

Food Research and Innovation Strategy for Finland 2021-2035



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FOOD RESEARCH AND INNOVATION STRATEGY FOR FINLAND 2021-2035

A food research and innovation strategy was prepared for Finland. Change paths were defined towards a healthy and sustainable global food system that promotes wellbeing of individual and society and offers new economic growth opportunities for the Finnish food system actors based on scientific knowledge and food innovations.

The grand mission of the Finnish food research and innovation strategy is to position Finland as a key actor in the transition towards a healthful and sustainable global food system, which leads to economic growth and well-being of the people and society.

Four sub missions are defined towards 2035:

1. Healthy, safe, and sustainable diets are viable for all Finnish citizens.
2. Food and feed production in Finland is sustainable, competitive and resilient.
3. Resource efficiency and zero waste are key determinants in the Finnish food system.
4. Finland is a forerunner and leading testbed for sustainable food system innovations.

Research and innovation activities are central in developing an internationally competitive, sustainable Finnish food system and well-being from food, and thus, the up-to-date research strategy is critical for Finland. In the strategy work, the research goals and priorities were defined taking into account the new business and growth opportunities. Furthermore, the current characteristics of the Finnish food system together with its strengths, weaknesses, opportunities and threats (SWOT) were identified.

Finnish strengths include water resources and transparent food chain that is relatively short and easy to manage, and that is already renewed by the high tech and ICT expertise. Strong nutrition and food technology competence are also defined strengths for Finland. Recognized weaknesses are fragmented research, low critical mass, and lack of national research agenda, funding and cross-disciplinary research. Then again, Finland has several opportunities and knowledge in renewal of primary production and engaging citizens and information technology to the innovation processes. Regenerative agriculture, vertical farming, and biotechnical food production, capitalizing on water resources and new protein sources are examples of the opportunities for Finland. Role of data-based and digital solutions will become increasingly important, and they should be developed throughout the value chain to develop a uniform food system with new services. Agile food production systems, built also on circular economy -based solutions, facilitate reaching both zero waste and wellbeing targets. Furthermore, it's important to emphasize trustful research communication and dialogue about role of policies and legislation in renewal of food system. Active co-work and dialogue between cross-disciplinary experts, research organizations as well as stakeholders should be promoted.

As an implementation plan, we suggest to 1) establish a Finnish food research forum to promote food system related education and research and increase dialogue across disciplines 2) start a governmental, cross-ministry food research network, and 3) engage business actors through innovation ecosystems, for example, via Food & Beyond and the regional ecosystems that promote innovation activities to achieve improved efficacy of the Finnish research and infrastructure investments.

PREFACE

The strategy was prepared during the year 2020 in a participatory and collaborative process engaging actors and expertise across disciplines and organizations. The core group consisted of food scientists from VTT Technical Research Centre of Finland (VTT), National Resources Institute Finland (Luke), Finnish Institute for Health and Welfare (THL), Finnish Food Authority (Ruokavirasto) and University of Helsinki (UH), University of Eastern Finland (UEF) and University of Turku (UTU).

The aim was to revisit the strategic research agenda from 2011, made as part of the no longer operational ETP Food for Life Finland. Because the Finnish Graduate School on Applied Bioscience: Bioengineering, Food & Nutrition, Environment (ABS Graduate School) has ended as well, there is a need for a national level research networking platform to bring together food system researchers across disciplines.

Recent national and EU strategies were used as inputs during the process. These include the National Food Strategy Food 2030 from 2017, the research strategy for the Finnish food industry from 2018, and current government policy, as well as the EU policy initiatives and research and innovation strategies such as Green Deal missions, including the Farm to Fork Strategy from 2020.

During the work, several food researchers with diverse backgrounds provided input, either via an online survey or during task force break-out discussions. Various stakeholders, including representatives from Finnish food industries and government officials also participated in virtual stakeholder events.

We thank all the participants of the strategy process, which in itself was a fruitful dialogue among both the participating institutes and other food innovation system actors. We would like to acknowledge VTT for its financial support. We hope that the strategy will assist in defining necessary research actions and collaboration platforms towards a sustainable food system in Finland by 2035, and that Finland will be the pioneer for global gold standard for sustainability.

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GLOBAL AND EUROPEAN CHALLENGES IN FOOD PRODUCTION

The global food system is strained by extraordinary grand challenges triggered by a growing population with increasing demand for food and by climate change as well as loss of natural resources and biodiversity (Figure 1). The food system is responsible for one fourth of global greenhouse gas emissions. Half of the habitable land together with 70% of global fresh water resources go for agriculture, and more than three-quarters of this is used for livestock¹. Agriculture, including livestock production is the largest cause of biodiversity loss and ecosystem destruction. On a global scale, the food system has three major paradoxes:

1. too much food is wasted at the same time when we need more food
2. people are suffering from obesity while others are undernourished
3. natural resources are used inefficiently and unsustainably, too much for feed rather than food

Although EU agriculture managed to reduce global greenhouse gas (GHG) emissions² by 20% since 1990, a new target of 50% reduction by 2030 has been set with the new EU Farm to Fork Strategy³. A big challenge also in EU is the dependency of industrial livestock production on the human-edible crops, especially cereal grains and soy. Globally, 36-40% of crop calories are used for feed^{4,5,6}.

Planet earth has a dinner reservation for 10 billion people in 2050.



By 2050, human society will require two times the Earth's resources.

Figure 1. Global food system challenges.

The global food production system is inefficient; half of the food produced is either lost or wasted in various parts of the production system from farm to fork.

It is estimated that the current food volumes could indeed feed 11.5 to 16 billion people^{Error! Bookmark not defined.} if used efficiently. The sustainable growth and disruption potential lays in how we approach solving these food-related paradoxes. We have to find research and innovation paths enabling efficient and sustainable use of traditional and novel resources for food, protecting biodiversity, and reducing GHG emissions, freshwater consumption, and eutrophication. This needs to be done while

maintaining the core food elements of “nutrient content and sensory properties” and also addressing societal issues such as livelihoods of farmers and food producers and being responsive to societal values such as affordability, acceptability, and accessibility of healthy and sustainable food.

¹ <https://ourworldindata.org/environmental-impacts-of-food>

² http://www.fao.org/fileadmin/templates/wsfs/docs/Issues_papers/HLEF2050_Climate.pdf

³ https://ec.europa.eu/food/sites/food/files/safety/docs/f2f_action-plan_2020_strategy-info_en.pdf

⁴ <https://www.ciwf.eu/media/7435795/unea-4-achieving-sustainable-food-systems-january-2019.pdf>

⁵ Cassidy, E. S., West, P. C., Gerber, J. S., & Foley, J. A. (2013). Redefining agricultural yields: from tonnes to people nourished per hectare. Environmental Research Letters, 8(3), 034015. <https://doi.org/10.1088/1748-9326/8/3/034015>

⁶ Pradhan, P., Lüdeke, M. K., Reusser, D. E., & Kropp, J. P. (2013). Embodied crop calories in animal products. Environmental Research Letters, 8(4), 044044. <https://doi.org/10.1088/1748-9326/8/4/044044>

THE FINNISH FOOD SYSTEM

In 2019, the entire food sector (including agriculture, retail, the food and ingredient industry, and food services) produced more than 19 billion € of added value, being 7% of the total added value to the Finnish economy (Figure 2). From this, 3 billion € comes from the retail section, 2.9 billion from the food services sector, 2.8 billion from industry and 1.2 billion from agriculture. Also many other sectors in Finland are indirectly involved in food production by providing materials and services. The demand for intermediate products in the food sector generates a value added of EUR 5 billion for these other sectors. In practice, the effects of the food sector extend to all other sectors, including the manufacturing industry, transport, trade, energy production, and waste and water management.

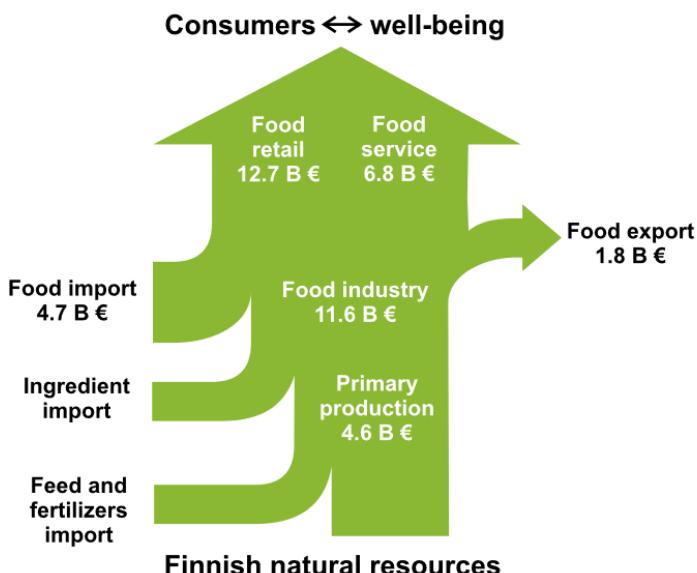


Figure 2. Inputs and outputs of the Finnish food system.

The labor force involved in the Finnish food sector is 320 000, which is 12% of the employed workforce in Finland. The proportion of agrifood products of Finnish exports is 2.4% and imports 7.9%. In 2020, Finnish agrifood product exports reached a record-breaking 1.8 billion euros. The domestic content of the food sector is still relatively high, 80%, considering production and import in euros.

PRIMARY PRODUCTION

There were 46 800 agri- and horticultural farms in Finland in 2019. Of these, 29% were mainly oriented towards animal production. Agricultural land covered 2 273 899 hectares, of which almost half was used for cereal production and one third was grassland for forage production. The 4 billion kg cereal production included 1.7 billion kg barley, 1.2 billion kg oats, 900 million kg wheat and 180 million kg rye. Potato was cultivated on 22 000 hectares and faba bean on 17 700 hectares.

Altogether 2 305 million liters of milk, 76 million kg of eggs and 400 million kg of meat were produced on animal farms. Milk production is decreasing by more than 1% annually, but meat production (especially poultry meat) is increasing by 3%⁷. Organic production is modest but increasing: in 2019 3% of milk, 1% of meat, and 3.6% of cereals (half of which, oat) were produced by organic farms. Almost half of agricultural income⁸ comes from livestock production, where the dairy sector is the biggest, also providing up to 85% of beef consumed in Finland. Horticulture (berries and vegetables, both in greenhouses and fields) constitutes about 20% of the agricultural income. The Finnish cereals sector is self-sufficient except for rye. Finland's cereal stocks are high in comparison to other countries. Finland has the highest export potential in oats. Special oat products in particular have good opportunities for the export market⁹.

⁷ https://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/161359/MMM_3_2019_Turvallista%20ruokaa%20Suomesta.pdf?sequence=4&isAllowed=y

⁸ Finnish agri-food sector outlook 2020. <http://urn.fi/URN:ISBN:978-952-380-095-3>

The global and European challenges are mostly valid for Finland as well. However, it has been forecast that climate change will induce significant changes in Finnish agriculture that can also be considered beneficial. It is predicted that the rising temperature will lead to longer growing seasons and increased precipitation, resulting in cultivated areas shifting northward, and opening potential for new crops and cultivars. Then again, it will also bring more uncertainty from extreme weather, new pests and diseases, and risks of erosion. Therefore, adaptation to the changing climate, and using all our potential to mitigate the effects of food production on global ecological stability as well as ensuring food security are the key challenges for future food research in Finland.

From a European and global perspective, Northern areas will be increasingly important for sustainable food production and food security in the future. For Finland, this creates opportunities to increase foodstuff exports significantly. However, at the moment, Finnish food production relies on imported inputs, like fossil fuels and inorganic fertilizers. There has been a declining trend in agricultural income during last two decades mostly due to challenges in adapting to the demanding operating environment after joining the European Union. The situation of primary producers within the food system has become weaker and they will need support to improve profitability in the form of new skills and technologies, innovations, and specialization.

THE FOOD INDUSTRY

The food industry in Finland employs approximately 38 000 full-time personnel in nearly 1800 enterprises. The sector is dominated by micro-enterprises which mainly provide employment opportunities for seasonal work. The value of the food industry output was EUR 11.6 billion in 2019, showing an increase of 2.1 % on the previous year (Fig 2)^{9,10}. The value-added of the food industry, EUR 2.8 billion, increased by 3.6% from the previous year. In addition, food exports amount to EUR 1.6 billion (Figure 2). The food industry is Finland's largest manufacturer of consumer goods, providing sales to retail, wholesalers, food services, and other food businesses as well as directly to consumers. The Finnish food industry is diverse and includes processing of dairy, meat, fish, vegetables, berries and fruits, as well as manufacturing of cereal products and beverages. Activities are guided by environmental and nutritional awareness as well as responsibility. Carbon neutrality is seen in the food industry as a success factor that increases the value of food¹¹.

NUTRITION AND HEALTH

Along with environmental challenges, we still face several health challenges (Figure 3) at the population level that are tightly related to our lifestyles, including food choices. Thus, it is evident that via targeted changes in the food system we may reach or enable health benefits at the population level. In 2017, 26% of men and 28% of women were obese ($BMI \geq 30 \text{ kg/m}^2$) in Finland¹². Despite the national nutrition recommendations¹³ and followed implementation actions to increase the awareness and acceptability of healthy eating and food choices, the eating patterns are not yet optimal^{14,15}.

⁹ Statistics Finland. National Accounts, Income and production by sector and industry, annually, 1975-2019.

¹⁰ https://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/162570/TEM_2020_2_T.pdf

¹¹ https://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/162851/TEM_2021_9.pdf?sequence=1&isAllowed=y

¹² <https://thl.fi/en/web/thlfi-en/-/familiar-health-problems-still-common-in-finland-but-positive-development-is-also-apparent>

¹³ <https://www.ruokavirasto.fi/en/themes/healthy-diet/nutrition-and-food-recommendations/adults/>

¹⁴ <https://thl.fi/en/web/thlfi-en/-/adults-diet-is-far-from-the-recommendations>

¹⁵ https://www.julkari.fi/bitstream/handle/10024/137433/Raportti_12_2018_netti%20uusi%202.4.pdf?sequence=1&isAllowed=y

The main outcomes of the National FinDiet 2017 survey¹⁶ showed that Finnish adults eat too little vegetables, fruit and berries, and too much red and processed meat. For example, it is recommended that Finns should eat 500g/day of fruits, berries and vegetables (excluding potato), while the current amount eaten is some 200-300 g/day depending on gender. This would mean annual increase of 50 kg/year/capita to reach 185 kg/year/capita. Consequently, the availability of fruits, berries and vegetables needs to be secured by import as well as increased domestic production, to be achieved by adapting efficient harvesting and farming technologies including agricultural robotics. A marked observation was that men's and women's diets are increasingly different, men's diets being worse than women's. Attention should especially be focused on the nutritional quality of dietary fats, carbohydrates, and protein¹⁷. However, beneficial outcomes included dietary changes which support sustainability as well as increased intake of both dietary fibre and vitamin D and reduced intake of sucrose. The food consumption data of children, adolescents, and elderly is lacking in Finland.

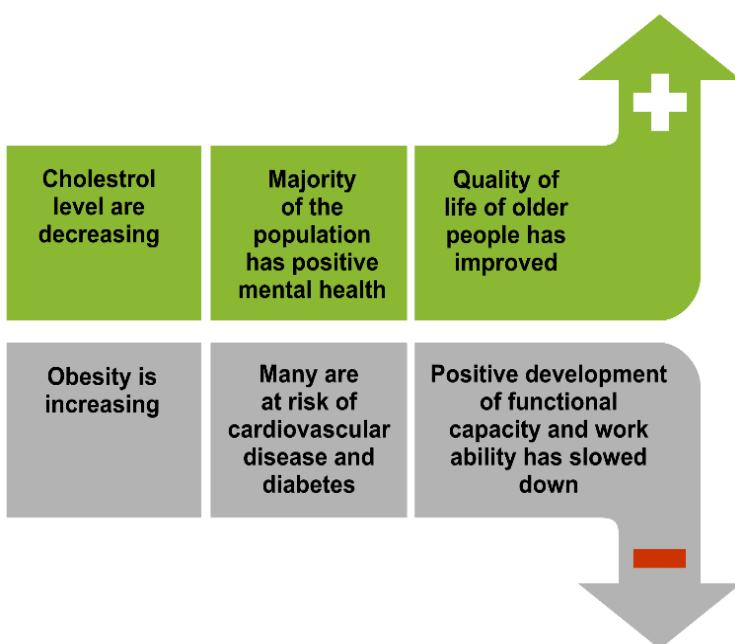


Figure 3. Major health issues based on Finhealth study.

healthier and sustainable nutrition and diets. There is currently a consumption trend towards healthy eating and sustainability among consumers. It is of note that consumption trends have significant effects on domestic food production. It is predicted that by 2035, the consumption of red meat will decrease by 20% whereas the poultry consumption will increase by 20%. Dairy consumption is expected to reduce by 10 - 15%¹⁹.

The nutritional recommendations go hand in hand with reducing the environmental impact of food production. It is expected that this approach will be strengthened in the current update process of the Nordic Nutrition Recommendation. New Nordic Recommendations are expected during 2022, forming the basis for the Finnish Nutritional Recommendations. For example, it has been estimated that the climate impact of Finnish diet can be reduced by 30–40% with dietary changes and taking care of field carbon storage, if average meat consumption is reduced to one third¹⁸. Therefore, it is of great importance to narrow the knowledge gap in the nutritional value of food and the impact of different diets on climate change. Moreover, food and nutrition research should focus on enabling a justified and facilitated transition towards

¹⁶ Valsta, L., Kaartinen, N., Tapanainen, H., Männistö, S., & Sääksjärvi, K. (toim.). Ravitsemus Suomessa – FinRavinto 2017 -tutkimus. Terveyden ja hyvinvoinnin laitos (THL). Raportti 12/2018, 239 sivua. Helsinki 2018.

¹⁷ <https://www.slideshare.net/THLfi/finravinto-2017-tutkimuksen-tulokset>

¹⁸https://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/161742/VNTEAS_47_Ruokavaliomuutoksen%20vaikutukset.pdf?sequence=1&isAllowed=y

¹⁹ [https://www.mtk.fi/documents/20143/0/Kalvot+Maatalouden+ilmastotiekartta+Lehtonen+150720 +%281%29.pdf/e8e30157-b3b4-78b0-bd5d-d6e0aac44d32?t=1594791165107](https://www.mtk.fi/documents/20143/0/Kalvot+Maatalouden+ilmastotiekartta+Lehtonen+150720+%281%29.pdf/e8e30157-b3b4-78b0-bd5d-d6e0aac44d32?t=1594791165107)

FOOD SYSTEM TARGETS IN FINLAND

The Finnish food research and innovation strategy supports sustainability, nutrition and economic growth targets set for the Finnish food system in recent national and EU-level strategies (Table 1). The core interest in these strategies is in environmental sustainability. In line with the global sustainable development goals and current European Farm to Fork Strategy, Finland should be a pioneer in achieving a global standard for sustainability to protect nature, resources, and ecological diversity. Environmental values are also highly ranked in the preferences of Finnish consumers, who value local, ethically grown, minimally processed and sustainable food²⁰. Health is also an important part of overall sustainability. Thus, the Finnish food research and innovation strategy puts a strong emphasis also on health and well-being. National nutrition recommendations based on the Nordic Nutrition Recommendations have been built along the sustainability principles of food production. Consumer choices are among the key components needed to build up a sustainable food system. According to a recent consumer study made by Eurobarometer, the five most important criteria when consumers purchase food were taste, geographical origin, nutrient content, safety, and cost²¹. Understanding consumer viewpoints is thus critical, and we need to support healthier and affordable choices via effective research to support policy makers also from a health point of view.

Table 1.Finnish food system related targets.

Target and link to original report	Set by
<u>Halve the food waste by 2030</u>	EU, agreed in Finland
<u>Carbon-neutral Finland by 2035</u>	Government
<u>16% less GHG emissions compared to 2005 levels</u>	Government
<u>Double the value of Finnish food exports to 3 billion euros by 2025</u>	Business Finland
<u>Carbon footprint targets to reach 2.5 (tCO2e) in 2030, 1.4 by 2040 and 0.7 by 2050 per person</u>	Sitra
<u>More vegetables, fruit and berries: increased to 500g/day*</u> <u>More dietary fibre in diets: 25-35 g/day - cereals as whole grain, increase the consumption of vegetables, berries, and fruits *</u> <u>Less salt, saturated fats, added sugar, red and processed meat*</u>	Finnish Food Authority

* targets are for adults

²⁰ Salmivaara, L. (2019). <https://helda.helsinki.fi/bitstream/handle/10138/317757/THESIGNI.pdf?sequence=1&isAllowed=y>

²¹ <https://ec.europa.eu/commfrontoffice/publicopinion/index.cfm/survey/getsurveydetail/instruments/special/surveyky/2241>

PREVIOUS EUROPEAN AND FINNISH RESEARCH STRATEGIES AND PROGRAMMES

There are numerous reports and strategies on food and nutrition made by various research organizations or the European Commission as well as some other actors (Table 2). Similarly, there are many strategy documents outlining the goals of the Finnish food system from different perspectives (Table 3). The Farm to Fork Strategy is at the heart of an EC priority area, the European Green Deal, and aims to make food systems fair, healthy, and environmentally friendly. The sustainable European food system should have a neutral or positive environmental impact; help to mitigate climate change and adapt to its impacts; reverse the loss of biodiversity; ensure food security, nutrition and public health, making sure that everyone has access to sufficient, safe, nutritious, sustainable food, and preserve affordability of food while generating fairer economic returns, fostering competitiveness of the EU supply sector and promoting fair trade²².

One of the key targets set by Ministry of Agriculture and Forestry report Food2030 is to have Finnish consumers eat sustainably and ethically produced domestic, tasty, healthy, and safe food by 2030. Moreover, the Finnish Food and Drink Industries Federation states that an “innovative and responsible Nordic food production enables a competitive food industry and consumer well-being, both in Finland and globally” by 2025. All these strategies and roadmaps briefly summarized in Tables 3 and 4 have given inspiration and valuable input to the current strategy process.

Table 2. European and FAO food research and innovation strategies and roadmaps.

Organization	Name
European Commission	<u>Horizon Europe</u>
European Commission	<u>A Farm to Fork Strategy for a fair, healthy and environmentally-friendly food system</u>
European Commission	<u>Bioeconomy policy FOOD 2030</u>
FoodDrinkEurope	<u>European Technology Platform (ETP) Food for Life</u>
European Institute of Technology	<u>EIT Food</u>
Public-private partnership of European Union and Bio-based Industries consortium	<u>Bio-Based Industries Joint Undertaking (BBI-JU)</u>
European Commission	<u>Joint Programming Initiative (JPI) Agriculture, Food Security and Climate Change (FACCE)</u>
European Commission	<u>Joint Programming Initiative (JPI) Healthy Diet for a Healthy Life</u>
European Commission	<u>One Health European Joint Program</u>
FAO - Food and Agriculture Organization of the United Nations	<u>The future of food and agriculture – Alternative pathways to 2050</u>
Nordic Council of Ministers	<u>Megatrends in Nordic Baltic Food Systems</u>

²² https://ec.europa.eu/food/farm2fork_en

Table 3. Strategy reports dealing with the Finnish food system.

Government	<u>Government programme</u>	2019
	<u>Food 2030</u>	2017
	<u>Ministry of Economic Affairs and Employment report on food sector</u>	2020
	<i>Sitra various reports on:</i>	
	<u>Megatrends</u>	2020
	<u>Opinion on the EU's Field to Table strategy</u>	2020
	<u>New strategy out now</u>	2020
	<u>Cities and circular economy for food</u>	2020
	<u>Food industry strategy report 2018</u>	2018
	<u>Food industry strategy report 2020</u>	2020
Industry	<u>Food from Finland programme</u>	
	<u>Business Finland Scenarios 2019</u>	
	<u>Agricultural climate road map</u>	2020
Research	<u>Food Economy 4.0</u>	2017
	<u>Critical Success Factors of the Finnish Food Chain, in Finnish)</u>	2017
	<u>Digitalization in the development of the food chain (in Finnish)</u>	2017
	<u>Arctic Food Production</u>	2015

FINNISH FOOD RESEARCH AND INNOVATION STRATEGY (2021-2035)

AIM OF THE STRATEGY

The aim of the Finnish food research and innovation strategy is to position Finland as a key actor in the transition towards a healthy and sustainable global food system and to simultaneously create new economic growth opportunities based on scientific knowledge and food innovation for the Finnish food producers and the food industry. The strategy was prepared during 2020 in a participatory and collaborative process, engaging actors and expertise across disciplines and organizations. The process is described in detail in Appendix 1.

The starting point of the strategy work was to provide a holistic view from the social sciences and humanities, business and technology, health and natural sciences on aspects of food production and consumption. This illustrates these aspects and identifies the contributions of different disciplines to food research. The two inner layers of the figure, connecting people and food systems, are at the core of food research. External perspectives, such as business models and strategies, values, public and planetary health, environmental issues, and developments in process and digital technologies, are not usually considered as core parts of food research. However, as these factors condition and influence in many ways the development of food systems, it is important to explore the systemic interactions between them and food systems as part of a food research strategy.

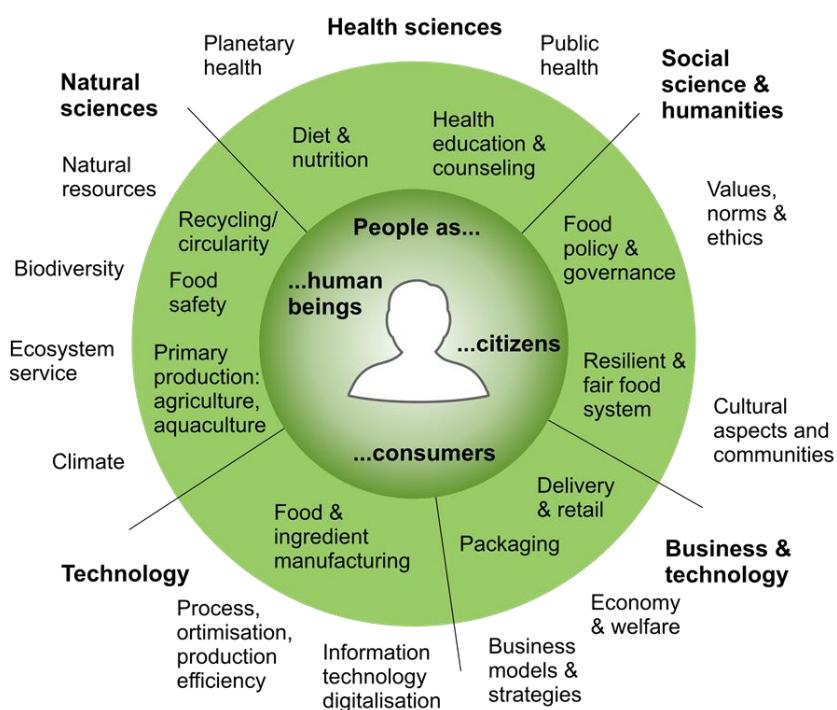


Figure 4. Research perspectives for the food research strategy development.

STRENGTHS, WEAKNESSES, OPPORTUNITIES, AND THREATS TO THE FINNISH FOOD SYSTEM

A SWOT analysis was made with various food system stakeholders to identify the ability of the Finnish food research system to contribute to the transition towards a more sustainable and healthful food system (Table 4). The SWOT was further utilized to define the missions and their research contents.

Among the strengths, Finland has recognized expertise in food, nutrition, and ICT in agriculture where research activities support industry needs. There is also good communication between research and innovation actors.

Fragmented research initiatives, difficulty in building critical research mass, and a lack of interdisciplinary research are some of the weaknesses of the Finnish food system. Public communication of science is not strong in Finland, while the lack of trust in science is increasing.

There are several opportunities identified for the Finnish food research and innovation system. In order to move towards sustainable food production, new ways of production including, for example, vertical food production and regenerative agriculture is a prerequisite. During this systemic transition we should develop an understanding of the socio-economic impacts of these new production methods from the perspective of consumer, safety, the environment, and business opportunities. New value creation through clean water resources and green capital are also essential. Development of new healthy and sustainable food and feed from Finnish raw materials such as underutilised fish rapeseed, faba beans, and oats will support the achievement of protein self-sufficiency also on the EU level. While developing new ingredients and foods, we have to close the knowledge gap between nutrition, health effects, and climate impact. Platform economies based on data and digitalization can be utilised not only to track and ensure food safety, authenticity, and traceability, but also to enable individualised food production and delivery. Substantiating the sustainability and climate effect of food products and processes is essential and will provide opportunities to influence consumers' decision making towards more environmentally friendly and sustainable food solutions.

The major threats that were identified included fragmented initiatives and lack of critical mass in research expertise, inadequate national research funding, and misalignment between research strategies and policies.

Table 4. SWOT analysis of the Finnish food system

Strengths	Weaknesses
<ul style="list-style-type: none"> • Recognized knowledge in food and nutrition • Top-notch ICT knowledge within the field of agriculture • Research activities support industrial needs, good communication between research and companies. • High education level leads to active engagement and positive attitude towards science among citizens • Food chain in Finland is short and quite easy to manage. • Safe and transparent primary production. • Animal health and welfare standards are high. • Abundant amounts of clean water and environment • Small country with trust between the different actors in food chain with opportunities to focus on the key issues and act as testbed. • Consumers are open to test new food related solutions. • Policy makers and government recognize circular economy to make Finland forerunner. 	<ul style="list-style-type: none"> • Fragmented initiatives, working in silos, lack of research harmonization • Difficulty to build critical mass in research expertise due to lack of research area focus. • Food related data harmonization, sharing and utilization • Lack of interdisciplinary approach including human sciences and arts, too much focus only on technology - lack of knowledge on consumer and user-oriented value creation. • Lack of public scientific communication • Inadequate funding for research, innovation, infrastructure and go-to-market activities
Opportunities	Threats
<ul style="list-style-type: none"> • New production methods, e.g. vertical food production, cellular agriculture • Research and development in regenerative agriculture • Consumer interest towards local and sustainable foods • Substantiating sustainability and climate effect of food products and processes. • Adaptation/ Positive climate change for Finnish agriculture • Systemic smart technology approaches to cut down agrifood waste and losses • Big data as tool for development and innovation • Collaboration between various regional food ecosystem players and Finland as testing ecosystem for (international) companies for new ideas, products and solutions • Cross-disciplinary research environment catalysing the innovations • Use of public food procurement to support new innovations and sustainability • Green capital and value creation through clean water resources 	<ul style="list-style-type: none"> • Fragmented research • The attitude of being defensive instead of taking a step for renewal • Farmers unengaged to research, need for farmer incentives • No implementation of the joint vision • Focusing only on hot topics (guided by funding opportunities) and missing the opportunities to develop disruptions • Lack of climate/shock resilience • Loss of resources in domestic competition • Lack of trust towards data sharing. • Current Covid-19 and associated economic crisis • Policies and research strategies do not align. • Regulations risking the opportunities, e.g., environmental regulations risking domestic climate-friendly fish production. • Climate change and decrease in biodiversity will increase risk of foodborne zoonoses and also new emerging infectious threats.

MISSIONS OF THE FOOD RESEARCH AND INNOVATION STRATEGY

The grand mission of the National Food Research and Innovation strategy is to make Finland a global standard for a healthy and sustainable food system which leads to economic growth and to wellbeing of the society.

Four sub-missions towards 2035 form the foundation of the strategy which are:

1. Healthy, safe, and sustainable diets are viable for all Finnish citizens.
2. Food and feed production in Finland is sustainable, competitive, and resilient.
3. Resource efficiency and zero waste are key determinants in the Finnish food system.
4. Finland is a forerunner and leading testbed for sustainable food system research and innovations.

MISSION 1: HEALTHY, SAFE AND SUSTAINABLE DIETS ARE VIABLE FOR ALL BY 2035

Background: Food environment is currently in strong transition both at the system and consumer levels (Figure 5). This sets demands for the food system to provide feasible, palatable, healthy, safe, and sustainable food choices for the consumer to maintain and support their health and well-being from birth to old age. On the other hand, consumers need to be motivated to make more sustainable and healthful choices. It is clear that more research combining expertise in nutrition, food technology, and behaviour is needed to support nutritionally high-quality food choices (Figure 4). In addition, the impact of research-based actions needs to be measurable and solutions created to be cost-efficient. For these purposes, valid indicators need to be developed to support policy makers.

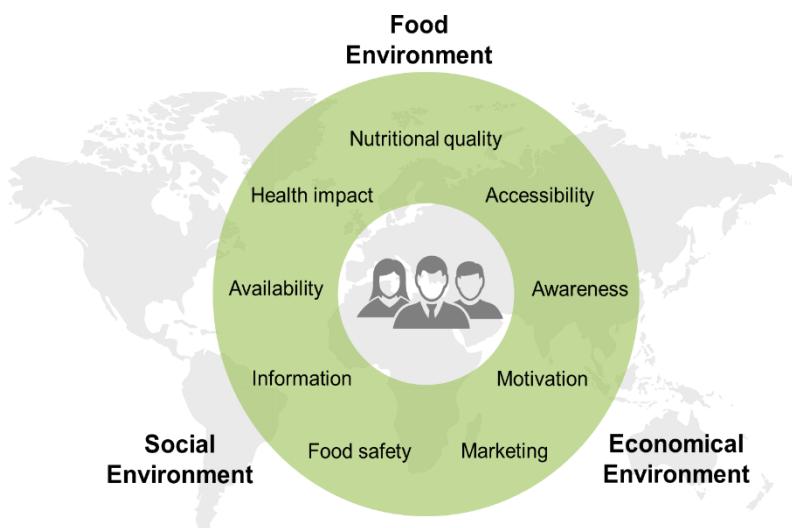


Figure 5. Levels of environment and environmental factors where individuals make the food and other lifestyle related choices.

Focus areas of research: There are three high-priority research areas recognized by the stakeholders, closely linked to the individual: 1) physiological and health responses; 2) food and health technology; 3) food, environment, and education.

Physiological and health responses: There is a demand to increase the consumption of plant-based food by all population groups, despite its largely unexplored nutrient bioavailability. Consumption of plant-based foods supports overall health and wellbeing, but we are far from understanding the health effects of new sources of food, and those meant to replace

animal-based foods. There is urgent need for research on the bioavailability and capability of these foods to support childhood growth and development as well as maintenance of physical and cognitive performance. Since many of the health impacts seem to be mediated via their interaction with microbiota, immune system, inflammation, and gut barrier function, these topics warrant thorough research from mechanisms to clinical applications. Research and knowledge on individual and group-level responses have great additional value to support individual physiological needs.

Technology: Research is needed to understand how promotion of health and wellbeing could be more efficiently supported via food and health technological advances. The rapid development of food technologies and personalized eating concepts together with moving towards a data-driven era must be holistically researched to reach good nutrition and sustainability. There is also a need to investigate the nutritional potential of alternative protein and food sources (e.g. new plants, microbial and insect-based) as high-quality and safe foods for humans, as well as to study the agrifood chain side-streams.

Food environment and education: How to translate the on-going transition clearly, understandably, and equally for all consumers is a key question. More research is warranted on education, choice architecture, and communication actions that efficiently and equally increase awareness and accessibility to nutritionally superior and environmentally friendly foods and diet. There is an urgent need to create science-based solutions and food environments to facilitate and motivate consumers towards healthier food choices and eating patterns from youth to old age.

Key focus points for Finland:

- increase understanding of food consumption, dietary patterns, and dietary intake in relation to health in vulnerable population groups, e.g. in children, adolescents, and the elderly
- focus on gut microbiota and gut barrier function, the immune system, and inflammation in mediating the health impact of food
- address role of food and digital technologies and choice architecture in promoting and enabling healthful eating
- investigate the variability in physiological responses and examine predictions for individual variability by using machine learning and data science

MISSION 2: FOOD AND FEED PRODUCTION IN FINLAND IS SUSTAINABLE, COMPETITIVE AND RESILIENT.

Background: The effects of climate change on agricultural production are currently highly uncertain; variable weather conditions with extreme events will challenge stable food production (Figure 6). Therefore, we must mitigate the negative environmental impacts on production and find resource-efficient and resilient solutions leading to secure, novel, competitive, and zero-emission food and feed production. Food safety and sustainability should form the basis for competitiveness of Finnish products also for export in the future.

Focus areas of research: The high-priority research areas for climate-smart food production are: 1) resilience and food security; 2) environmental sustainability; 3) just and sustainable transition.

Resilience and food security: Sustainable agriculture and aquaculture systems are prerequisites for continued food and nutritional security. Agriculture, aquaculture, forestry, and horticulture should be integrated into the Systemic One Health approach. Resilient food production will require research to improve resource use efficiency and resilience to biotic and abiotic stresses, as well as development of renewable fossil-free fertilizers and biostimulants. Solutions are needed to increase yield per input as well as protein

and nutritional quality, while reducing the environmental and ecological footprint of primary production. Genome editing should be accepted and taken into use as an important tool for breeding (plants and micro-organisms) towards improved climate change resilience. Basic research is needed for new production technologies and innovations (e.g. vertical farming, cellular agriculture) as well as traits conferring resilient plants and algae for novel food and feed sources. Digital solutions should be developed for transparency and precision production.

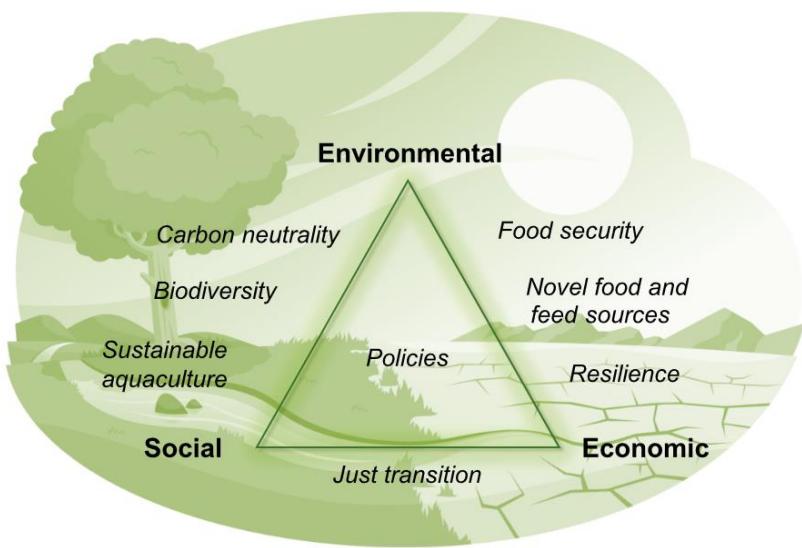


Figure 6. The research priorities to combat challenges in sustainable food production.

aquaculture practices will enhance and preserve biodiversity and food security. Development of indicators and use of tools for managing biodiversity and preserving soil health, including agroforestry and regenerative agriculture, will increase resilience to climate change and promote plant, animal, and human health. Research should be targeted towards reducing GHG emissions, fossil fuel dependency, and nutrient losses at all steps in agri- and aquaculture as well as enhancing carbon capture and storage in the soil. Further development of indicators for assessment of traditional and novel production methods and products is needed.

Just and sustainable transition: A just transition to sustainable food production necessitates inter- and transdisciplinary research. The role of the social sciences should be further strengthened in the analysis of socio-economic drivers and the governance of sustainable production. Research attention should be directed towards effective, coherent and transformative policy means and strategies that can enable a sustainable and just transition. Food system analysis is needed to understand better the interplay between various food chain activities (from consumption to processing and production) as well as between public and private measures in transition. Research on up-scaling of sustainable production methods and products is of critical importance for resilience and competitiveness.

Key Focus points for Finland:

- sustainable land and water use including aquaculture
- increasing profitability and resilience (of primary production), assuring security of supply, reduction of import of required inputs, transparency with digital solutions
- added value from Nordic hemisphere in primary production for branding and increasing export

MISSION 3: RESOURCE EFFICIENT AND ZERO WASTE ARE KEY DETERMINANTS IN THE FINNISH FOOD SYSTEM BY 2035

Background: Prevention of food loss and ensuring material efficiency of food systems are of global as well as national importance in promoting a circular economy. To achieve this, Finland needs to intensify public-

private partnerships regarding new ideas, transfer of knowledge and exploitation of both existing and new technological solutions. Simultaneously, it is of importance to engage the consumers as well as the political actors to fully realize the environmental and societal impacts of the actions.

Focus areas of research: Three national high priority research areas have been recognized: 1) resource efficiency, 2) packaging and supply chain, and 3) societal impact.

Resource efficiency: The action of main importance is the identification of gaps in the agrifood system by focusing not only on nutrient recycling but also on energy efficiency and water and land use. This

Figure 7. Priority research areas to achieve resource efficiency and zero waste.

requires an ecosystem-level approach, and both quantitative and qualitative mapping of the streams in the whole value chain. This action needs to be followed by valorisation of the waste- and side streams with innovations aiming for higher material hierarchy as well as for new integration. Technology development, including industrial biotechnological and data-driven solutions, smarter use of existing technologies, novel production methods (e.g. vertical farming, cellular agriculture) and crops (e.g. faba bean for protein) as well as adopting technological solutions from other fields, are important means to support the achievement of resource efficiency. Food safety, authenticity, and traceability should be of key importance when developing new food products. The challenges of the novel food regulations ensuring safe foods and food ingredients should be overcome. Moreover, national self-sufficiency and both regional and national origin of raw materials should be valued. **Packaging and supply chain:** Bio-based intelligent packaging using agro-industrial by-products should be further developed. Know-how for future development of regulations regarding food contact material from the food safety perspective is a necessity. Actions should also be targeted towards development of package information to better enable consumers to favour sustainable choices. In addition, packaging recycling and delivery solutions with optimized logistics and digitalized systems are needed.

Societal impact: Business opportunities including side-stream valorisation, food services, digital solutions, and recycling should be among the actions for societal impact. Modelling system-dynamic tools, e.g. to match the piling up of resources and business opportunities within a certain region are needed. It will be of importance for these actions to be facilitated by motivating consumers and citizens through education and engagement, and by new pricing and investment policies that favour zero waste solutions and sustainability in general.

Key focus points for Finland:

- Development of a digital platform of waste- and side-streams from the (domestic) food value chain
- New circular economy concepts based on cross-sectorial strengths that improve existing technologies but also integrate disruptive technologies

MISSION 4: FINLAND IS A FORERUNNER AND LEADING TESTBED FOR SUSTAINABLE FOOD SYSTEM RESEARCH AND INNOVATIONS BY 2035.

Background: Food systems require systemic change, where all food actors, including researchers, companies, and citizens, should be engaged in joint activities. To facilitate systemic and behavioural change, enabled by innovations, multidisciplinary is a key (as illustrated in Fig 4). Combining technology and natural sciences with human-social sciences to empower food system research in Finland as well in Europe is needed more than ever for the generation of innovations. Finnish citizens are willing to participate in research and our supply chain is rather short and easy to manage; these are great assets for Finland to serve as a testbed, globally.



Figure 8. Triangle of the Finnish research and innovation ecosystem, combining the priority areas for work in Mission 4).

Focus areas of research: Three high-priority research areas were recognized to create the triangle of the research and innovation ecosystem: 1) systemic transformation; 2) engaging citizens and co-creative activities; 3) sustainable business creation (Figure 8).

Systemic transformation: There is a need to boost disruptive innovations and systemic change. This requires both high-tech and soft innovations, and raising interest globally for investment into Finnish RDI. Systemic transformation substantially influences the whole society; understanding economic, cultural and social effects is

a prerequisite. More knowledge on how the transition of food production influences diets is also needed. Digitalization is a key driver for systemic change and the efficient use of transparent, traceable, and secured data from farm to fork should be ensured and developed. Related to a data-driven food system, in order to promote behavioural change, an agile food production system employing innovative and personalized solutions that support human well-being and sustainable food choices is very important.

Engaging citizens and co-creative activities: Engaging citizens and consumers in the innovation ecosystem will facilitate the implementation of innovations. Empowering communities towards systemic change is also very important. Co-creative tools to increase consumer and community engagement should be developed. There is a call for innovative nudging activities to promote individuals towards sustainable choices. The impact of food education for children and adults should be studied more efficiently and applied to society.

Sustainable innovation ecosystem and business creation: Solutions and knowledge on how to create responsible business and new business models should be studied in the context of sustainability and to boost

export of Finnish innovations. New financing instruments should be used to engage global funders to invest in Finland. Collaboration between researchers, companies, start-ups, and accelerators should be boosted. Competitive marketing and branding tools need to be developed. A cornerstone for sustainable business creation is to develop sustainable and health-promoting food products that are accepted by consumers.

Key focus points for Finland:

- Developing data-driven food systems that apply a Finnish farm to fork chain that is transparent, short, and easy to manage
- Engaging citizens and various actors in research and innovation by taking advantage of the common willingness of Finns to participate in research and to test new solutions.
- Boosting an interdisciplinary approach that connects the humanities and arts to technology and science to fill the gap between consumer-oriented knowledge and the feasibility of food and eating solutions.

IMPLEMENTATION PLAN

Research and innovation activities have an important role in developing an internationally competitive, sustainable Finnish food system that generates wellbeing for the people and society. As indicated earlier, skills of many disciplines need to be combined, and there is a need not only for better coordination and awareness between distinct research programs involving different R&D actors, but also for communication of policies and national targets among different government actors and research community members. The food system transition will need to meet the challenges of sustainability, economic growth, food security, and well-being at the same time. Data and digital solutions are becoming increasingly important and should be developed from farm to fork for an integrated and transparent food system.

To achieve improved efficacy for Finnish research investments in food systems, we suggest the following actions of implementation:

Establish a Finnish Food Research Forum

- Develop a shared vision for food system transformation
- Promote researcher training and dialogue across disciplines and organizations
- Identify new opportunities for cooperation within the food sector to generate and support innovations.
- Organise workshops to engage actors to the transformation targets for the Finnish food system and multidisciplinary research needs, as well as to communicate research results, in order to catalyse communication between research, government and business actors.
- Create visibility and influence food system transformation through white papers and opinion papers in national and international forums.
- Coordinate the development and use of food and nutrition research infrastructures in Finland to foster innovation and implement research and to be compatible and integrated into European and international infrastructures.

Start a governmental food network

- Communicate and discuss European Union's and Finnish policies, regulations, and targets in a coordinated, direct and timely manner across various ministries and research actors.

- Consider and define joint actions among the Nordic countries, especially with respect to a common Nordic agenda on food systems.
- Initiate dialogues on setting-up a new funding mechanism (across ministries and/or industry) to secure resources towards a critical research mass for solving the most important Finnish food system challenges.

Establish a network of business ecosystems

- Develop current ecosystems (Food & Beyond (Create Platform, Protein Cluster), Food Valley, Flavoria Research Platform, Viikki Food Innovation Lab) into a nationally coordinated activity for generation of innovations and new businesses.
- Organise a series of match-making events under existing ecosystems and forums.
- Utilise innovation ecosystems to raise industry interest towards new research topics (e.g., cellular agriculture, protein crops, insects) and create business from research via incubating start-up companies and supporting their growth (EIT FAN Helsinki Hub, Viikki Food Innovation Lab).

FINAL WORDS

The time is now ripe for a change in the food system. The future of food lays in successful research, collaboration, and demonstration of new innovations. Finland could be a key actor in the transition towards a healthy and sustainable global food system, and also benefit from the concurrent economic growth opportunities.

The Government report on food policy Food 2030 set, in 2017, a vision for Finland: "*The best food in the world. In 2030, Finnish consumers eat tasty, healthy and safe Finnish food that has been produced sustainably and ethically. Consumers have the ability and possibility to make informed choices. A transparent, highly skilled, flexible, internationally competitive and profitable food system that responds to demand. The growth and advancement of the sector are supported by well-coordinated, high-level research, development, innovation and teaching. There is a high level of marketing and communication skills in the sector. Finland is a significant exporter of high quality and safe foodstuffs and food sector skills.*"

After that, in 2018, The Finnish Food industry defined the vision that "*Innovative and responsible Nordic food production enables a competitive food industry and consumer well-being, both in Finland and globally.*" Four research themes were then identified: 1) resource-efficient Nordic food production, 2) digital food consumer services, 3) innovative production technologies and 4) food that is proved to increase well-being. One of the objectives was in increasing the interaction between research areas and developing high-quality food research environments.

In September 2020 Sitra, in its commentary on the EU Farm to Fork strategy, encouraged Finland to strongly address the remarkable economic opportunities associated with a sustainable food system. Sitra also pointed out the rapid transformation on-going in the food sector, leading to opportunities of Finnish plant-based ingredients and alternative protein sources.

We do hope that the analyses, research priorities and implementation plans described in the current report will assist in more efficient, better focused, and influential research activities towards achieving a sustainable food system transition. While pursuing excellence, different scientific disciplines should communicate and collaborate in a synchronized way. Research, government, and business actors should work together for the common goal of making Finland a model for a sustainable and healthy food system. This would be for the benefit of agriculture, business, society, and consumers.

APPENDIX: THE STRATEGY PROCESS AND PARTICIPANTS

The Finnish food research strategy was prepared in a participatory and collaborative process aiming to engage a broad range of actors across disciplines and organisations to provide their input for the defined goals and priorities. The strategy process steps are summarized in Figure 9. Invitations to the kick-off meeting for the strategy work were made by VTT on January 23rd, 2020. During that meeting, a strategy core group gathering expertise from diverse scientific disciplines and from various research organizations including VTT, National Resources Institute Finland (Luke), University of Eastern Finland (UEF), University of Helsinki (UH), University of Turku (UTU), National Institute for Health and Welfare of Finland (THL) and Finnish Food Safety Authority (RUOKAVIRASTO) was formed.

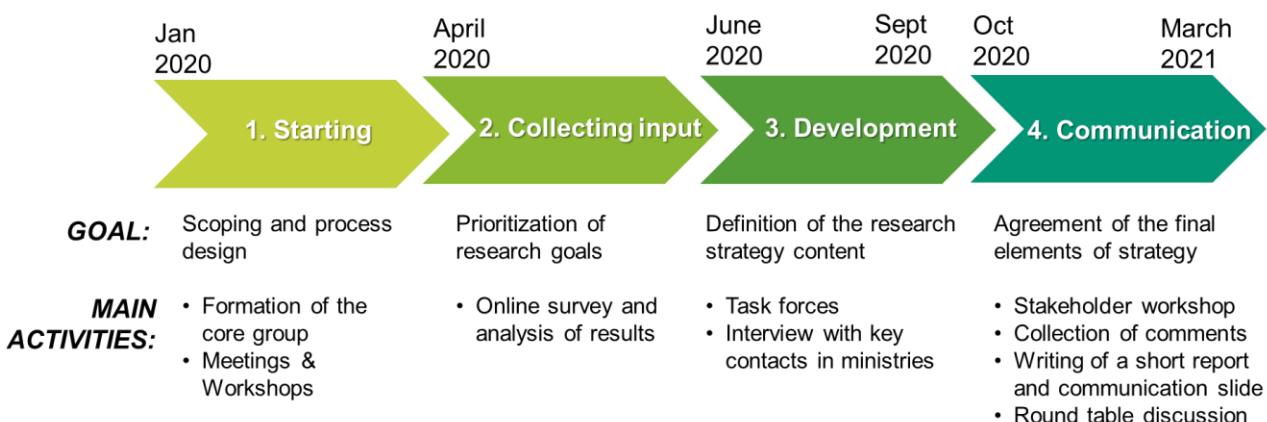


Figure 9. Finnish food research and innovation strategy process steps

In the second core group meeting in March 2020, we concretised and prioritised the future food research priorities for Finland, started the mapping of the strength and weaknesses of the Finnish food system, and organised four thematic task forces:

Theme 1: Healthy, safe and sustainable diets, leaders Marjukka Kolehmainen (UEF) and Susti Virtanen (THL)

- List of participants:** Jenni Korhonen (UEF), Heli Kuusipalo (THL), Kirsi Laitinen (UTU), Elina Mattila (VTT), Anne-Maria Pajari (UH), Merja Saarinen (Luke), Natalia Rosa-Sibakov (VTT).

Theme 2: Climate-smart food production, leaders Johanna Vilkki (Luke) and Liisa Maunuksela (RUOKAVIRASTO)

- List of participants:** Eva-Mari Aro (UTU), Minna Kaljonen (Syke), Tuure Parviaainen (VTT), Alan Schulman (Luke), Hanna Tuomisto (UH).

Theme 3: Circular and resource efficient food systems, leaders Marina Heinonen (UH) and Baoru Yang (UTU)

- List of participants:** Ali Harlin (VTT), Anu Kaukovirta (Luke), Hanna Koivula (UH), Raija Lantto (VTT), Kirsi Mikkonen (UH), Anne Pihlanto (Luke), Pirkko Tuominen (Ruokavirasto).

Theme 4: Food innovation systems and consumers, leaders Mari Sandell (UH) and Emilia Nordlund (VTT)

- List of participants:** Ilmo Aronen (UH), Anu Hopia (UTU), Antti Saurama (TSE/CCR), Bodo Steiner (UH).

We performed an online survey in May/June 2020 to reach a broader range of experts active in food research and innovation fields in Finland. There were 140 respondents, representing different research fields who have provided their input to the research topics and priorities. After this, based on the survey and internal workshops, the thematic task forces of the core group developed further the missions and research priorities of the strategy. The initial suggestions were discussed in one-to-one meetings with ministries, government bodies, and associations such as MMM, TEM, YM, STM, Business Finland, ETL, and the Finnish Food Authority. Finally, to get feedback and input from the key stakeholders, a virtual stakeholder workshop was organised in October 2020 reaching diverse actors from food industry, administration and research organisations.

During this process, we all experienced (and are still experiencing) the COVID-19 pandemic, which has generated multiple waves of unprecedented local and global impacts. We already started to feel the COVID-19 impacts on transportation, the food supply chain, labour availability, and crop balances. During this time, we have learned the importance of resilient and self-sufficient food systems. We have to mitigate the impacts of the pandemic on the Finnish food system and develop research strategies to tackle those impacts and to be prepared for future crises.

The extended strategy core team consist of:

Mirva Lampinen, Anna Leinonen, Emilia Nordlund, Kaisa Poutanen, Nesli Sözer and Maria Åkerman (VTT)

Daniel Granato, Anu Kaukovirta, Sari Mäkinen, Anne Pihlanto, Tuomo Tupasela and Johanna Vilkki (Luke Natural Resources Institute of Finland)

Kati Hanhineva, Maaria Kortesniemi, Kaisa Linderborg and Baoru Yang (University of Turku)

Marina Heinonen, Hanna Koivula, Kirsi Mikkonen and Mari Sandell (University of Helsinki)

Marjukka Kolehmainen and Jenni Korhonen (University of Eastern Finland)

Liisa Maunuksela (Finnish Food Authority)

Suvi Virtanen (THL Finnish Institute for Health and Wellbeing)

Online workshop (October 2020) attendee list

Susanna Airaksinen (Raisio)

Hanna-Leena Alakomi, Anne Arvola, Mirva Lampinen, Raija Lantto, Anna Leinonen, Elina Mattila, Emilia Nordlund, Tuure Parviaainen, Kyösti Pennanen, Kaisa Poutanen, Anneli Ritala and Rosa-Sibakov Natalia (VTT)

Laura Albareda (Lappeenranta University of Technology)

Aki Finer (Motiva)

Laura Forsman, Anu Hopia, Kirsi Laitinen, Kaisa Linderborg, Riikka Saarimaa and Baoru Yang (University of Turku)

Daniel Granato, Lotta Heikkilä, John Kettle, Sari Mäkinen, Tuomo Tupasela and Johanna Vilkki (Luke Natural Resources Institute of Finland)

Pirjo Hakanpää (Business Finland)

Marina Heinonen, Mari Sandell and Alan Schulman (University of Helsinki)

Ardita Hoxha-Jahja and Jenni Lappi (Savonia)
Laura Hyvärinen (Finnish Society of Food Science and Technology)
Laura Höjer (BSAG)
Antti Isokangas (Makery Oy)
Harri Kallioinen and Riita Partanen (Valio)
Marjukka Kolehmainen (University of Eastern Finland)
Sara Kupsala and Liisa Maunuksela (Finnish Food Authority)
Marjaana Lahti-Koski (The Finnish Heart Association)
Vivian Leung (Food Techies Finland)
Loponen Jussi (Fazer)
Ulla Luhtasela (Nestlé)
Vahid Mortazei (Vahid Mortazei Studio)
Harri Mäkivuokko (ProAgria)
Kaisu Riihinne (Avena)
Suvi Ryynänen and Birgitta Vainio-Mattila (Ministry of Agriculture and Forestry)
Salminen Anna (The Finnish Grocery Trade Association PTY)
Mika Tuomola (Honkajoki Oy)
Suvi Virtanen (THL Finnish Institute for Health and Wellbeing)

Online round table discussion (Jan 2021) attendee list

Jussi Manninen (VTT)
Ari Koponen (Parliament of Finland, Committee of the Future)
Pekka Lindroos (Ministry of Economic Affairs and Employment of Finland)
Satu Haapaniemi (Ministry of Agriculture and Forestry)
Esa Wrang (Business Finland)
Heli Anttila (Fazer)
Johanna Buchert (Luke)
Tuomas Salusjärvi (Valio)
Maija Tenkanen (University of Helsinki)

Government advisors and association representatives complemented to the strategy

Tarja Haaranen (Ministry of Environment)

Pirjo Kutinlahti and Petra Tarjanne (Ministry of Economic Affairs and Employment)

Arja Lyytikäinen (VRN Nutritional council)

Pia Mäkelä (Finnish Food Authority)

Suvi Ryynänen and Minna Huttunen (Ministry of Agriculture and Forestry)

Sirpa Sarlio (Ministry of Social Affairs & Health)

Tanja Suni and Heta-Elena Heiskanen (Ministry of Environment)

Marleena Tanhuanpää (Finnish Food and Drink Industry)

Esa Wrang and Pirjo Hakanpää (Business Finland)