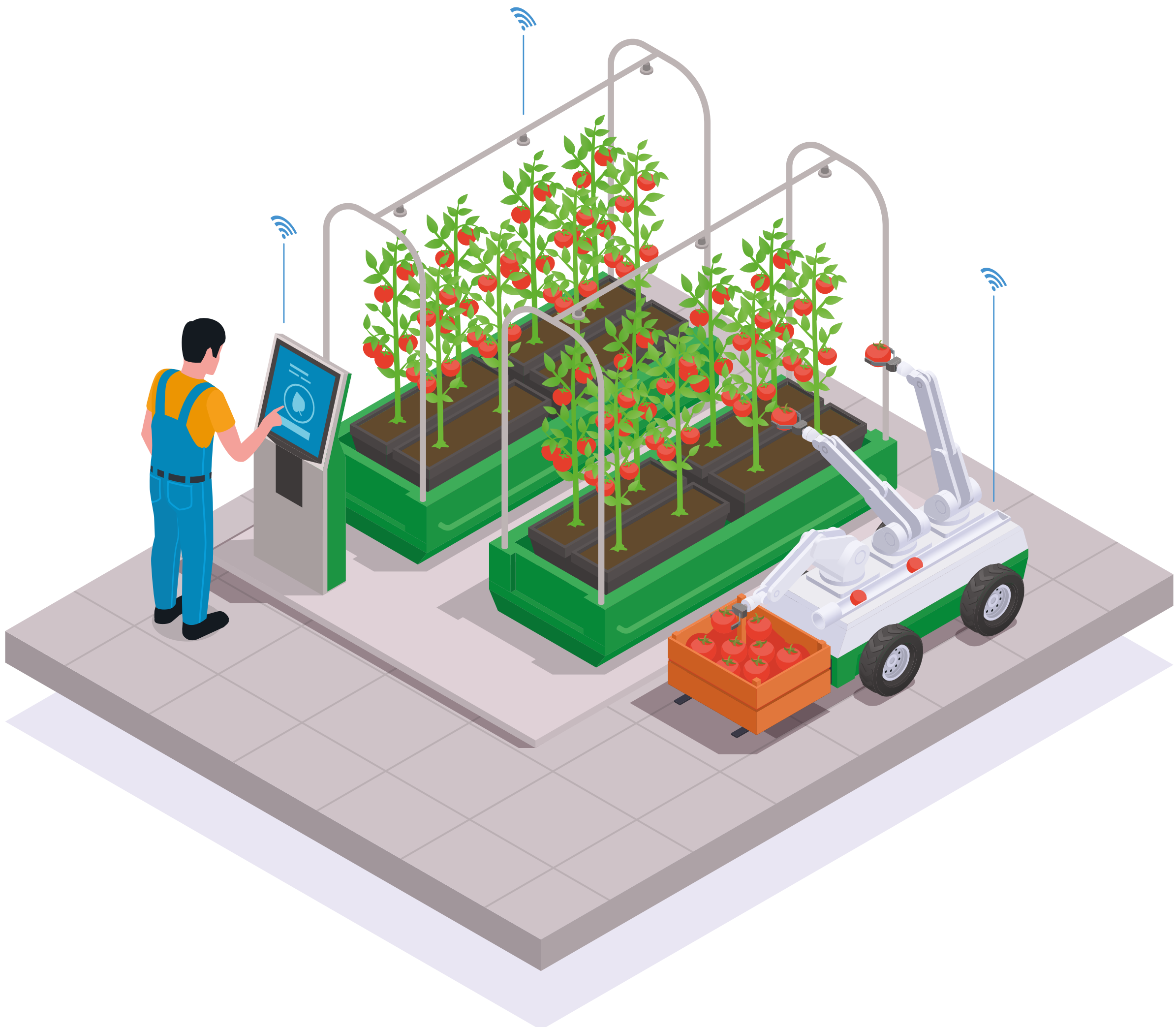
The introduction of completely new food production methods must take into account, among other things, what kind of expertise and information is needed in companies and research and development organisations in the sector, what means are there to promote the development of technologies, what measures are needed to accelerate investments and what opportunities there are for developing the distribution chain in these new forms of production. Development of these solutions and their market entry may be hindered by production, economic, political and legislative barriers. There are already a few operators in Finland that have begun working on these new forms of food and feed production. By examining the views of them and other professionals in the field, and by combining this information with existing research and other information, paths can be built through which we can accelerate the spread and growth of these new production methods in Finland.

The introduction of completely new methods must take into account, for example, what kind of competence and information is needed in companies and research and development organisations in the sector and what measures are needed to accelerate investments.

Objective

This report examines cellular agriculture and plant production in controlled environments, which can drastically reduce the use of arable land for food and feed production. The purpose of the study was to map the factors enabling and slowing down the introduction of these two methods of production. In addition, the aim was to identify measures that could promote the adoption of these technologies in Finland. Attention was paid to technical, economic and political factors, including sustainable development, in particular climate impacts and regional perspectives. The aim was to collect information from experts and stakeholders in the field and to activate food system operators to develop the new production methods. The online survey and workshops were used to collect expert information, which was supplemented by research data and views collected by experts from VTT and the Natural Resources Institute Finland in the Food without Fields project.

The aim was to examine the factors enabling and slowing down the introduction of food and feed production methods that drastically reduce arable land use, i.e. new plant production methods and cellular agriculture, as well as the development needs of the sector and measures that could promote the adoption of these technologies in Finland.



Description of new food production methods

Climate change challenges the Finnish food production system to change rapidly. In particular, significant land use and greenhouse gas emissions from food production are a considerable problem. Climate change increases variation in weather conditions, and the risk for crop production yields increases worldwide. Urbanisation and changes in land use needs also affect food production methods and profitability. Plant production in controlled environments, controlled environment agriculture (CEA), and cellular (i.e. biotechnical food production), offer promising solutions to these challenges. They enable year-round food production under controlled conditions and require considerably less land than current production methods.

Plant production under controlled conditions

Plant production in controlled conditions generally refers to cultivation in plastic tunnels, greenhouses or vertical farming (Figure 1). Controlled environments have the advantage of being able to control the factors affecting plant growth as well as the negative impacts on production, such as the use of pesticides and bad weather conditions, which can be significantly reduced or even eliminated. In this context, the technical level of equipment usually refers to the use of irrigation system and growing media in tunnels, but artificial lights, for example, are not typically used. In greenhouses, climate control is more advanced than in tunnels, and year-round

Figure 1. Cabbage seedlings in vertical farming. (Image: Titta Kotilainen/Luke)

Figure 2. Soybean plants in a greenhouse. (Image: Titta Kotilainen/Luke)

cultivation requires the use of artificial light. Vertical farming, on the other hand, uses almost exclusively artificial light (LED fixtures), various cultivation layers depending on the plant species stacked on top of each other, and climate conditions which can be precisely regulated. Vertical farming can be seen as a way of producing homogeneous food around the year, regardless of weather conditions, without nutrient emissions and close to urban consumers. Modular and small units in urban environments are also needed in developing areas where there are no suitable conditions for food production (Gómez et al. 2019, Kozai & Niu 2016).

At the moment, various types of vegetables are grown in Finnish greenhouses. Berry production in tunnels, especially strawberry and raspberry, is rapidly becoming more common (Luke Puutarhatilastot 2021). Small and fast growing plants, such as lettuces and herbs, are usually grown in vertical farming. Various solutions and technologies are being developed, which could enable the cost-effective production of climbing and/or high-wire plants such as cucumber, tomato or beans in vertical farming (Figure 2). For the purposes of this report, new plant production methods refer to (i) greenhouse production and the case of expanding the variety of plant species grown in greenhouses, in particular protein crops, such as soybeans and (ii) vertical farming.

Studies show that there is unexploited potential in controlled environment agriculture, but more information is needed on the control and optimisation of the production process (Shamshiri et al. 2018; Beacham et al., 2019) so that the economic and technical efficiency of the production process as well as the environmental impacts (energy consumption, carbon footprint) reach the desired level. From an economic and technical point of view, vertical farming is quite dependent on electricity and its production method (Al-Chalabi, 2015). According to Even (2015), LED technology should achieve a minimum efficiency ratio of 50-60% (light: energy) in order to be competitive. However, LED technology is only one of the factors affecting the cost competitiveness of indoor farming.

For the purposes of this report, new plant production methods refer to (i) greenhouse production and the case of expanding the variety of plant species grown in greenhouses, in particular protein crops, such as soybeans and (ii) vertical farming.

Banerjee and Adenauer (2014) estimated that, depending on the crop, a vertical farm produces 1.3-5.4 times as much yield per hectare as conventional agricultural production. For example, it was estimated that the yield for peas and lettuces was 1.5 times higher, 3.4 times higher for tomatoes, 4.4 times higher for sweet peppers, and 5.4 times higher for potatoes. Banerjee and Adenauer (2014) estimated that a large 37-layered vertical farm could produce vegetables, fruit and fish at a unit cost of between €3.5 and €4.0 per kg of product. According Cámara-Zapata et al. (2019), the profitability of controlled cultivation varies depending on the cultivation technology. However, the use of technical solutions requires substantial investments. The costs are influenced by the location of the production facility (Brin et al. 2016, Benke and Tomkins, 2017). However, with technology, the logistics, packaging and storage costs of end products and land use (Wittmann et al., 2020) can decrease. Heat and electricity consumption and their production methods affect profitability and environmental impact calculations. So far, there is little research data on the environmental impacts of the vertical farming production method in Finland. In general, technology and automation need to be further developed to enable the sustainable spread of the production of various nutritionally important plants (such as starch and protein-rich crops) in controlled environment agriculture (Kozai & Niu 2016).

Cellular agriculture solutions

Biotechnical food production, i.e. cellular agriculture, refers to the utilisation of microbial, animal, plant and algae cells for food and feed production. In other words, instead of arable farming and animal production, it is possible to produce feed and food in cell factories in bioreactors that are similar to brewery tanks (Figure 3). Using similar biotechnology, industrial enzymes are currently produced for use by the food industry, for example.

Microbes and other cell cultures can produce a wide range of ingredients in cell factories for food preparation. These methods can be used to produce edible microbial biomass (Ritala et al. 2017, Nyyssölä et al., 2022), such as Quorn™ fungal biomass, which has been in the market since 1985, plant cells (Nordlund et al. 2018) or cultured meat ('cell meat', 'artificial meat') but are still under development (Zheng et al., 2020). Microbial biomasses, often also referred to as single cell protein, contain plenty of protein, and many other nutrients, are often used to produce alternatives to meat products. The Finnish company Solar Foods is building a process utilising carbon dioxide from the air for producing edible food consisting of microbes. Another Finnish company, eniferBio, is developing technology to produce microbial biomass, Pekilo fungus, as fish feed, using soluble side streams from industry. The purpose of plant cell cultivation is to find more sustainable production forms for products such as coffee, avocado and other valuable or rare food crops, especially those with a high environmental load, such as some fruits and berries (e.g. Kobayashi et al. 2021, Rischer et al. 2022). So far, plant cell production has not yet been commercialised for food use, and product launches for cultured meat are yet to be carried out on the consumer market.

Biotechnical food production, i.e. cellular agriculture, refers to the utilisation of microbial, animal, plant and algae cells for food and feed production. In addition to the food use of the whole cell mass, cells can also be used to produce certain ingredients, such as animal proteins or fats.

In addition to the food use of whole cell mass, cells can also be used to produce certain ingredients, such as animal proteins or fats, which are added to the food manufacturing process to guarantee the desired end quality. In this method, microbial biomass is not the main product, but a protein, lipid or other ingredient produced by microbes separated from the microbial mass. For example, the Finnish start-up company Onego Bio aims to commercialise the production of egg proteins with microbes, while the American company Perfect Day uses microbes to produce dairy proteins.

Cellular agriculture has been estimated to be an environmentally sustainable production method, but it is important to take into account the sources of nutrients, energy and water in the development of production processes. The first calculations show that, for example, the production of egg protein in cell factories, instead of growing chickens, greenhouse gas emissions by up to 72% and land use by 90% (Järviö et al., 2021a). The microbial production process using carbon dioxide has also been calculated to be significantly more environmentally friendly than that of animal origin (Järviö et al., 2021b). In other words, this process can be built on a sustainable basis if carbon dioxide or other carbon rich side streams are available as sources of food for cell factories and the energy production is based on renewable energy. The same observations on cellular agriculture have also been made in a study by Tuomisto et al. (2020). It is important to examine how cellular agriculture solutions can be integrated into the processes of existing industry and food production. Effective utilisation of side streams affects the profitability of cell factory processes (Voutilainen et al., 2021). Voutilainen et al. (2021) concluded that the cellular agriculture origin Pekilo protein should have been on average EUR 5160/tonne, Fusarium protein 6549, Torula protein 7311 and recombinant protein (e.g. egg or dairy) 9007/tonne to make the production of these test cases profitable. Capital costs accounted for 39-46% of the production cost, other fixed costs accounted for about one fifth and other costs for 31-41% of the total production cost.

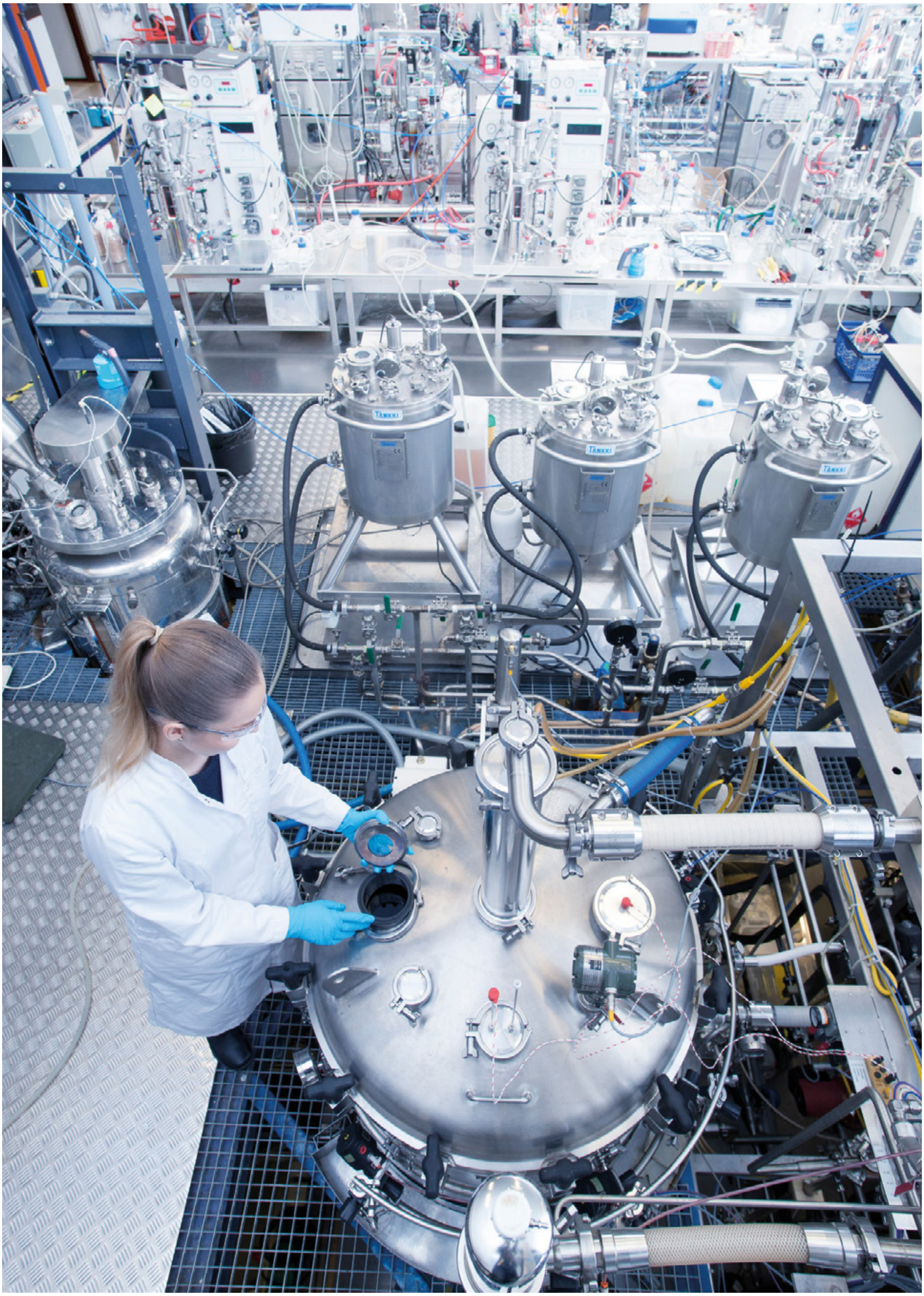


Figure 3. Pilot scale bioreactors in VTT's experiment facility. (Image: VTT)

Data collection through surveys and workshops

The data collection was carried out both as an online survey and through workshops. The online survey was carried out first, preparing the ground for the workshop. The online survey was carried out on the Webropol platform in October and November 2021. The invitation to the online survey was distributed to Finnish food system experts and stakeholders identified by the project research group. In addition, the questionnaire was distributed by email to expert networks working with cellular agriculture, greenhouse production or related sectors as well as on social media (LinkedIn, Twitter). Attention was also paid to the regional perspective when the survey was distributed. As part of the work of the Food without Fields project is targeted at the regions of Southern Ostrobothnia, Southwest Finland and Uusimaa, the research group sought to ensure that the respondents had experts working in these areas. Responding to the survey was voluntary. Two reminder messages were sent to potential respondents encouraging them to respond to the survey. The respondents had the opportunity to answer only one or both parts concerning a plant production technologies or cellular agriculture. The questionnaire is presented in Annex 1.

A total of 41 responses to the survey were received. A total of 22 people responded to questions concerning plant production technologies and 28 to questions concerning cellular agriculture (Figure 4). Questions concerning cellular agriculture were answered in particular by persons using or potentially using or buying cellular

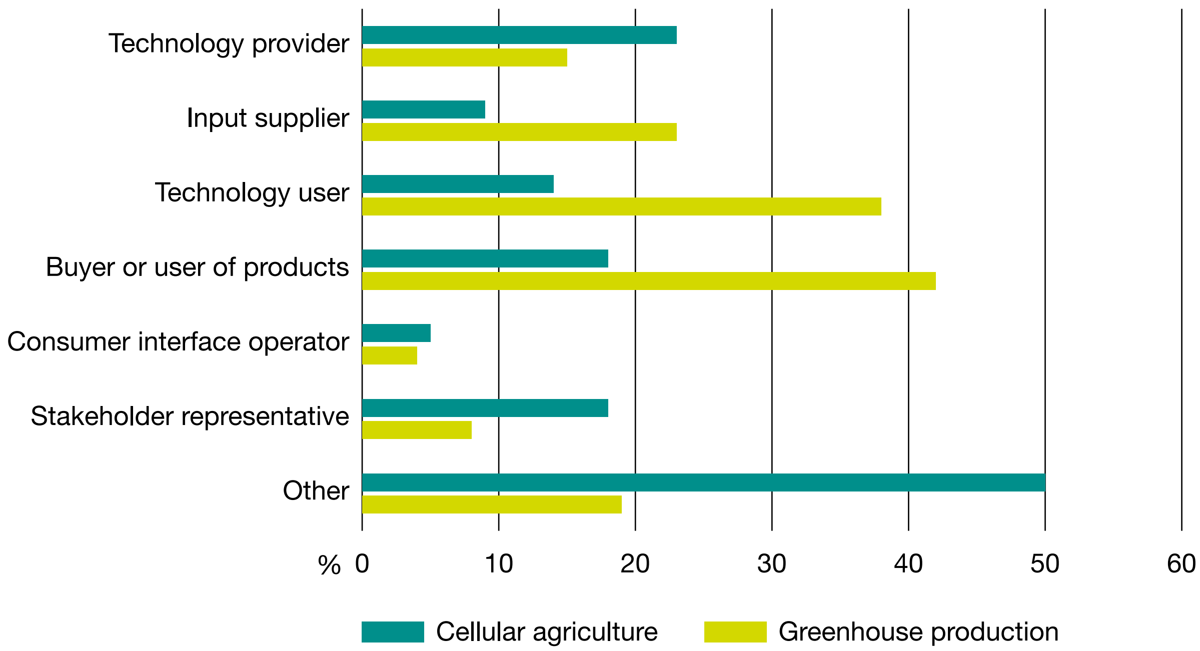


Figure 4. Distribution of the respondents to the online survey between different operators in cellular agriculture (N = 28) or plant production technologies (N = 22) themes.

agriculture technology themselves, such as food industry experts. Half of the respondents to questions on plant production methods indicated that they belong to the 'something else' group, including experts in research and education in the field. After the survey material had been compiled, a summary of the answers to both the multiple choice and the open questions was prepared. After this, the questions were analysed in terms of quality, taking into account the issues raised in the open questions. The issues raised were grouped into suitable entities according to their importance based on direct responses and open comments.

The implementation of the expert workshop was partly planned based on the results of the online survey. The workshop was organised as an online event using Teams and Howspace platforms in December 2021, as due to COVID-19 restrictions, physical meetings were not possible. Experts who had enrolled in the expert workshop using an online enrolment form were invited to attend the workshop. The registration link was distributed using the same channels and distribution lists as the online survey. Among the 37 experts from different fields who participated in the workshop were experts from research, education and training in the food or feed sector, technology users, interest groups and organisations, education and technology developers (Figure 5).

At the beginning of the workshop, experts from the Food without Fields project gave short presentations on 1) the potential of cellular agriculture in feed and food production, 2) protein crops in greenhouse production and efficiency of vertical farming, and 3) the results of the online survey with title 'What attracts and causes doubt in new types of plant production and cellular agriculture?'. After the presentations, the participants were divided into four breakout groups.

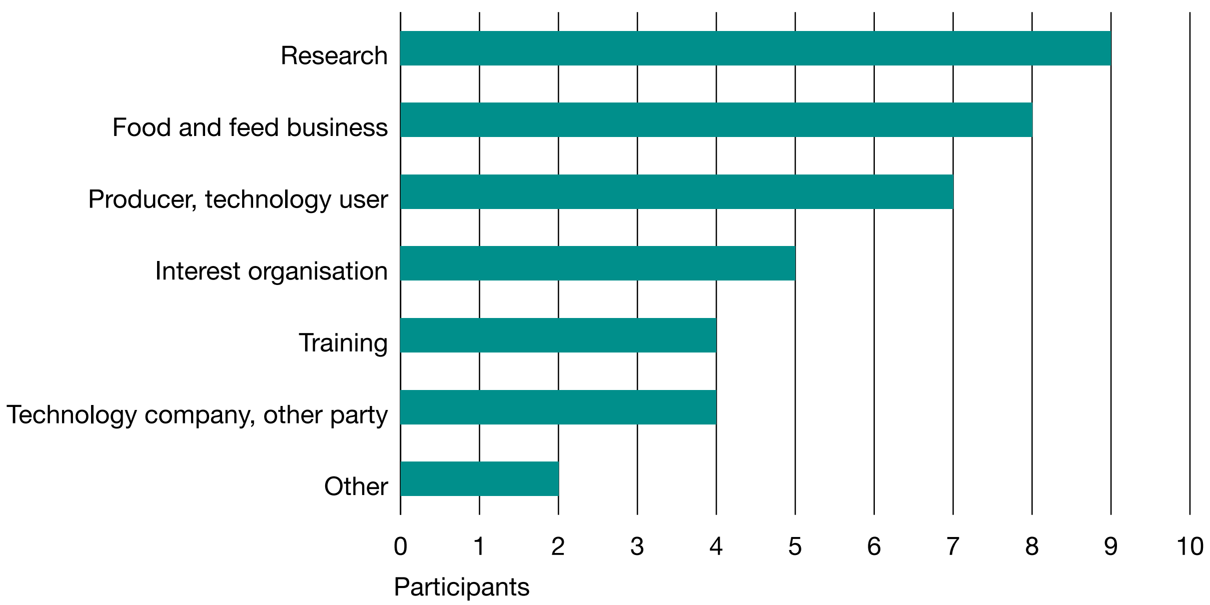
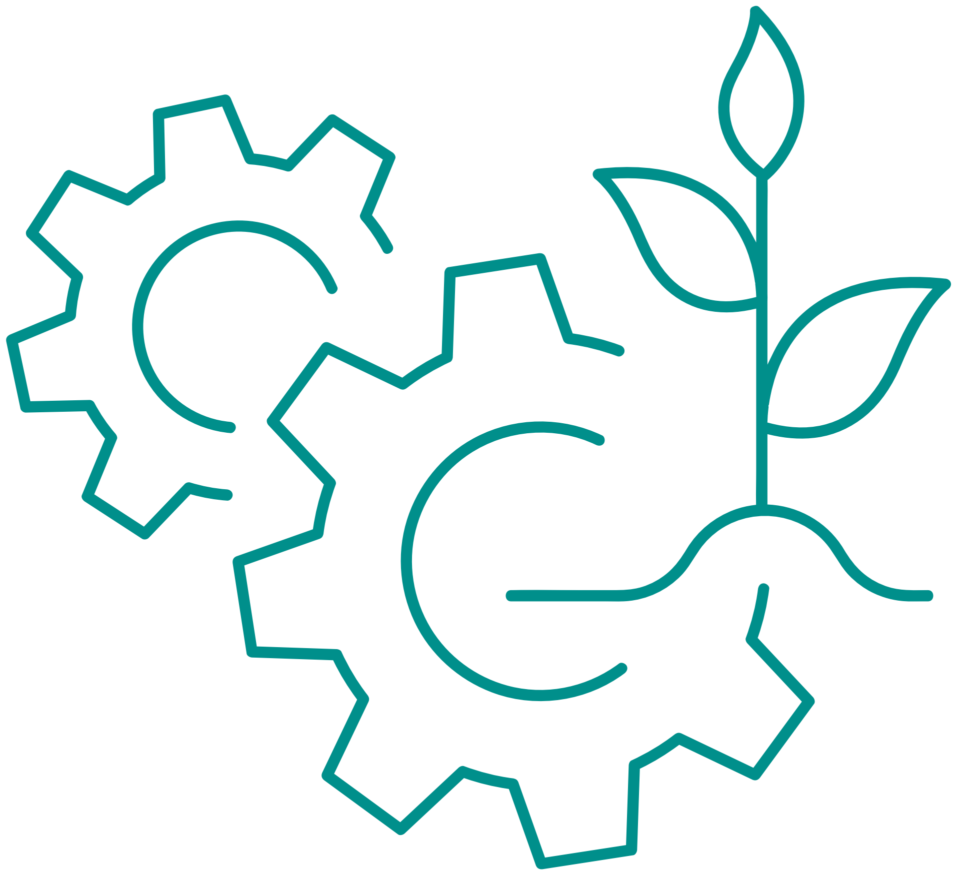


Figure 5. Background organisation of persons who participated in workshop discussions (N = 39).



Cellular agriculture and plant production technologies were discussed in breakout groups on the basis of a framework of three to five predefined questions. The questions covered the following themes:

- What are the main benefits of the new food and/or feed production methods (e.g. from the point of view of production, economy or sustainability)?
- Does the new production method have specific advantages or opportunities that can be exploited in the consumer market?
- What new operators would be needed to make progress with the new production method?
- What factors prevent or slow down the introduction of the new production method?
- What would it take to remove these barriers and delays?
- What could we learn from other countries about cellular agriculture, controlled cultivation and/or the production of new protein crops in greenhouses?
- What is the participant's view of the future of the new production method in Finland?

The themes mentioned above were discussed in the group discussion, first writing them independently in the Howspace workspace and then in a group discussion. The participants had the opportunity to complete their responses for two weeks after the workshop. The discussion at the workshop was recorded by the project experts and, on the basis of a qualitative analysis, an effort was made to identify the factors and solutions that the participants had generally considered important. The results of plant production technologies and cellular agriculture were examined in parallel to compare their similarities and differences. The expert information collected in the online survey and workshop was complemented with research data, which the experts of the Food without Fields project compiled from different sources and their own research work.

Benefits of new production methods

Based on the responses to the online survey, both controlled environment plant production methods and production methods based on cellular agriculture have significant benefits, which are summarised in Table 1. The identified benefits shared by both production methods are the possibility to produce food with small environmental impacts, to place the production plant in a location that is profitable from the point of view of either the availability of inputs or the demand for products, to manage the production process and to tailor production to demand. Both production methods require little land and the carbon footprint is estimated to be small if renewable energy is used in production, although energy consumption may be higher than in conventional food production. In addition, the traceability of products can be ensured. Environmental benefits were mentioned as important arguments in the marketing of products to consumers. Uniform year-round availability of products can be ensured in both forms of production, and new products can also be produced as local food in Finland. The cost-effectiveness of production was seen as an opportunity, although it still requires further development of these new production methods.

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In plant production, it was seen as an advantage that the almost complete control of growth conditions, closed nutrient cycle and optimisation of conditions increase yield reliability and reduce production risks. Because of the management of growth conditions, it would be possible to import new plants into the consumer market, and the plants currently imported could also be sold as freshly produced. The yield variation caused by the weather is smaller than in traditional greenhouse production or arable farming. According to experts, the need for pesticides and the risk of contamination in production are also lower in controlled environment production, which can be demonstrated by the purity of the final products.

According to the preliminary survey, plant production in vertical farming may be more energy efficient than traditional greenhouse cultivation, as heat loss is smaller than in traditional greenhouses due to temperature and humidity management and thermal insulation. Furthermore, due to the recycling of water and nutrients and the controlled of conditions, irrigation costs may be lower than in traditional greenhouse production. The benefits identified by the participants are in line with the benefits identified in the research literature. According to Al-Kodmany (2018, Table 2), the overall costs of vertical farming using advanced technology may be 30% lower in proportion to the production volume than in conventional cultivation. In particular, this is due to low energy consumption (LED lighting, amount and quality of light adjusted according to plant needs), lower labour costs (e.g. due to automated climate management and control), lower water consumption (up to -90% compared to arable farming), lower need for plant washing, treatment and plant protection and possibly lower transport costs.

In particular, the benefits of cellular agriculture were mentioned as environmental benefits, the cleanliness of products through a controlled production process and the possibility of ethically more accepted production, which were perceived as important arguments in the consumer market. Cellular agriculture can offer an alternative to products of animal origin in particular, as ingredients can be produced without ethical questions related to animal production and production can only focus on the production of products for which there is demand. In an optimal situation, cellular agriculture can very efficiently transform inputs (nutrients) into a product (for example, the need for so-called maintenance energy, i.e. energy used by the organism for activities other than actual growth, is very low), and side streams can be used as inputs. A closed nutrient cycle helps to make efficient use of available nutrients. Microbes and the compounds produced (e.g. proteins, fats and micronutrients) were found to be underutilised so far and new opportunities were recognised. The scalability of technology and the export potential of technology were also seen as the benefits of cellular agriculture.

Table 1. Key identified benefits and challenges of new plant production methods and cellular agriculture based on the online survey responses.

	BENEFITS	CHALLENGES
Plant production methods	Risks are better managed (yield, weather, variation in supply, quality and cleanliness of products).	The high efficiency of conventional greenhouse production does not attract the transition to new technologies.
	Productivity improvement, year-round production possible.	Legislative constraints; subsidy is only available for some plant species; the novel food regulation may restrict the use of various plant parts even for already used plant species; plants grown entirely under artificial light cannot be certified as organic.
	If well implemented, reduced environmental load (energy, irrigation water, nutrient recycling, need for arable land, carbon footprint, pest and diseases management).	Threshold to start: lack of knowledge and experience, the industry is still in its infancy, low awareness of the technology.
	Production facility location according to the availability of inputs (energy, waste heat).	High initial costs, electricity dependency and electricity cost.
	Local food, possibility to produce close to the consumers or to produce new plants.	Lack of operators, in particular lack of technology suppliers.
	High quality, especially cleanliness.	Consumer prejudices, plants in greenhouse production are not considered organic.
Cellular agriculture	Alternative to animal products, no ethical questions related to animal production in cellular agriculture.	Not considered organic, genetic modification possible, prejudices towards genetic modification (EU, companies, consumers).
	An efficient way to convert inputs into food, side streams can be used as feedstocks.	Legislation, in particular slow and costly authorisation of novel foods.
	Export potential and scalability of technology.	High investment costs, uncertainty of profitability of production.
	Environmental benefits (less land use and carbon footprint, resource efficiency, no need for plant protection agents, weather independent).	Consumer acceptance and consumer habits, consumer barriers for substituting novel sources of protein for products of animal origin.
	Production can be placed close to consumption or inputs, decentralised production possible.	Limited research data so far, small investment in research and development activities in the field in Finland.
	Versatility: a wide range of ingredients can be produced as needed.	Production technology and process readiness, not yet ready for mass production, value chain is underdeveloped.

Challenges of the new production methods

The responses to the online survey identified a number of challenges that need to be addressed before the new food and feed production methods can be introduced on a wide-scale (Table 1). The challenges mentioned included companies' readiness to adopt new technologies, dependence on electricity and consumer prejudice against new production methods. The high initial investment costs of the production and the availability of funding for start-up type operations, especially production process investments, were seen as challenges in both forms of production. Possible a novel food authorisation needed was seen as a clear challenge.

The lack of operators in vertical farming, especially the lack of a technology suppliers, was seen as a challenge. As the industry is new, this may be reflected in higher technology prices. The lack of knowledge and experience also slows down the development of the sector. In addition to the availability of funding, the introduction of new production methods and investments are slowed down by the high significance of energy use in the production cost structure. The already high efficiency of conventional greenhouse production and the low overall profitability of primary production were seen as factors that slow down the introduction of new methods.

In cellular agriculture, the need for novel food authorisation was considered the most important challenge, as the approval process is expensive and time-consuming. It may be challenging to compete with traditional production, which already has strong expertise and existing functional structures and value chains. The development rate of cellular agriculture technologies and processes may not yet be sufficiently advanced for mass production (e.g. scalability, costs), and the value chain is undeveloped and partly incomplete. The limited amount of research and product development inputs was considered a challenge, as relatively little research is available on the possibilities of cellular agriculture. The potential use of genetic modification (GM) techniques in the production process may also raise questions, as consumers in particular can be prejudiced about products that utilise GM techniques. Cellular agriculture products are not yet widely known among consumers. For example, Quorn™ is a product that 32% of Finnish consumers do not know at all (VTT, unpublished information). Even for those familiar with the product, it is not necessarily clear that it has been produced by means of cellular agriculture. In general, very little information is available on consumer attitudes towards cellular agriculture products. It would be important to better understand the potential factors affecting purchasing in terms of production methods, and to explore consumers' interest in the consumption of these new products.

Almost half of the respondents to the online survey estimated that financial support was not sufficient to enable the development of the new plant production methods. Only about a third of the respondents estimated that legislation makes it possible to sufficiently develop cellular agriculture. Approximately 40% of all respondents estimated that the political atmosphere makes it sufficiently possible to develop new production methods. On the other hand, more than half of the respondents estimated that research and product development, competence and training as well as market demand would enable the development of new production methods (Figure 6).

The energy and technology-intensive nature of new production methods can be considered a challenge. The way in which energy is produced and its price can be crucial for the success of the new production method. Energy should preferably be affordable and renewable. Thus, safeguarding the energy supply and functionality and feasibility of technology are important factors.

A production method based on the use of technology may, for its part, stimulate discussion among consumers.

In order to use new food and feed production methods, the acceleration of research, product development and investments, increasing and sharing expertise, new agricultural policy thinking and new equipment and technology suppliers in the sector were required.

In order to successfully introduce new methods of food and feed production in Finland, the following were considered necessary:

- Support, especially funding both for research and product development and for boosting investments
- A new kind of thinking for agricultural policy that would take better account of future challenges, such as environmental issues and security of supply
- Training and open sharing of information and experiences on new production methods both in Finland and internationally.
- New players in the sector; for example, equipment and technology suppliers were mentioned as factors that enable the start of new production.

In plant production, the respondents required plant production expertise and pioneers who would take the sector forward in practice. So-called added value crops should be identified, as these will cover the high production costs. In the plant production research and in the production development, attention must be paid to the recovery of heat, nutrients and irrigation water.

In cellular agriculture, the authorisation of novel foods was seen as a major challenge, and help was requested for carrying the process through, as well as cooperation in the form of joint background studies, not forgetting funding. One of the key challenges of novel food legislation is the duration of the authorisation process, and it was proposed that the process should be speeded up. It was also proposed to reduce the bureaucracy of the process. In cellular agriculture, export expertise was highlighted as one of the areas of development, as the sector was identified as offering opportunities for technology exports.

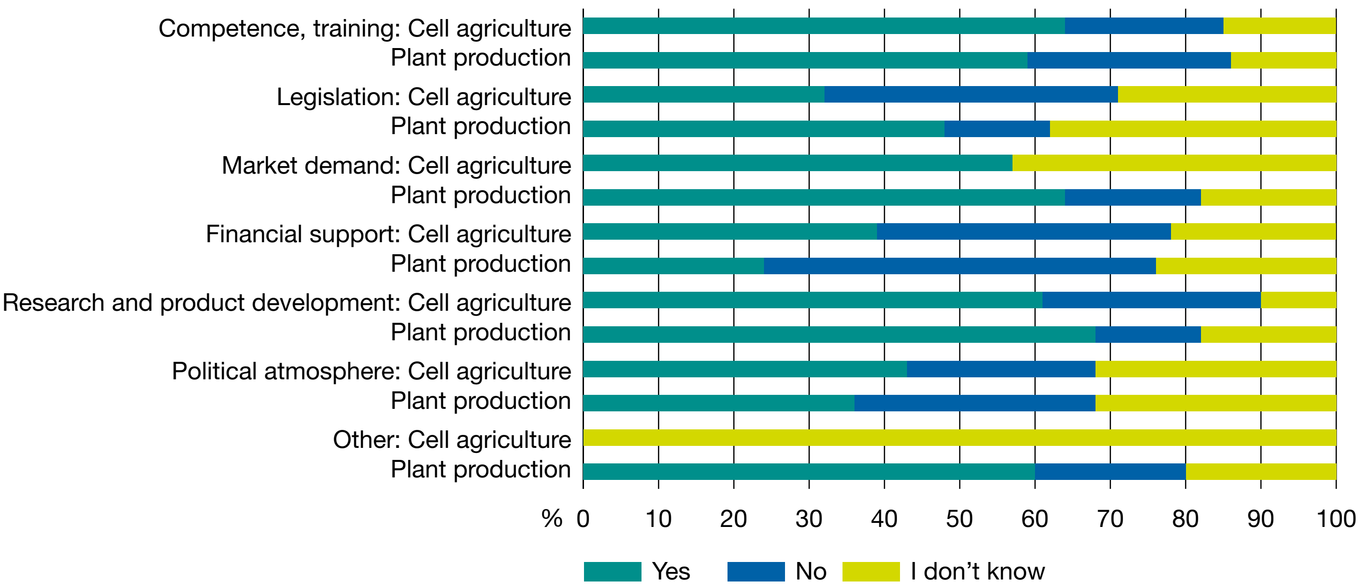


Figure 6. The online survey respondents' view of whether the various factors enable the development of a new production method sufficiently. Dark bars are answers for plant production and light bars for cellular agriculture.

The common view was that versatile expertise is needed in both, plant production and cellular agriculture. The sector may lack operators whose entry would solve business challenges, such as the use of side streams, the availability of various expert and technical support services, or the processing and distribution of products. Therefore, the operating models and structures of the food system should be considered open-mindedly. As part of solving financing problems, it was proposed that funding providers would provide support for both traditional and start-up companies. It was hoped that the interaction between research and the rest of society would increase and that new production methods could be put into practice quickly. For example, there would be illustrative demonstrations for educational institutions and companies, facilities and platforms where the new technologies could be tested. Attention should be paid to overcoming consumer and producer prejudices and communicating about the new production methods.

Experts and stakeholders were asked what to learn from other countries about these new forms of production. In other countries, there are both research and business activities from which we can learn and which we could adapt in Finland. Bringing good practices and solutions to Finland from experts at the forefront of the field was mentioned in this context. For example, crop production in controlled environments should be developed boldly and the benefits to various products should be demonstrated, and some of the respondents felt that we could learn and seek experiences on this topic from abroad. We could learn about marketing, development of new products and preparation for sale, i.e. making agricultural and horticultural products fit for sale or processing (e.g. packaging, sorting into quality classes, washing, cleaning roots or removing unmarketable products, increasing product information), from foreign operators. For example, the structure of supply chains and the demands from the consumer market are perspectives, and foreign experiences can be studied as background information. Benchmarking should also be carried out actively with foreign operators.

Political and regulatory perspectives

The political and regulatory perspectives were considered to have an impact on the introduction of the new food production methods examined in this report. In particular, the regulations on novel food and genetic modification provoked discussion, but subsidiary policy also provoked discussion.

According to Regulation (EU) 2015/2283 of the European Parliament and of the Council, a novel food authorisation for the marketing of products is required if the product, its ingredient or the production method applied does not have a history of use in the EU before May 1997. The authorisation can be obtained by a notification procedure if the product can be shown to have been in a traditional and safe use in a non-EU country for at least 25 years. The application procedure must determine the safety of the product in accordance with the regulations of the European Commission.

Ingredients and products produced by cellular agriculture fall under the novel food legislation. In individual cases, evidence of food use has been found before the 1997 deadline. For example, torula yeast has been found suitable for food use without going through the novel food process (European Commission, 2022). Products produced by cellular agriculture containing genetically modified cells are subject to GMO legislation. In the case of a component (ingredient or compound) isolated from a genetically modified organism and if the product no longer contains genetically modified cells, the novel food legislation process is applied. In this case, it is important to be able to show the purity and equivalence of the produced component (e.g. animal protein is the same that the animal produces, such as egg white protein). The regulation on novel foods may restrict the diversification of the range of crop species in production, as the use of different parts of known plants may be restricted.

The novel food authorisation process under Regulation (EU) 2015/2283 contains several steps. The application for novel food is sent to the EU Commission via the electronic system and the Commission requests the opinion of the European Food Safety Authority (EFSA) no later than one month after the verification of the appropriateness of the application. EFSA shall deliver an opinion within nine months of the date of receipt of the appropriate application by the Commission and shall take a decision within seven months of the date of adoption of the opinion by EFSA. Due to the large amount of information required for the authorisation, the authorisation process, including studies and reviews, can last from two to four years and can cost a few hundred thousand to millions of euros (European Commission, 2013; see also the Brookes report on the old novel food legislation (2007)). A novel food authorisation is granted for a product that meets the definitions drawn up on a case-by-case basis. An authorisation for a similar (but not identical) product is insufficient, and a separate authorisation must be applied for if the same competing product has not previously been authorised. However, the authorisations are not specific to the applicant or marketing name. Anyone can take advantage of the accepted authorisation and introduce an already authorised novel food into the market to compete with a similar product already present there. Information on the identification, production process, composition, history of use, proposed uses and levels of use of the novel food, among others, is required for the application. In addition, information is needed on the absorption, distribution, metabolism and excretion of the novel food, nutritional composition and potential toxicity and allergens.

Pursuant to Regulation (EC) No 1829/2003 of the European Parliament and of the Council, genetically modified organisms or foodstuffs may not be placed on the market unless they have been authorised by the European Union (EU). All genetically modified materials in the EU undergo a strict approval procedure, including an opinion on the safety of the genetically modified product prepared by the European Food Safety Authority (EFSA). Approved genetically modified materials do not adversely affect human, animal or environmental health. The consumer shall be informed of the genetically modified species or ingredients used in the manufacture of the food. The list of ingredients in the food packaging shall indicate its genetically modified nature immediately after the genetically modified ingredient or after the ingredients of the genetically modified species. The use of genetically modified organisms and products thereof authorised in the EU is permitted in animal feed under certain conditions. However, the limited presence of genetically modified material in animal feed is permitted without a labelling obligation, provided that the genetically modified feed material does not exceed 0.9% of the feed and the mixing has been occasional or technically unavoidable.

When building a facility for both cellular agriculture and new types of plant production, attention must also be paid to the fact that the construction and commissioning of the facility may require various permits related to the property and its operations. For example, a building permit is required for the construction of a new building or for significant renovations and modifications of an existing building. For activities posing a risk of environmental pollution, a permit in accordance with the Environmental Protection Act (YSL 527/2014) is required. These activities include the forest, metal and chemical industries, energy production, large animal shelters and fish farming. The environmental permit may include provisions on the scope of operations, emissions and their reduction. The prerequisites for a permit include that the activities must not cause health hazards or significant environmental pollution or a risk thereof.

In the future, legislation will be better guided by recording, investigating and reporting on the formation and utilisation of various side and waste streams, which is likely to be beneficial when developing new circular economy solutions for food production. Under the Waste Act (646/2011), it is prohibited to incinerate or take to a landfill any waste collected separately for preparation for reuse or recycling. According to the European Commission Decision Decree ((EU) 2019/ 1597) of 2019, Member States must henceforth report on the amount of food waste at different stages of the food chain on an annual basis. In addition, the new Waste Act approved by Parliament (Act amending the Waste Act 714/2021) contains provisions on the obligation of food business operators to do accounting and provide information on food waste. These new laws and regulations naturally aim at reducing waste, but at the same time encourage the use of side streams in food and feed production. The information collected on the use of waste and side streams promotes the utilisation of various raw material streams, for example in cellular agriculture processes.

Cellular agriculture is not eligible for agricultural subsidies, and only some of the plant species produced under controlled conditions can apply for the financial aid based on the common agricultural policy of the EU subsidies. This may affect the company's ability to start production. In greenhouse production, farmers' subsidies play a small role as they account only for 5-7% of the revenue generation in the greenhouse sector (Luke Taloustohtori, 2020). In addition, plants grown solely under artificial light cannot be certified as organic, which may limit the introduction of new methods. This can cause contradictions when plants can be produced under artificial light in an environmentally friendly manner and without pesticides. Organic production emphasises, among other things, the organic nature of the production method and the management of soil fertility and biological activity (European Parliament and Council, 2018), and plants produced in controlled environments can be seen as having characteristics that are contrary to the spirit of organic production. However, production in controlled conditions can contribute both directly and indirectly towards achieving organic production objectives, as it does not necessarily require pesticides, energy used can be renewable, nutrients are recycled efficiently, and land area is freed for other uses.

Cellular agriculture is not covered by agricultural subsidies, and only some of the plant species produced under controlled conditions can apply for subsidies. This may affect the company's ability to start production.

The objective of the EU's common agricultural policy is to develop the EU's agricultural production, taking into account, among other things, the well-being of the environment and the vitality of rural areas. Agricultural policy includes various support measures and other measures. The farmer subsidies paid today have been determined over the decades in connection with various policy reforms. In the early 1990s, agricultural products in the European Community benefited from price support, depending on their production volume, which was implemented to a relatively large extent by maintaining border protection (customs duties, import restrictions, etc.), which kept producer and consumer prices in the community high. In other words, consumers supported agriculture by paying a high price for the products. Agricultural policy was significantly reformed in the 1990s. With the reforms, prices for agricultural products in the EU were lowered and, at the same time, the use of price subsidies was shifted towards area subsidies, which compensated farmers for price reductions. Consequently, the production was no longer subsidised by consumers in terms of the price of the products, and the aid was paid out of tax resources and the production was allowed to be determined more freely on the market. Since then, various policy reforms have increased the market-orientation of farming: Support has been decoupled from production and increasingly targeted at various environmental protection measures. These policy changes have been underpinned by, on the one hand, societal pressure to increase the sustainability of food production and, on the other hand, by agreements promoting the liberalisation of international trade, in which production-linked support is considered the least acceptable form of support.

The possibility of applying for support for farmers or investments is limited to specific purposes. The aid for greenhouse production is a national aid payable throughout the country and may be applied for the following plants or groups of plants: tomato, greenhouse cucumber, gherkin, lettuce (*Lactuca sativa* and *Cichorium species*), lettuce, parsley, pepper, Chinese cabbage, cut flowers, cut foliage, and both outdoor and indoor ornamental plants. In addition, support can be applied for the production of lettuce and potgrown leaf dill and parsley for the farmer's own greenhouse production use. The amount of the aid depends on the crop area and the length of the crop cycle. The purpose of support for farmers is to ensure the profitability and continuity of production and is financed by the EU Agricultural Guarantee Fund, the EU EAFRD and national funds (Finnish Food Authority, 2022a). As a rule, new plants imported for cultivation in Finland are not covered by farmer subsidies, which may weaken the incentives for cultivation compared to plants currently cultivated in Finland.

An agricultural investment aid may be applied for by a farmer or a body governed by private law that is engaged in or will engage in agricultural activities on a farm, or by an association of farmers (greenhouse limited liability company). Agricultural investment subsidies can be applied for the expansion or renewal of the farm's operations. Eligible investments in greenhouse production (irrespective of the crop grown) include the necessary construction investments and the purchase of a growth tunnel for the production of a horticultural crop grown for food use. Support may be granted for construction investments and the purchase of machinery or equipment needed for the renovation of agricultural products, or for the purpose of improving working conditions, production hygiene or the state of the environment. In the A and B support areas of Southern Finland, a maximum of 30% of the eligible investment costs can be granted. In addition, an interest-subsidised loan of up to 65% of the eligible costs of the investment can be granted, and the interest subsidy of up to 10% of the eligible costs can be granted. Investment and start-up aid is funded from the EU's EAFRD and national funds (Finnish Food Authority, 2022b). Significant investments are required in the establishment of controlled crop production or cellular agriculture. However, cellular agriculture is not covered by agricultural investment aid, and there may be situations in which the planned investment is not eligible even in the case of controlled crop production. From this point of view, the current aid structure may preserve production structures, which may undermine companies' willingness to invest in new technologies, especially if investment aid is available for investments to a competing production method.

Solutions for identified challenges

The online survey asked for solutions to the challenges identified in the production methods of plants in controlled environments and cellular agriculture (Table 2).

In terms of economic and political challenges, both the survey responses and the workshop discussed the potential role of production and investment subsidies. In greenhouse production, the significance of farm subsidies was considered marginal and production is market-based. According to Luke's Taloustohtori (2020), subsidies account for approximately 5-7% of the income in the greenhouse sector. However, aids may play a greater role on individual crops, which may affect the choice of crops that are produced. In arable farming aids may play a greater role, which may affect the choice of production method. However, the workshop participants did not consider production aid to be a sustainable or realistic alternative for the future to develop new forms of production. Instead, the market-based operating method received more support. However, some of the participants raised the question of whether various subsidies should be allocated more clearly to the development of environmentally friendly production and to encouraging efficient use of the cultivated area. This was seen as a means of developing aid policy. On the other hand, investment support was seen as a more important form of support in the discussion, and the allocation of public support and funding accelerating investments in plant production (e.g. increased or targeted investment support) was brought up by several participants. One participant pointed out that the suitability of the aid for Limited Company-based Operators should be ensured.

As technology becomes more widespread and production volumes increase, investments were seen to bring more equipment manufacturers to the sector where current low volume is one significant bottleneck. Funding would be needed for product development, and several participants suggested that testing of new technologies, for example, could be carried out with public funds. The development of renewable energy sources was specifically mentioned, as energy is a major cost item in both plant production in controlled environments and cellular agriculture. The participants felt that various targeted research, product development and innovation funding instruments are part of the solution to accelerate the introduction of new food production methods in Finland.

Targeted research, development and innovation funding instruments are an important partial solution for accelerating the introduction of new food production methods in Finland.

Regular monitoring of the market situation (demand vs. supply; reasons for demand and its fluctuations) and production of both market-oriented and research data to keep operators up to date and even slightly ahead of cost development was seen as one solution for developing the operating conditions of the sector. However, market information should be produced and distributed taking competition legislation into account. High demand for new, more environmentally friendly vegetable protein raw materials was highlighted. At the same time, however, it was brought up that the price of plant proteins should not be too high and the processed products should be in an easily usable form (flour, protein concentrates and protein isolates).

Regarding tackling future policy challenges, it was noted that more dialogue is needed between decision-makers, organisations, farmers and other actors. In this way, opportunities and challenges can be highlighted and shared discussions can be held, avoiding confrontation between production methods. Breaking down barriers to the introduction of new food production technologies was considered important so that the opportunities for progress in Finland would be as good as possible. However, it must first be possible to demonstrate the environmental impact of various new food production solutions on a case-by-case basis to ensure that environmentally more sustainable solutions are promoted. In addition, increasing the attractiveness of the sector, for example through active communication, was considered important. Supporting information would promote marketing and would attract the interest of entrepreneurs and financiers. It could dispel suspicions of technology and technological dependence and provide information.

Table 2. Summary of the solutions to identified challenges highlighted in the online survey related to new food production methods.

PRODUCTION METHOD	CHALLENGE TYPE	SOLUTION TO THE CHALLENGE
Plant production methods	Financial	More targeted research, product development and innovation funding instruments and funding for both research and business to demonstrate the potential of new technologies and increase their readiness level. Developing renewable energy solutions to ensure that the energy source is both sustainable and cost-effective.
	Political	A clearer targeting of growers' subsidies for the development of environmentally friendly production. Increasing dialogue between stakeholders and the network of operators, supported by decision-makers, in order to make effective use of new methods instead of confrontation.
	Competence	Increasing knowledge: active communication about the market situation and about new research results. Continuous investment in research, product development and innovation activities: More operators in the sector as technology becomes more common and the sector grows. Examples and demonstrations through teaching, advice and test platforms.
Solutions for cellular agriculture	Financial	More targeted research, product development and innovation funding instruments and funding. Must attract venture capitalists and foreign investors. A clearer targeting of production subsidies for the development of environmentally friendly production. Integration of processes into existing industry: using side streams as inputs.
	Legislative	The processes required by the novel foods regulation and the fulfilment of the requirements are supported by the state and investors. More cooperation, clear instructions and competent operators to support in the authorisation process. Speeding up the authorisation process with a common database that contains already existing research data. Speeding up the reform of GMO legislation, more actively involving Finns in the lobbying work.
	Market demand	More consumer research and fact-based communication with consumers to ensure acceptance without undue concerns, for example in relation to the benefits of the products and the GMO discussion. Branding and marketing of products: developing the approrpiate terminology, for example how to name the origin of products. Development of the distribution network and sales channels.

In the debate on cellular agriculture, it was stated that the development of business requires not only public funding but also venture capitalists. The food industry and even consumers were proposed as co-funders. Cellular agriculture also needs sufficiently large and long-term support for the research phase and support for investments, especially in the early stages of commercial activities, for example through Business Finland, the EU and ministries. In the comments on cellular agriculture, it was proposed that Finland should be branded as an attractive pioneer in food technology, thus attracting foreign investors to Finland. It was also hoped that funding for branding would be strengthened.

Scaling up and automating cellular agriculture production were suggested to achieve economies of scale. All industrial and agricultural side streams should be evaluated as raw materials for the new processes. The utilisation and development of existing value chains from this perspective was also proposed. It would be essential to ensure the supply of inexpensive raw materials and the utilisation of side streams. For example, a source of carbon and nitrogen from industrial side streams can help solve challenges related to the profitability of production and improve the environmental friendliness of the process. It was stated that the reform of the food system must guarantee the fair treatment of all existing operators, so-called sustainable and fair adaptation and transition.

Support, active cooperation and effective guidance from experts were proposed for the processes required by novel foods regulation and the fulfilment of authorisation requirements.

When discussing the development of cellular agriculture, the novel food authorisation was identified as a very important legislative challenge for which it would be important to find solutions. Support from the state and financiers, active cooperation (e.g. cooperation in novel food applications) and effective guidance by experts were proposed for the processes required by the novel food regulation and the fulfilment of the requirements.

Many participants suggested speeding up and simplifying the novel food process. The introduction of new technologies could include an EUlevel network of operators and a database that would collect information on research carried out by all operators for the novel food process. Some of the participants had difficulties in identifying concrete actions that should be taken at the EU level. It was also hoped that the regulation of the food sector would be slightly relaxed in order to give companies some flexibility. There was a desire for clearer instructions on how to comply with legislation. Which nutrients can and cannot be used to grow microbes was suggested as an example. As a legislative solution, it was proposed that the reform of the GMO legislation would be sped up to ensure that the uncertainty about future European legislation would not alienate investors.

In solving the challenges related to market demand, it was emphasised that the consumers' views should be known and taken into account, and that production should be branded. Important product characteristics for consumers that should be developed and highlighted were price, quality, sensory characteristics (taste, structure), attractiveness, health effects and appearance, and sciencebased environmental claims. The vegan or 'animal free' cellular agriculture products were seen as important arguments in the production of ingredients of animal origin. In this context, it was stressed that the input materials used in the process should be vegan. The participants hoped for investments in marketing and branding. Examples included investments in the naming of products (e.g. how to market products of animal origin produced in cellular agriculture) and in creating realistic images.

In both forms of production, it was hoped that appropriate and competent information on the production method would be communicated to consumers, for example through social media channels. In order to meet consumer demand, a new sector must create a sales and distribution network. Although cellular agriculture products can be more easily acceptable to consumers as ingredients used by the food industry (rather than consumer products), a functional distribution chain and sales channels must also be created for business sales (B2B).

At the moment, genetic modification has not been used in most cellular agriculture products. However, questions related to genetic modification can play an important role in the approval of cellular agriculture products among customers and consumers, as genetic modification is subject to a lot of prejudices and, in particular, the concepts are often confused in a polarised discussion. The participants in the survey and workshop felt that in the future, genetic modification will also be increasingly involved in cellular agriculture. It is therefore important to keep the concepts as clear as possible and to provide consumers with information on both the environmental aspect and safety of products.

Pressures to change the food production system may revive the GMO debate again in Europe. As a result, consumers weigh more carefully the benefits of GM technologies in food production, making GMO easier to accept and support.

Consumer approval and communication in cellular agriculture, especially in GM technologies, were considered a significant challenge. At the same time, it was pointed out that, for example, many enzymes used by the food industry are produced with GM organisms, but as purified proteins they are not included in the GM legislation. Today, retail requires GMO freedom from producers and industry, as it is used in consumer marketing. However, GMO-based biomass could already be used for feed at the moment. However, pressures to change the food production system can bring up the GMO debate again in Europe. As a result, consumers weigh more carefully the benefits of GM technologies in food production, making GMO easier to accept and support. In addition to demand, political decisionmaking in particular can serve as a driver for GMO approval.

More operators were needed in the value chains of both cellular agriculture and new plant production in order to develop the production method and its value chain. In both value chains, research operators, inventors and innovators, bold entrepreneurs and farmers, product developers and national and international venture capitalists were needed.

Education providers, advisors and information providers on the production method were needed for plant production value chains. In addition, experts in data-driven production were needed, and especially Finnish manufacturers of vertical cultivation technology (e.g. equipment, automation, artificial intelligence, software). The entire production chain, from equipment suppliers and production facilities to maintenance, was considered an important development target. Once the production and value chain has evolved and finished, the operating model will be easier to replicate.

The participants were unsure of what kinds of operators are needed in the value chain of cellular agriculture. Biotechnology companies were mentioned as necessary new operators. Operators might be found through the renewal and reorientation of existing companies. Finland was perceived to have excellence in the field, but the transfer of expertise and technology to Finnish companies should be ensured. In the comments, operators were encouraged to engage in active start-up business, and large Finnish companies were hoped to have more courage to make new openings.

Increasing competence in Finland

A number of measures were proposed to address the challenges of skills and training in new production methods. Monitoring the development of the sector through Finnish and international top operators and sharing the best operating models and ideas in different forums, seminars and events between operators in the field were considered important. In plant production, it would be possible to learn from international companies, especially on a large scale, as the majority of operators in Finland are still small.

Multidisciplinary expertise (Table 3), new types of combinations of expertise and closer cooperation between educational institutions, research institutes and companies were called for in both forms of food production. Test platforms, pilots and the utilisation of up-to-date infrastructure were proposed for plant production in teaching (visits to operating companies, demonstration, internships, theses) to increase the competence of both students and teachers. This set of needs is also relevant for cellular agriculture. It was hoped that broad-scale investments would be made in product development and innovation.

Wide-ranging expertise and vision are needed in the development of protein plant cultivation. In the development of plant cultivation competence, more attention should be paid to the impacts of plant photobiology and growth environment climate management on plant productivity. The content of studies should be tailored to new technologies. Versatile and wideranging expertise in the fields of technology, digital skills, cultivation, analysis methods, financial management and plant biology and physiology were identified important in the field of plant cultivation (it is important to be familiar with, for example, sensors, measuring devices, strategies, future skills, risk management, economy, technology management, optimisation, marketing, customer relationship management; LED lighting technology and the utilisation of renewable energy). In equipment development, plants and the preconditions for their growth and plant production process must be better known. In addition, supporting expertise is needed in the assessment of environmental impacts and sustainability and their utilisation as positive environmental claims.

Multidisciplinary expertise, new types of combinations of expertise and closer cooperation between educational institutions, research institutes and companies were called for in both forms of food production.

Combining information and the role of cooperation will increase. Plant producers were seen to be more like engineers in the future, which could attract new and innovative work-force to the sector. As plant production becomes more technology-oriented, more cooperation is needed between different fields and interfaces and different experts, especially engineers interested in plant production. The discussion found that vertical farming requires a team of experts with expertise in many fields. The combination of different fields of education should be done early, during studies, especially between the fields of biology and technology, for example by providing students of plant production in controlled environments with an understanding of the possibilities offered by technology, without forgetting basic studies of the cultivation on which these technological lessons are built. Market and financial expertise were also seen to be necessary (e.g. financial instruments, construction of a sales network, business planning).

In cellular agriculture, the competence needs for technological development were partly similar to those in plant production. A broad understanding of the entire process and production chain ('from cell factory to dinner table') and cooperation between various operators are also essential in cellular agriculture. The competence needs mentioned included biotechnological competence, the development of microbial strains, management of growth conditions, safe production methods and process automation. Other competence themes mentioned included processing side streams as nutrients for the cells, increasing the production capacity of processes, separation and downstream processes after bioreactor cultivation, and versatile competence in further processing and product development of end products. Transfer to a larger production scale requires 'engineering thinking', understanding energy balances and bioprocessing skills. In cellular agriculture in particular, increasing consumer understanding and consumer-oriented marketing of products and the related good commercialisation competence and branding both in Finland and in export markets emerged as an important competence area. Regulatory expertise is also needed. Competence related to digitalisation and artificial intelligence was also mentioned as a competence needed in the optimisation of production technology and process.

Capabilities for cooperation with various companies as well as bold strategic and visionary thinking was expected from experts. New openings were expected before the products are introduced on the market. Top experts who do not really yet realise that they are or could be innovators in the food sector should be actively sought for. Based on the workshop, investments should also be made in transferring competence to operators and acquiring competence and experts from abroad.

Table 3. Highlighted special competence needs identified as important for the development of new food production methods.

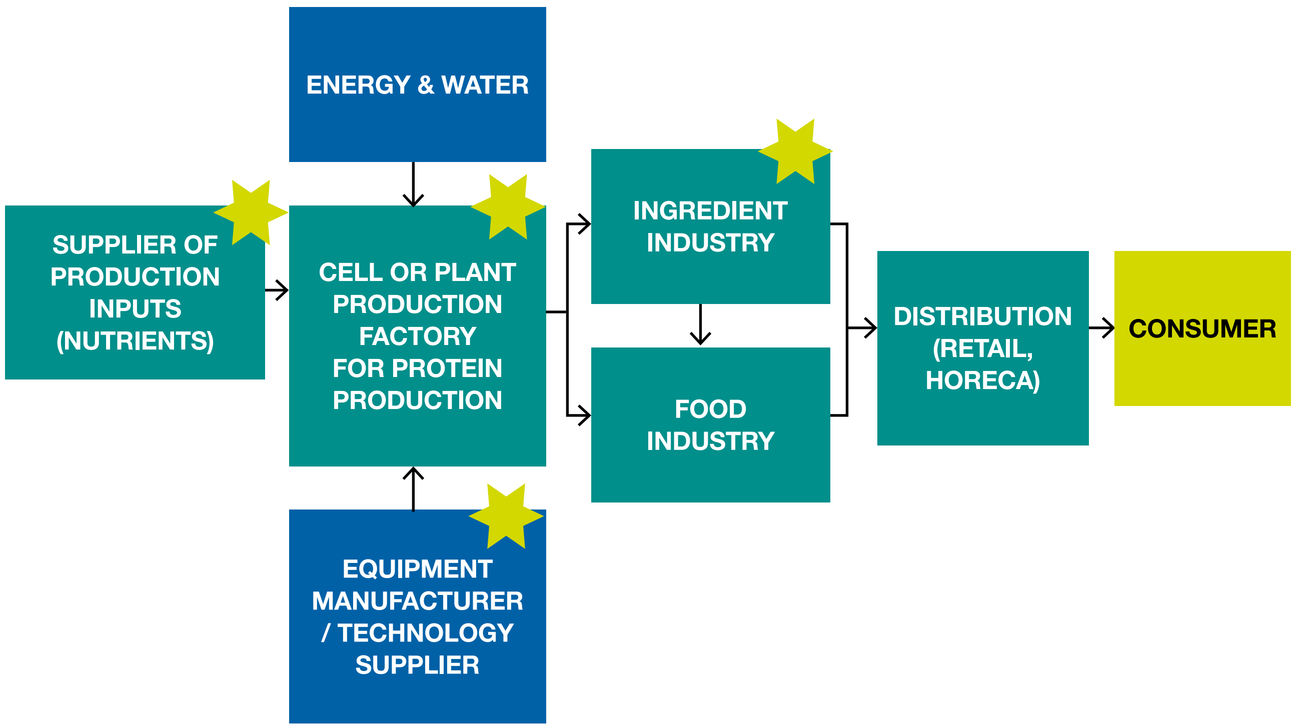
PRODUCTION METHOD	COMPETENCE NEEDS
Plant production	• Technology and process competence (engineering degree), in particular equipment development, LED lighting technology, energy solutions • Digital skills, IT and automation competence • Competence in plant cultivation, plant biology and physiology • Measurement and analysis methods (e.g. sensors and measuring instruments) • Understanding the environmental impacts and sustainability of production • Market and financial expertise, risk management
Cellular agriculture	• Biotechnology, molecular biology (development of microbial strains) • Bioprocess competence (management and development of cultivation conditions and production process, scaling of processes to industrial scale and optimisation) • Separation and postprocessing competence, also end product development • Consumer and market understanding, branding competence • Process automation, IT competence and utilisation of solutions based on machine learning • Legislative competence (in particular novel food and GMO regulations)

Development work from the perspective of value chains

The development of value chains related to new production methods was examined in a workshop from many different perspectives (Figure 7). From the perspective of production inputs, particular attention was paid to how side streams can be utilised as nutrients and what kinds of energy and water circulation solutions can be built in plant production and cellular agriculture.

The integration of cellular agriculture and plant production into a single production ecosystem has been identified as an opportunity in which both the nutrients of various biomass and the energy cycle between various production facilities can be implemented (Figure 8). Today, the side streams of biomass generated in greenhouse production are mainly composted. The utilisation of plant biomass used in greenhouses, at least for the production of biogas, but preferably as nutrients for cellular agriculture bioprocesses in the substrate, animal feed or insect feed, was seen as a desirable development. The need to look at the production ecosystem and side streams in a sufficiently broad way was raised: in particular, nutrient cycles could include various side streams and processes from agriculture and forestry. The utilisation of side streams should also be examined from the perspective of novel food legislation. Their use may even make the process more difficult, even if it makes sense to use side streams in terms of sustainability and profitability.

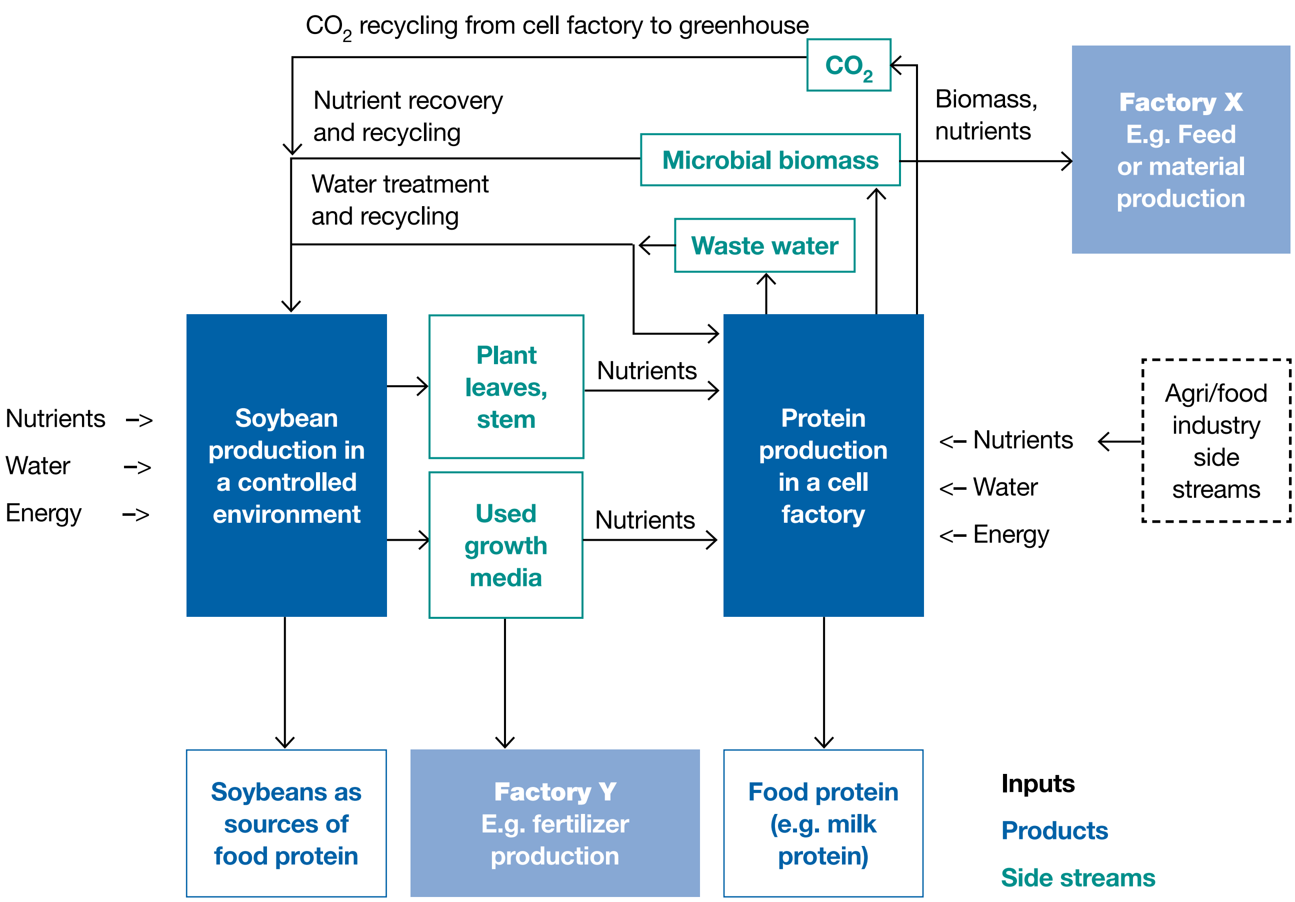
Figure 7. A value chain example of new food production methods. Especially in the parts marked with an asterisk there is a need for new experts and operators.



When further consideration was given to the utilisation of side streams, it was found that biomass logistics for the plant could pose challenges. If the side stream needs to be dried for e.g. stability reasons, it consumes a lot of energy. For cost reasons, wet or liquid biomass should not be transported over long distances, so their utilisation should be carried out close enough to the location where the biomass is produced. Alternatively, the logistics of side stream masses should be organised cost-effectively. The basic question is whether the by-product biomass produced by the greenhouse, for example, should be processed next to the greenhouse or somewhere else in a higher volume production facility. Similar consideration must be given to energy side streams. Eco-industrial parks, which have the opportunity to join food production, are mainly located near cities, which would enable food production close to consumer clusters.

Agroecological symbioses were highlighted in the discussion, the future of which was considered from the perspective of plant production in controlled environments and cellular agriculture. From the perspective of the benefits of symbioses, it is essential to evaluate can the use of inputs and level of outputs be improved with symbiosis. It was estimated that further processing of side streams would be easier to manage if the actors were well-networked, as it could increase the volume and commercial interest of side streams. The collection and utilisation of carbon dioxide produced by the production process in a parallel production facility or process was highlighted, and the use of carbon dioxide emissions from other industrial factories (e.g. paper factories) as a production input in cellular agriculture or plant production processes was also noted.

Image 8. An example of potential integration between plant production and cellular agriculture in the same production ecosystem.



The availability and quality of side streams have been examined in various projects, such as the Arvobio project, the results of which give and indication of the potential of side streams (Kymäläinen and Suojala-Ahlfors, 2020), Side streams in the business project (Thermopolis, 2016) and Luke's Biomass Atlas, which provides a database of side streams (Luke, 2020). The food industry produces a wide range of organic side streams, the quantity and quality of which depend on the company's sector, size and manufactured products. Production processes in the food industry are becoming increasingly automated, production volumes are increasing, and byproducts are increasing in volume. According to Lehto et al. (2021), plant fractions account for about 40% of plant production. To increase the use of side streams, their characteristics should be better known. This requires, for example, analysis of the composition and quality of side streams and development of pre-treatment processes. In principle, side streams must be stabilised to ensure uniform and safe use.

Opportunities were seen in the utilisation of energy side streams. For example, it is possible to connect a greenhouse to a low-temperature district heating network. Based on the workshop, a key factor related to the use of energy in plant production was the development of energy control solutions. The recovery and utilisation of excess heat energy from lighting, e.g. for heating other premises of the company, or the use of waste heat from industrial plants in the heating of the greenhouse or elsewhere was seen as an opportunity. As both plant production in controlled environments and cellular agriculture depend on electricity, developing efficient and environmentally sustainable energy sources was considered important. Examples included solar panel solutions and the development of a system in which solar energy can be stored to guarantee continuous electricity generation.

In addition to nutrients and energy use, water use and recyclability are important in both cellular agriculture and plant production processes.

In addition to nutrients and energy use, water use and recyclability are important in both cellular agriculture and plant production processes. Based on the results of the workshop, cost-effective and phytosanitary safe water recycling systems need to be further developed. The hygiene of the water must be taken into account in the rainwater circulation. There are already solutions for the recycling of water and nutrients, but there is not yet enough information on their functionality. Water circulation can take place in symbioses with other production systems, as water can be circulated in other production processes. For example, an idea was put forward in the discussion as to whether the waste water from the greenhouse could be utilised, for example, as a substrate for algae farming. In cellular agriculture, it is already possible to achieve an advanced water circular economy.

Special questions related to the bioprocess were raised in the discussion on cellular agriculture, such as the breaking down of carbohydrates from side streams into sugars for better use in cell cultures and the management of harmful substances from side streams. Substances harmful to humans are not necessarily harmful to cells, which expands the possibilities of using biomasses. In addition, side streams can be purified or modified, and cell cultures can be modified to prevent potential contaminants from causing damage to cells or end product users. For example, side streams unfit for direct human consumption (e.g. products with a past sell-by date) could be converted for food use by means of cellular agriculture, or harmful side streams could be used in the production of biomaterials (i.e. other than feed or food use). However, it is important to know how much impurities there are in the side streams. In the online survey, cellular agriculture was estimated to have either equal or more potential in feed production than food production.

> **Special questions related to the bioprocess were raised in the discussion on cellular agriculture, such as the breaking down of carbohydrates from side streams into sugars for better use in cell cultures and the management of harmful substances from side streams.**

The profitability of production and market demand naturally play a key role in considering the start of new business (B2B or B2C). Without commercial interest and a profitable production process, value chains will not survive. Value chains must be developed so that in addition to the so-called main product, other outputs can bring business value for the company. In plant production companies, opening a new business area outside the core activities is often unfamiliar and there are missing operators in the production chain. For example, various agroecological symbioses and circular economy solutions associated with greenhouse production have been tested with insects and algae, but the time has not been mature for their entry into the market. Direct sales or a short distribution chain were seen as an opportunity for plant production. However, when operating on an industrial scale, the distribution chain must be adapted to the production volume. The business of the chain should be transparent, including cost transparency. However, increasing the transparency of the costs of the production process may reduce the bargaining power of the producer, as competitors and buyers of products will see the level of the production costs, and it may be more difficult to obtain additional value added for the producer company compared to a situation where the costs remain known to the producer company.

In the discussion on cellular agriculture, the operating model of the business was considered. The question raised was whether it would be simpler to sell a product from a company to a company (B2B) as an ingredient in the early stages of cellular agriculture instead of end products to consumer (B2C). In cellular agriculture, it was hoped that new partnerships between companies would be developed for the production of both inputs (especially nutrients for cells) and ingredients. Products of high added value should be brought to the market. For example, baby food and pet food could be products where buyers are willing to pay a premium. Around the world, children's food includes components produced by cellular agriculture (e.g. using GMO production to produce accurate protein composition in breast milk). Customised ingredients with new and better properties were mentioned as an opportunity such as the potential for special compounds / added value products of native species (e.g. largescale production of milk compounds of landraces) and the production of ingredients for meat substitutes.

Platform economy solutions were mentioned as a potential trend. In any case, value chains should pay attention to the manageability and coordination of inputs and product flows and related information, and platform economy could help in achieving this. For example, the platform could provide operators with information on how side streams can be used, what they are like, where and at what price they can be obtained. More sustainability analyses were requested for cellular agriculture concepts so that the production method can be reliably compared with other ways of producing food.

The placement of production facilities sparked discussion, the solution being either a local or a national operating model. Producing food where there are significant inputs or where there is consumption or the possibility of large-scale production were seen as alternatives. Both options have weaknesses and strengths, and the conclusion is that both options, partly local, partly concentrated production, are potential and even desirable operating models, depending on the circumstances. In any case, both plants and cellular agricultural products could be marketed as local food. It may be easier to locate and start new types of production in areas that do not already have established food production chains. However, well-functioning food industry facilities may be potential actors in these new value chains, either as input suppliers or endproduct consumers, which may facilitate the placement of new production in the region.

In order to support the establishment of production facilities, information is needed on how large the production volume and customer base need to be in order to be profitable, and especially what is the impact of the local versus regionally larger customer base on profitability.

In order to support the establishment of production facilities, information is needed on how large the production volume and customer base need to be in order to be profitable, and especially what is the impact of the local versus regionally larger customer base on profitability. For example, a vertical farm can be located in Northern Finland because it is not dependent on weather conditions or sunlight. Reducing energy costs requires innovation, some of which may be local, such as using compost, biogas or seasonal storage of local energy sources. The balance between a sufficiently large production scale and short transport distances of inputs should be analysed and optimised. The possible location of production in cities, their suburbs or rural heartland areas and the environmental and economic impacts of the logistics of these alternatives should be investigated. Decentralised local production would support the rural development and production and security of supply in Finland, but sufficient infrastructure must be ensured at different sites (e.g. further treatment of waste water and side streams). Different regions may have different readiness to adopt new technologies, so development work could be integrated into regional industrial policy.

Cellular agriculture highlighted the 'cross-pollination' of various value chains, the collision of different sectors and the formation of symbioses. The technology used should be affordable and scalable also for small volumes of production. However, scalability is important in both cellular agriculture and plant production solutions. It was mentioned that so far too little has been invested in locally scalable concepts. In all of the factors mentioned above, attention must be paid to topical information and training in the network of operators and the utilisation of the potential of new technologies in both local and centralised solutions.

Future prospects and followup measures

The online survey examined the respondents' views on the future prospects of cellular agriculture and new plant production methods in Finland. The respondents to the online survey were very positive about the future of new forms of production in Finland. Both cellular agriculture and the production of new plants were perceived as production methods that will become more widespread in the future, but first all obstacles must be removed and technology must become more affordable. It was felt that the development of both production methods will take time. It was estimated that the new forms of plant production will become significant at the earliest within approximately 10 years, and in cellular agriculture, the time required for significant production was estimated to be at least 10–15 years (Figure 9). However, views on the growth rate of production methods varied, and many also replied 'I don't know' to the question of the future significance of cellular agriculture.

Respondents felt that the method of production and the marketing of food should be connected in an appropriate manner. The production method as such is not a significant competitive factor, but flavour and price are still the main criteria in food selection. In marketing, the emphasis should therefore be on the quality, availability and sustainability of the product, which are enabled by new technology and production methods. By emphasising quality and sustainability, we can appeal to features that make the product important and meaningful to consumers. In addition to Finland, commercial and other cooperation opportunities were also seen on the international market (Figure 10).

Plant production in controlled conditions was considered to be the production method of the future, but the obstacles to its spread must first be removed and the costs of production technology must be calculated.

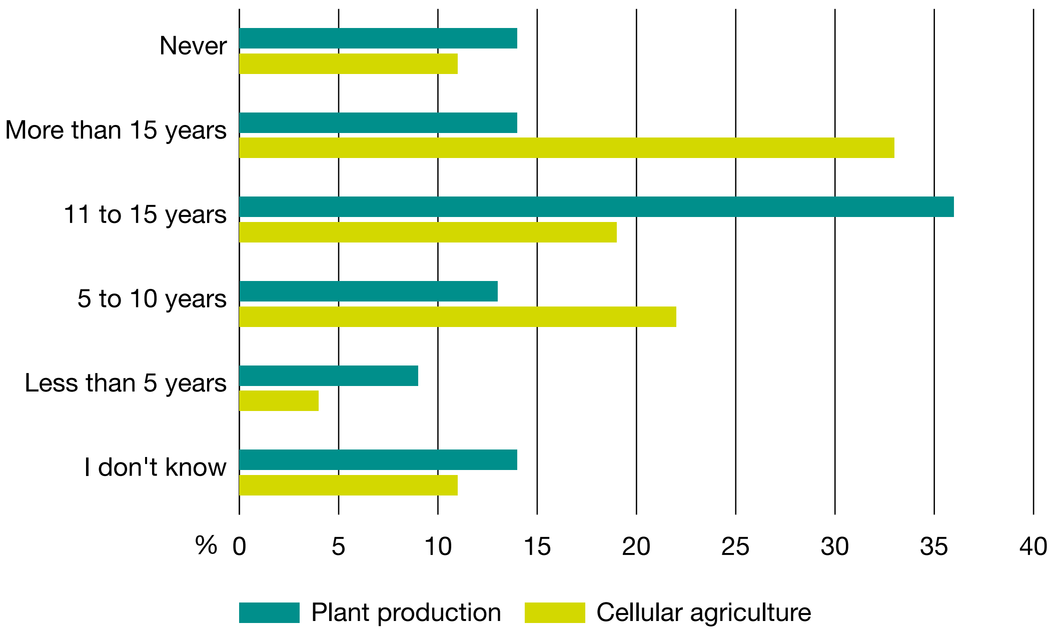


Figure 9. Online survey respondents' view of the timeframe when cellular agriculture or new plant production methods are an important production method from the perspective of protein self-sufficiency.

Achieving a significant market share would require substantial investments in production facilities. Partial utilisation of natural light and vertical farming in connection with greenhouse production could be solutions suitable for Finland. This would combine new and old approaches. Finland could become an export country of vertical farming technology. Plant production in controlled environments may be justified in the production of some low-volume products or special products and may complement the production of high-volume plants. In addition to or instead of bulk production, new production methods may have the potential to produce special products such as spices or other high added value ingredients.

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Not all considered controlled plant production methods as a key solution in solving problems associated with land use, but emphasised the reduction of animal production and agro-ecological farming methods as more significant and straight-forward factors in the development of a sustainable food system. For example, agroecological cultivation methods do not necessarily require the same scale of one-off investments needed to start indoor farming in northern conditions. When examining changes in land use, it is essential to consider what is being done in the land area freed up by indoor farming. Therefore, the assessment of the overall sustainability of the production method requires a comprehensive assessment.

Views on the expansion of cellular agriculture varied. Some of the respondents believed that cellular agriculture will play a role in the future, although the time span for realisation of impacts may be long and difficult to understand. Some of the respondents felt that cellular agriculture will not spread very extensively as a food production method. Anyway, new production methods in cellular agriculture must be environmentally friendly and cost-effective in order for the production method to be viable in the future. In cellular agriculture, start-ups were also seen as playing an important role in accelerating the adoption of technologies. As the development of the sector takes time, the coexistence of the new and the old should be emphasised. Both traditional and new food production methods will be needed in the future, and all of them must function on a sustainable basis.

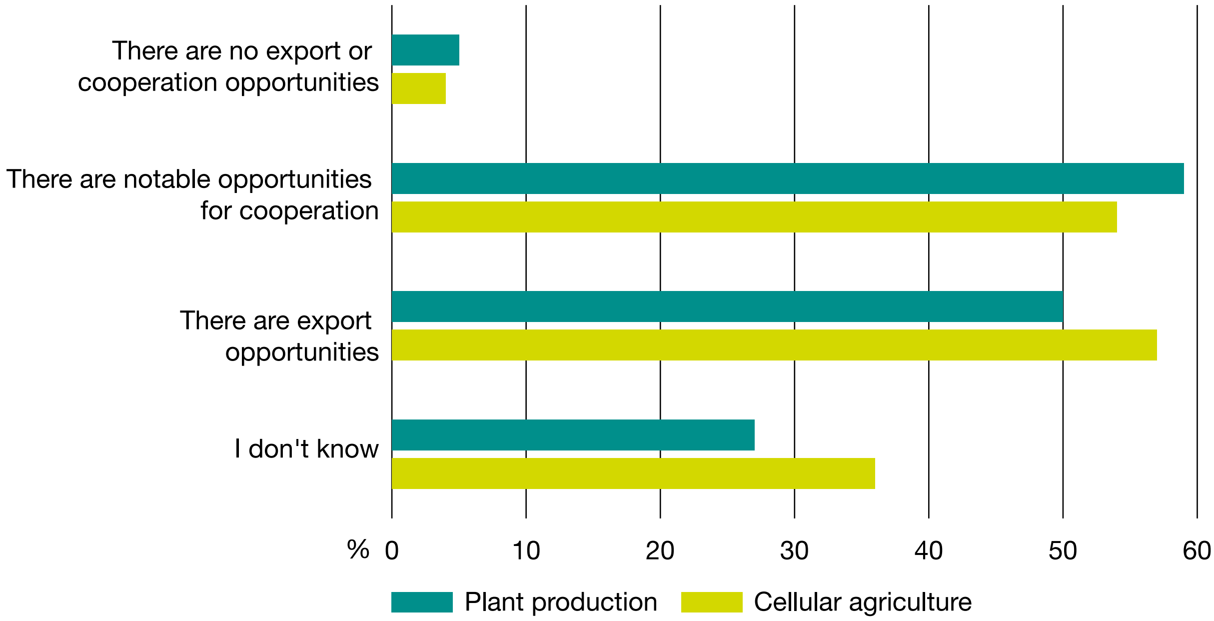

Image 10. The online survey respondents' view of whether there are opportunities for international cooperation in cellular agriculture or new plant production methods.

Production methods must therefore be both environmentally friendly, cost-effective and responsive to market needs.

> **In order to create a positive future both in cellular agriculture and in new plant production methods, research and product development carried out in cooperation between research organisations and industry as well as innovative startups are needed.**

In order to create a positive future, both in cellular agriculture and in new plant production methods, research and product development carried out in cooperation between research organisations and industry as well as innovative start-ups (including technology suppliers) are needed, as well as funding for launching operations, transfer of expertise to Finland and Finnish companies, and rapid response to new technical solutions that can enter the market quickly. The change must take into account the coexistence between the new and old production methods, as both are needed. The development of new production sectors requires Finland to have experts in the field, researchers, education providers, advisors, information providers on the production method, providers of auxiliary services (e.g. maintenance and IT solutions) and bold entrepreneurs in particular.

Proposals for measures

Based on workshops, online surveys and other background studies, proposals for measures to promote plant production methods and cellular agriculture in Finland were divided into six categories: 1. Funding for research and development activities and for the commercialisation of solutions, 2. Competence development, 3. Accelerating cooperation, 4. Raising awareness, communication, 5. Development of value chains and operating models, and 6. Strategic cooperation and decision-making to solve bottlenecks (Table 4).

One of the most important measures was to increase funding opportunities from basic research to investment subsidies. Based on the report, versatile investments are proposed in both research and product development and the commercialisation of solutions, including support for start-up companies and the construction of demonstration environments. Start-ups play an important role in the introduction and scaling up of new methods.

Competence development was another clear set of measures. It proposes investing in education and practical teaching projects, the construction of test platforms and the creation of new degree programmes that emphasise multidisciplinary competence. Various measures related to competence development that accelerate cooperation between different operators. Cooperation will increase the exchange of information and create new innovations through the collision of expertise and sectors.

It is proposed to increase awareness of production methods through factbased information both to the actual operators in the sector and to consumers and decision-makers. Information must be based on research data. In consumer communications, it is important to focus on the style and substance of information so that new production methods do not cause undue concern and suspicion in consumers. New products must be branded by utilising communications and marketing experts.

Value chains and operating models related to new production methods must be actively developed. In particular, the optimal location of production processes in different areas in Finland must be examined using systematic calculations to ensure continuous and profitable production. In addition, it is important to assess, develop and test the potential of various coordinated production ecosystems in research and development projects and corporate cooperation. In the calculation and scenario work, particular attention must be paid to objective, peer-reviewed profitability and environmental impact calculations.

Last but not least, legislative mechanisms were highlighted. For example, facilitating the novel food authorisation process through cooperation and advice, as well as subsidiary policy reforms, are important factors that can promote the introduction of new production methods.

Table 4. Proposals for measures to promote plant production methods and cellular agriculture in Finland.

TYPE OF ACTION	ACTION	PROPOSAL FOR AN IMPLEMENTATION METHOD
1. Funding for research and development activities and the commercialisation of solutions	Securing financing for companies' investments, especially for the commercialisation of innovations in start-ups. Support also for increasing the scale of production.	Business Finland (BF) and other financiers to build suitable instruments to support investments. Start-ups play an important role in the development of new technologies, in which case BF instruments should also support research and development projects in which start-ups are the business partners.
	Funding for research and development to raise the technology readiness level (TRL).	New research programmes from the Academy of Finland, BF, ministries and the European Commission that emphasise new food production techniques in their application themes.
	After basic research, building test platforms and supporting the implementation of pilots.	Build new research and development funding programmes and targeted thematic calls for experimental and demo phase research. Establish common test platforms by corporate collaboration (funded by companies).
2. Competence development	Training programmes and courses that emphasise a new type of combination of competence and entrepreneurship	Training new professionals as well as teachers. Education is provided at different levels (including universities, universities of applied sciences, vocational schools, general upper secondary schools). For example, the degree programmes in biotechnology could have specialisation courses in cellular agriculture.
	Advice and information, in particular technical and legislative guidance	Provide advice and training for both professionals and teachers through various expert networks and training programmes.
	Practical research and development projects for competence development	The use of up-to-date infrastructure in teaching (visits to operating companies, demonstration, internships, theses) to increase the competence of both students and teachers.
	Learning from mistakes and successes of others, especially from international operators	Analyse (benchmark) pioneering countries such as the United States, the Netherlands, the United Kingdom or Israel. Monitoring of operator networks: e.g. https://www.verticalfarmdaily.com; https://www.cellularagriculture.eu/; https://www.proteinreport.org/
3. Accelerating cooperation	Strengthening cooperation and exchange of information between companies, research and education and across scientific and administrative branches	The operators (e.g. the Protein Cluster) will be agreed and resourced to be responsible for communications in the sector, to speed up cooperation and co-creation, and to promote production methods towards decision-makers and consumers (cf. VYR, the co-operation platform of the Finnish cereal and oilseed sector). Build and utilise test platforms and pilots that can be utilised in research and development, teaching and commercialisation measures
	Creating new types of combinations of expertise through 'cross-pollination"	Networking events are organised (e.g. through the Protein Cluster). Finland already has excellent expertise in both agricultural and biotechnology and top experts in digital and smart technology, which can be combined to create competitive solutions.

TYPE OF ACTION	ACTION	PROPOSAL FOR AN IMPLEMENTATION METHOD
4. Raising awareness, communication	Extensive fact-based communication of new food production methods, taking into account both strengths and weaknesses	Existing communication platforms and channels that reach the general public (national media), the network of experts and operators (professional journals, scientific publishing) and decision-makers will be utilised.
	Product tests and trials	And production and product trials for companies, product developers and consumers. For example, through test production, tastings at various events (fairs, expert events).
	Investing in consumer communication and 'branding' of products as part of the commercialisation	The right brand message and narrative to be built with communications and marketing experts that does not raise unnecessary concern and suspicion (cf. polarised GMO discussion).
5. Development of value chains and operating models	Development and construction of the distribution chain and network of operators	Analyse the potential location of production facilities in different areas, taking into account the risks (e.g. whether production is dependent on individual input or supplier). Different integrations to be evaluated and piloted in cooperation with existing industry, including various circular economy solutions, utilisation of side streams.
	Performing scenario calculations to facilitate decision-making in order to know the realistic production volume and impact of different products, including environmental impacts	The economic potential of the solutions to be assessed using calculation models and the market potential to be assessed using consumer studies. Pilot projects to be launched that provide a sufficient picture of the development potential and a realistic estimate of the production volumes from the perspective of protein self-sufficiency. Conduct an objective assessment to demonstrate carbon footprint and other environmental impacts and ensure transparency.
	Creating a comprehensive concept for the import and introduction of new crops for cultivation in Finland	The concept must pay attention not only to the introduction of product development and new technological expertise but also to the commercialisation of practical cultivation instructions and illustrations. Previous experiences of bringing crops to Finland can be used as an example.
6. Strategic cooperation and decision-making to solve bottlenecks	Facilitating the novel food authorisation process	Facilitating the measures required for the novel food authorisation process by sharing information (EU-level information platform, joint studies) as well as targeted permit process grants (funding for the production of permit materials) and by encouraging operators. Inform experts who can help with the permit process.
	Reforming greenhouse gas production as part of the Älymaatalous 2030 road map (Pesonen et al. 2021)	Integrate the information produced by the sensors of cellular agriculture and new crop cultivation methods and its utilisation in steering production and communicating about the quality of products as part of the value chain. Creating experimental environments for new technologies.
	Amendment of the aid policy	Allocating investment subsidies and assembling new funders to launch a new type of production. More emphasis to be placed on reduced environmental impacts in the allocation of subsidies.
	Promoting the process of reforming GMO legislation	Reopening the GMO discussion particularly from an advantage perspective; the Finnish scientific community and decision-makers to actively promote the requirements for updating GMO legislation.

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Appendices

Appendix 1. Online Survey Response Form

VTT

Luke
NATURAL RESOURCES
INSTITUTE FINLAND

Catch the carbon
CLIMATE SOLUTIONS IN THE LAND USE SECTOR

Questionnaire of Food without Fields project

I agree to the Privacy Policy and participate in the survey

☐ Yes

Choose which of these themes you want to answer?

GREENHOUSE PRODUCTION

☐ The questions concern vertical farming of plants (controlled environment agriculture) and cultivation of new protein plants in greenhouses where renewable energy is used.

CELLULAR AGRICULTURE

☐ The questions concern the production of food and animal feed using microbes or plant cells. For example, the production of single-cell protein (i.e. protein-rich microbial biomass, such as Pekilo) for fish feed via using industrial soluble side streams, or egg white protein production with microbes.

The following questions concern *the new method of plant production*, which includes: Controlled-environment agriculture, vertical farming and/or new protein plants produced in the greenhouses. Which of the following options describes your situation?

Choose the most suitable options.

- ☐ I use controlled environments agriculture/vertical farming
- ☐ I plan to use controlled environments agriculture (vertical farming)
- ☐ I produce protein plants in the greenhouse
- ☐ I plan to produce protein plants in a greenhouse
- ☐ I know the method of production in any other way, how?
- ☐ I'm not familiar with the methods.

Would you like to answer the following questions about the new production, method controlled-environment agriculture (vertical farming), production or from both perspectives?
From the point of view of greenhouse cultivation or both?

- ☐ From the point of view of controlled-environment agriculture
- ☐ From the point of view of greenhouse production of new protein plants
- ☐ From both perspectives

What do you think are the key benefits of a new method of production (e.g. benefits from the viewpoint of production, economics or sustainability)?

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Do you think the new method of production has special advantages or opportunities, which can be exploited in the consumer market?

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What role does the organization you represent have or may have in a value chain using the new method of production?

You can choose more than one option.

- [ ] Technology supplier
- [ ] Inputs supplier (e.g. supplier of nutrients or side streams)
- [ ] User of technology (e.g., a vertical farmer)
- [ ] Buyer or user of products (e.g. food industry)
- [ ] In the consumer interface, the operator (e.g. retail trade)
- [ ] Stakeholder representative (e.g. front organisation)
- [ ] Something else? Please specify:

What new operators would be needed to ensure that the new food production methods progress at the best possible way in Finland?

What factors are preventing or hindering the adoption of new production method in Finland?

What would be required to eliminate these barriers and hindering factors?

Will the following factors sufficiently enable the development of a new mode of production?

	Yes	No	I don't know
Competence, training	☐	☐	☐
Legislation	☐	☐	☐
Market demand	☐	☐	☐
Financial support	☐	☐	☐
Research and Product Development	☐	☐	☐
Political climate	☐	☐	☐
Something else? Please specify:			

Is there sufficient knowhow in Finland to allow for a new method of production to be developed and be exported to the market?

☐ Yes

☐ No

☐ I don't know

Is there a new way of production for Finnish products or know-how export prospects or international cooperation opportunities?

☐ There are export prospects

☐ There are viable cooperation opportunities

☐ There are no export or cooperation opportunities

☐ I don't know

Further information

What we could learn from other countries concerning controlled-environment (vertical) agriculture and/or on producing new protein plants in greenhouses?

What is your view on the future of a new method of production in Finland?

In what time span do you believe that the new method of production is used in Finland significantly from the perspective protein self-sufficiency?

- [ ] In less than 5 years
- [ ] 5–10 years
- [ ] 11–15 years
- [ ] In more than 15 years
- [ ] Never
- [ ] I don't know

The rest of the questions concern *cellular agriculture* as a new method of production.
How you know that method of production?

- [ ] I use it
- [ ] I plan on using it
- [ ] I feel it any other way, how?
- [ ] I don't know the method

In your opinion, does cellular agriculture have more potential in feed or food in production?

- ☐ More in feed production
- ☐ More in food production
- ☐ Equally much in both feed and food production
- ☐ I don't know

What do you consider as the key benefits of cellular agriculture (e.g. benefits from production, economic or sustainability perspective)?

Do you think cellular agriculture has specific benefits or opportunities that can be exploited in the consumer market?

What role does the organization you have or could have in the cellular agriculture value chain?

You can choose more than one option.

- ☐ Technology supplier
- ☐ Inputs supplier (e.g. supplier of nutrients or side streams)
- ☐ User of technology (e.g. ingredient industry)
- ☐ Buyer or user of products (e.g. food industry)
- ☐ Operating in the consumer interface (e.g. retailers)
- ☐ Stakeholder representative (e.g. an interest group organisation)
- ☐ Something else? Please specify:

What new actors would be needed for cellular agriculture to be as successful as possible in Finland?

What factors are preventing or hindering the adoption of cellular agriculture in Finland?

What would be required to eliminate these barriers and hindering factors?

Do the following factors sufficiently enable the development of cellular agriculture?

	Yes	No	I don't know
Competence, training	☐	☐	☐
Legislation	☐	☐	☐
Market demand	☐	☐	☐
Financial support	☐	☐	☐
Research and Product Development	☐	☐	☐
Political climate	☐	☐	☐
Something else? Please specify:			

Is there sufficient knowhow in Finland to allow for cellular agriculture to be developed and be exported to the market?

- ☐ Yes
- ☐ No
- ☐ I don't know

Are there export prospects or international cooperation opportunities for the products or expertise of new production methods?

- ☐ There are export prospects
- ☐ There are viable cooperation opportunities
- ☐ There are no export or cooperation opportunities
- ☐ I don't know

Further information

What can we learn on cellular agriculture in other countries?

What is your view on the future of cellular agriculture in Finland?

In what time span do you believe that cellular agriculture is used in Finland significantly from the perspective protein self-sufficiency?

- [ ] In less than 5 years
- [ ] 5–10 years
- [ ] 11–15 years
- [ ] In more than 15 years
- [ ] Never
- [ ] I don't know

On December 8th, Food without fields project will organize a workshop to develop the production methods examined in this survey. Due to the change in the corona situation the workshop will be organized as an online event only. Would you like to sign up to the workshop??

- [ ] I sign up for an online workshop
- [ ] I don't want to register for a workshop

If you wish to register for the workshop, please fill in your contact details below.
Registrants will be sent a Teams link to participate in the workshop on December 7th.
Contact information is only used for workshop arrangements.

Given name ______________________

Surname ______________________

E-mail ______________________

Other remarks ______________________

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Programme, December 8th, 2021

9.00–9.10	Welcome, Emilia Nordlund VTT
9.10–9.55	Presentations:
	Possibilities of cellular agriculture in feed and food production, Anneli Ritala VTT
	Protein plants for greenhouse production and their efficiency in vertical farming, Irene Vänninen Luke
	What attracts and concerns in new plant production methods and cellular agriculture?, Jarkko Niemi Luke
9.55–10.05	Break
10.05–11.10	Workshop, working in breakout groups
11.10–11.30	Summary and closing the workshop

Appendix 2. Participants enrolled in the workshop

SELECTED THEME/ PRODUCTION METHOD	PARTICIPANT	ORGANISATION
Greenhouse, Cellular agriculture	Heikki Aro	HKScan
Cellular agriculture	Elisa Arte	eniferBio
Greenhouse	Niina Kangas	Kauppapuutarhaliitto – Finnish Glasshouse Growers' Association
Greenhouse, Cellular agriculture	Anne Kivimäki	Medfiles
Greenhouse	Titta Kotilainen	Luke
Greenhouse	Janne Kruunari	Sataliina
Greenhouse	Arto Kujanpää	Hortimill
Greenhouse, Cellular agriculture	Jukka Kuoppala	alajarvi.fi
Cellular agriculture	Olli Kähkönen	Nordic Bioproducts
Cellular agriculture	Marja Nappa	VTT
Greenhouse, Cellular agriculture	Jarkko Niemi	Luke
Greenhouse, Cellular agriculture	Emilia Nordlund	VTT
Cellular agriculture	Markus Ojala	SeAMK
Cellular agriculture	Kari Ollikainen	Porlammin
Cellular agriculture	Riitta Partanen	Valio
Greenhouse	Matti Pastell	Luke
Cellular agriculture	Suvi Rajala	Sammatin tila
Greenhouse, Cellular agriculture	Merja Rehn	Metropolia
Cellular agriculture	Anneli Ritala	VTT
Cellular agriculture	Susanna Rokka	Luke
Greenhouse	Anna Tall	SeAMK
Greenhouse, Cellular agriculture	Auli Turkki	oulu.fi
Greenhouse	Hannu Uusihonko	Food Park
Greenhouse	Marjo Valtonen	SeAMK
Greenhouse, Cellular agriculture	Miia Viinamäki	Fazer
Cellular agriculture	Katriina Virtanen	DAVA Foods
Greenhouse	Irene Vänninen	sic.fi
Cellular agriculture	Ingmar Wester	Raisio
Greenhouse, Cellular agriculture	N.N.	
Greenhouse	N.N.	
Greenhouse, Cellular agriculture	N.N.	
Cellular agriculture	N.N.	
Cellular agriculture	N.N.	
Greenhouse	N.N.	
Greenhouse	N.N.	
Greenhouse	N.N.	

FURTHER INFORMATION

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