SUSFOOD2 ERA-Net Cofund

on Sustainable Food production and consumption

SUSFOOD e-Book

TOWARDS SUSTAINABLE FOOD SYSTEMS: 10 YEARS' RESEARCH FOR A BETTER FUTURE

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 727473

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SUSFOOD2 EXECUTIVE COMMITTEE | 2022

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Content

01 Introduction

SUSFOOD has worked for 10 years (5.5 years under H2020) on programming and aligning of national, EU and international R&I strategies and funded research with impact on sustainable food systems. The scope from production to consumption (beyond primary production) is of high relevance and needs more political attention in the future. In SUSFOOD2, partners from 15 countries have worked together to maximise the contribution of research, to increase impact, to pool resources and to avoid duplication. Also in the future, there is a need to support excellent research with effective and efficient funding practices, to put emphasis on stakeholder engagement, to involve industry more inclusively and to improve the science-policy interface.

SUSFOOD has invested largely in networking and connecting people: the ERA-Net partners, the funding bodies in joint calls, the research community and the stakeholders. Knowledge transfer, capacity building and dissemination and exploitation are key and SUSFOOD2 has put up a number of activities in this regard including preparation of the Strategic Research Agenda, SUSFOOD Country Report, 5 calls for research projects, reports, workshops, trainings and webinars.

This e-book is prepared to give information about SUSFOOD network, summarize its major activities and achievements and celebrate the 10 Years Anniversary of SUSFOOD.

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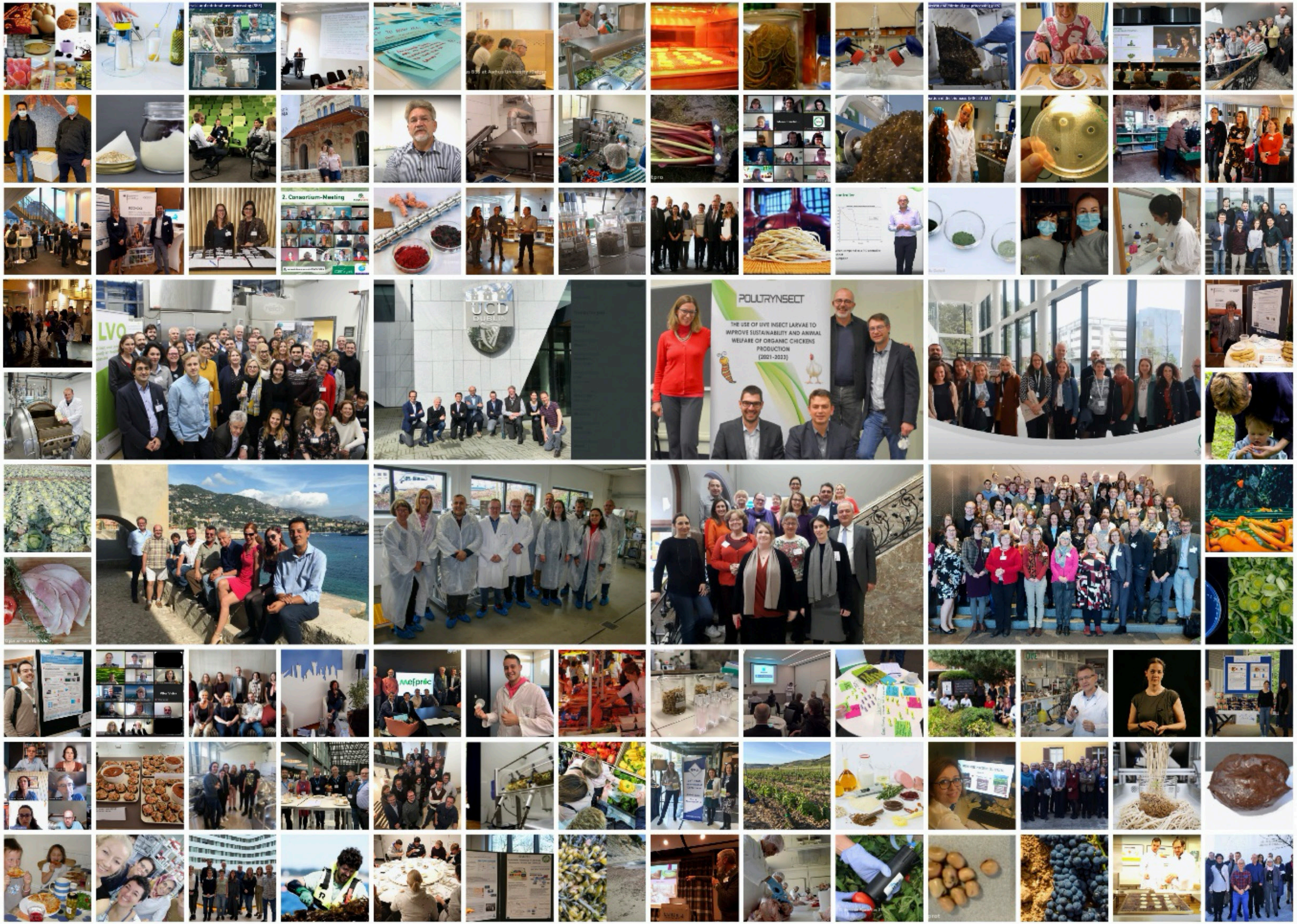

POULTRYNSECT
THE USE OF LIVE INSECT LARVAE TO IMPROVE SUSTAINABILITY AND ANIMAL WELFARE OF ORGANIC CHICKENS PRODUCTION
(2021-2023)
UCD DUBLIN
2. Consortium-Meeting
LVO

IMPORTANCE OF THE SUSFOOD PRIORITY RESEARCH AREAS

SUSFOOD is about the sustainable production and consumption of the food we eat. Eating food is, like drinking water and breathing oxygen, a fundamental necessity for everybody. It is therefore something done on a daily basis by everyone, probably in most cases without thinking too much about it. But how we produce and consume food does make a difference. Food can be produced and consumed in more or less sustainable ways. Big challenges and questions of the 21st century are connected to the way our food systems work. How do we ensure food and nutrition security for our growing world population? How do we counteract the increase of food associated diseases and address malnutrition and obesity? How to ensure that the food we eat does not worsen the climate crisis? How can we reduce food loss and waste? In short, what do we need to do to make our food systems sustainable* and resilient for everyone and the future generations?! In SUSFOOD we believe that Research and Innovation will play important roles to find the answers to these questions!

SUSFOOD Vision

Our Vision

All food chain partners contribute to achieving sustainable, secure and resilient food systems, which feed the world and make sustainable choices the easy and preferable choices for consumers

Our Aim

The overarching goal of Susfood is to maximise the contribution of research to the development of food systems aiming at more sustainability from production to consumption

To reach this vision and aim, SUSFOOD actions include the entire food supply chain. Our main focus is on the part of the chain beyond the farm gate, such as processing, packaging, transport, retailing, food services, storage and consumer activities.
SUSFOOD is a community of funders from European and associated countries using the ERA-NET instrument of the 7th European Framework Programme and the ERA-Net Cofund instrument of the Horizon 2020 Programme to achieve its goals. Currently, under SUSFOOD2, 26 Partners from 15 countries and 2 associated partners work together. Partners are either organisations that fund or manage research. SUSFOOD actions consist of funding activities (funding and monitoring of research projects), strategic activities (strategic analysis & reviews, impact assessment, policy recommendations, RRI), networking activities (outreach to industry, international outreach, thematic workshops) and communication and dissemination activities (social media, project seminars, stakeholder interaction).

SUSFOOD defines sustainability as: A food system that supports food security, makes optimal use of natural and human resources, and respects biodiversity and ecosystems for present and future generations, and which is culturally acceptable and accessible, environmentally sound and economically fair and viable, and provides the consumer with nutritionally adequate, safe, healthy and affordable food"

SUSFOOD in NUMBERS

26 Partners from
15 Countries
only SUSFOOD2 (H2020)

3.4 Mio Euro EC Grant for Management of the Network
(2 Mio under FP7, 3 years;
1.4 Mio under H2020, 5.5 years)

15 Network Meetings
(physical and online)

5 Calls for Transnational Research Projects

1 Strategic Research Agenda
(valid since 2014)
2 Strategic Scene Reports
(2018 and 2020)

Transnational support for R&I by **39** different funding institutions from **23** countries

750 Follower on Twitter
(756 on 08th June 2022)

44 Funded Projects Including
275 Researchers from **24** Countries

46 Mio Euro Funding Spent for R&I on Sustainable Food Production and Consumption

63% Gender Balance
(63% females in network,*
36% females in funded projects)
(referred to SUSFOOD2)

4 Research Areas
(based on 8 priority research topics)

18 Projects Funded with Industry Participation (30%)

9 Trainings and Workshops for Capacity Building of the Research Community

2 Joint Calls with Core Organic and FOSC

125 Peer-Reviewed Publications by Funded Projects of the Cofunded Call 2017 alone

11 Newsletters send out to ~740 subscribers

SUSFOOD ACHIEVEMENTS

SUSFOOD has worked for 10 years on programming and aligning of national, EU and international R&I strategies and to fund research with impact on sustainable food systems. Still, we see that the scope from production to consumption (beyond primary production) lacks attention. In SUSFOOD2, funders and managers from 15 countries have worked together to maximise the contribution of research, increase impact, to pool resources and to avoid duplication.

Also in the future there is a need to support excellent research in the field, to put emphasis on stakeholder engagement, to involve industry more inclusively and to improve the science-policy interface.

We have invested largely in networking and connecting people: the ERA-Net partners, the funding bodies in joint calls (also beyond SUSFOOD), the research community, the stakeholders.

Knowledge transfer, capacity building and dissemination and exploitation are key and SUSFOOD2 has put up a number of activities in this regard.

Research Area

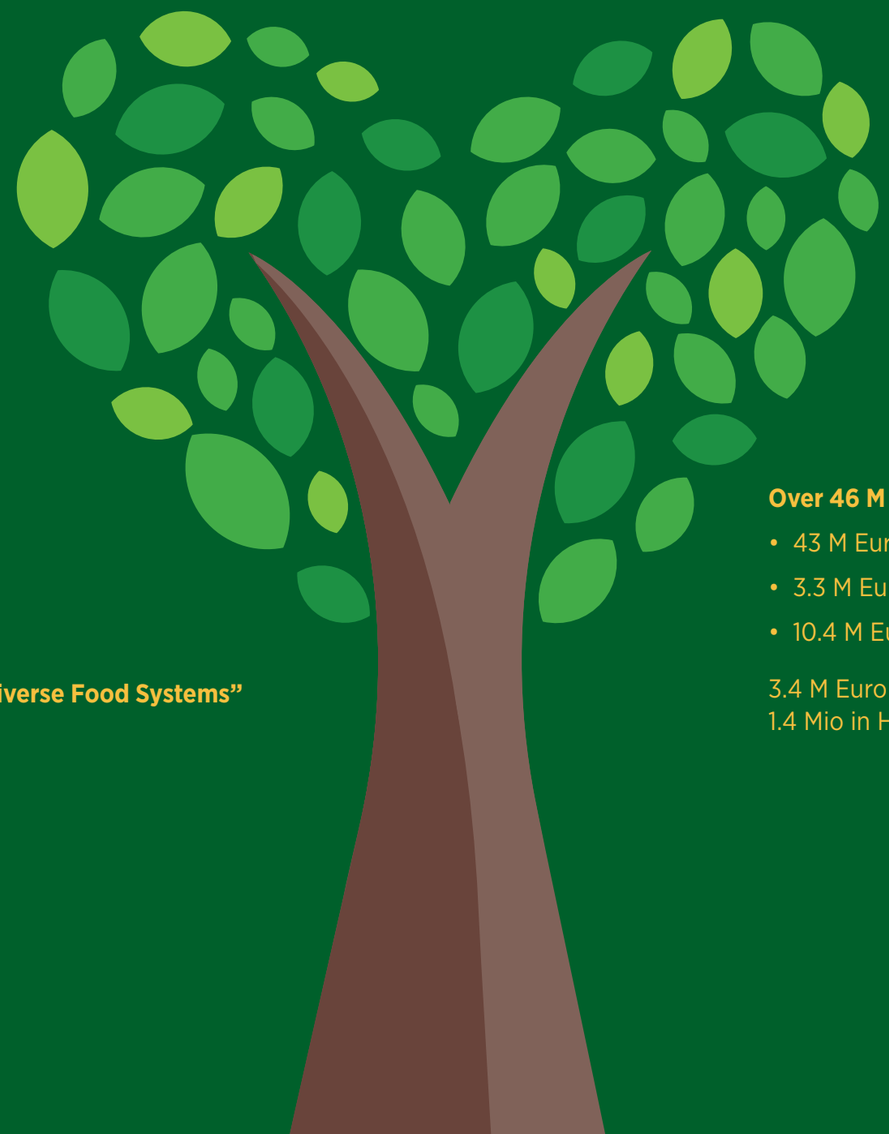
“Resource efficiency and valorization”

- 5 calls
- 20 projects

Research Area

“Processing technologies”

- 4 calls
- 14 projects



Research Area

“Consumer behaviour”

- 2 calls
- 5 projects

Research Area

“Sustainable & diverse Food Systems”

- 2 calls
- 5 projects

- 5 calls and 44 projects in total
- 275 researchers from 24 countries supported
- 36% of principle investigators are females
- 30% of projects involve partners from industry (14% of consortium partners are industry representatives)
- Workshops and trainings supporting capacity building and networking
- About 15000 visits to website
- More than 750 followers on Twitter

- 1 Strategic Research Agenda in 2014
- 2 Strategic Reviews in 2018 and 2020
- Meta-Knowledge Base for mapping (FP7)
- Country report in 2014

Over 46 M Euro awarded to projects from 2014-2022:

- 43 M Euro committed by funding bodies
- 3.3 M Euro top-up from the European Commission
- 10.4 M Euro additional in-kind/in-cash contributions

3.4 M Euro for administration of the ERA-Nets (2 Mio in FP7/ 1.4 Mio in H2020)

SUSFOOD IN PERSONAL VOICES - THOUGHTS ABOUT ACHIEVEMENTS AND MEMORIES

"SUSFOOD was, for me, a great opportunity to work at European level and to meet enthusiastic people sharing a common view of the needs of research on food." (Claude Yven, ANR, Network Partner)

"In a globalised world in which food chains transcend country boundaries, solving the food system sustainability challenges ahead can only be achieved through research and innovation that brings together the expertise and capabilities available at different states. SUSFOOD addresses precisely this need. It is therefore a pleasure and a privilege to be part of the bright SUSFOOD community to deliver this important mission." (Victor Aguilera, DEFRA, Network Partner)

"The timing for SUSFOOD was right. SUSFOOD brought sustainable food systems to the top of the policy agenda and it was the first ERA-NET / partnership with the aim to reinforce European R&I collaboration within the food area." (Niels Gøtke, Danish Agency for Science and Higher Education, FP 7 Network Partner)

"Tackling the issue of sustainability in food systems with a holistic point of view was the most valuable achievement of SUSFOOD." (Network Partner FP7)

"Inclusion of the entire food supply chain, interdisciplinary systems approach and continuous stakeholder engagement." (Maria Gernert, TP Organics, External advisory board)

"Bringing together institutions supporting research and innovation with the involvement of industry, and addressing topics covering the whole food system (from primary production to the consumer) also thanks to collaborations with other EU initiatives." (Elena Capolino, Mipaaf, Network partner)

"The SUSFOOD network has offered a framework to funders, stakeholders and researches to address the issue of sustainable food production and consumption. Ten years of SUSFOOD experience, knowledge and commitment in this area will be integrated in the coming European Food Systems Partnership." (Ivana Trkulja, AU-International Centre for Research in Organic Food Systems, Joint Call SUSFOOD2 and CORE Organic Cofunds 2019)

"International cooperation between industrial and academic partners in research projects. Possibility for companies and academia to broaden their horizon." (Marianne Claessens, VLAIO, Network partner)

02 SUSFOOD History and outlook to the future

The SUSFOOD ERA-Net was built on and accelerated the work of the SCAR (Standing Committee on Agricultural Research) Collaborative Working Group that was launched in Denmark in 2010.

In 2011, the first SUSFOOD ERA-NET was developed under the EU 7th Framework Program (FP7) and consisted of a durable focused network of national research funders in Member and Associated States of the EU. In SUSFOOD, 25 partners from 16 countries were active, coordinated by INRAE, France. fter it's ending in 2014, the SUSFOOD partners continued the network self-sustained until 2017 when a new grant was achieved for an H2020 ERA-NET COFUND under the name SUSFOOD2, coordinated by Project Management Juelich, Germany. SUSFOOD2 consisted of 26 partners from 15 EU Member states or 3rd countries.

The purpose of the first SUSFOOD was to share information, coordinate activities and work towards a common research agenda and mutual research funding activities in the field of sustainable food production and consumption. During this ERA-Net, a Strategic Research Agenda was developed to identify eight priority research areas. These were used to determine the topics of the two Joint calls that were initiated between 2011 - 2014.

SUSFOOD2 ends in June 2022, but the network will keep up the engagement to promote sustainable food systems through R&I. More precisely, SUSFOOD will be actively involved in two follow-up activities: the "**Green ERA-Hub**" (EC grant 101056828) and the CSA "**FOODPathS**" (EC grant 101059497), preparing the envisaged Partnership under Horizon Europe "Sustainable Food Systems for People, Planet and Climate".

03 General aim and objectives of SUSFOOD

The aim of SUSFOOD2 is to foster research and innovation in the field of sustainable food systems through enhanced cooperation and coordination between EU member and associated states. We want to contribute to the overall EU objective of building the European Research Area as well as a newly emerging Food Research Area.

Major challenges will influence future food chains asking for innovative solutions to:

- respond to increased demand for food by increasing production sustainably (Food and Nutrition Security)
- make optimal use of resources while mitigating the impact on the environment
- reducing losses and waste
- follow a whole food chain approach from production to consumption

Susfood Vision

All food chain partners contribute to achieving sustainable, secure and resilient food systems which feed the world and make sustainable choices the easy and preferable choices for consumers.

- improving the competitiveness of the European agri-food-business

SUSFOOD2 focuses on sustainability in post-harvest food production, thus covering relevant fields from natural sciences to food engineering and social sciences. SUSFOOD2 will strengthen efforts to support and fund excellent research in the food area. The consortium also aims at implementing other additional activities in a three-fold approach:

1. strengthening networking and knowledge transfer among various stakeholders (i.e. by workshops, stakeholder events etc.)
2. additional funding activities (preferably linked with other initiatives)
3. implementation and further advancement of the SUSFOOD Strategic Research Agenda

With the outlined approach, SUSFOOD2 will contribute to:

- maximizing impact of transnational cooperation pooling resources (material and intellectual) and implementing best practice
- using synergies and reducing overlap by

interacting with related (international) initiatives (especially JPIs HDHL, FACCE and Oceans)

- promoting the outputs of SUSFOOD2 network and funded projects via targeted dissemination thus sharing common vision and creating awareness for the field of food sustainability.

The strategic goal of SUSFOOD2 complements the EU bioeconomy and food policies, and aims to reinforce cooperation in research, development and innovation between EU members and associated States in order to maximize the contribution of research to the development of more sustainable food systems from production to consumption.

Global demand for food is expected to rise by at least 60% by 2050. At the same time the food supply chain is under pressure due to limited resources, water scarcity, soil degradation, biodiversity loss and the impacts of climate change. More than one third of the food produced in the world today is lost or wasted. Our food system has experienced huge transformation during the last century with changes in dietary preferences impacting on consumer health and food availability (e.g. increasing non-communicable diseases and obesity).

To meet these challenges we need to strengthen a sustainable* food system providing opportunities for all stakeholders to develop a secure, resilient and competitive sector.

The scope of SUSFOOD covers the entire food supply chain with the main focus on food chain sustainability beyond the farm gate (Primary production from both land and sea). The farm level will be considered if it has direct impact on the sustainability of the other steps in the food chain.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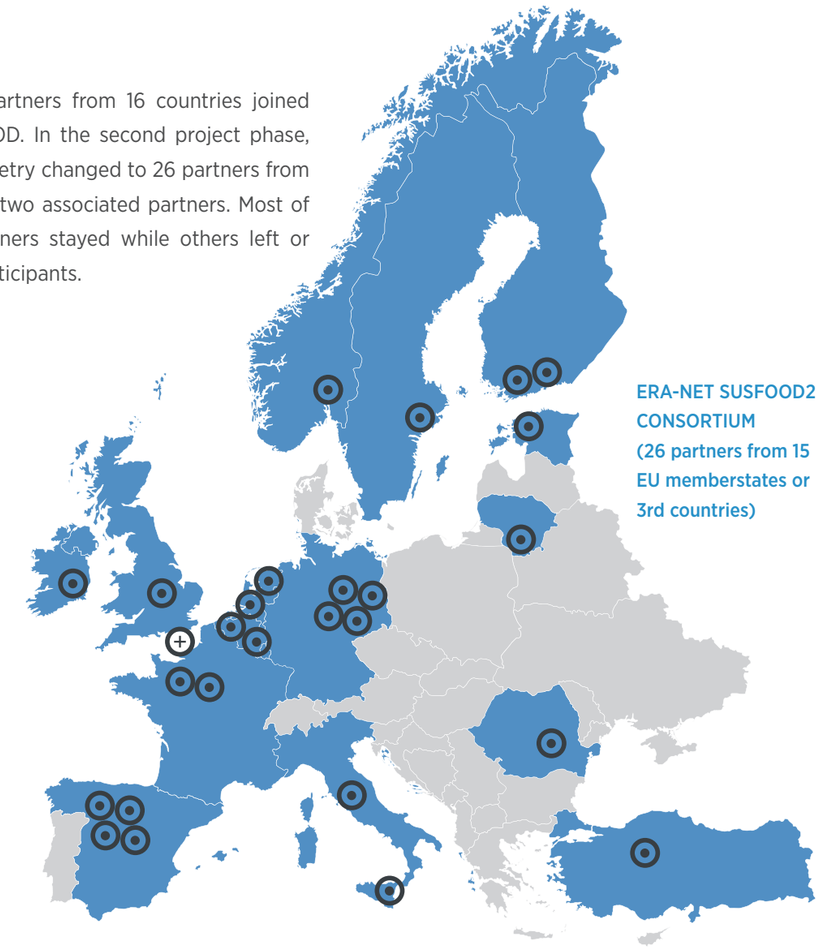
SUSFOOD2 promotes a cross-sectoral and multi-disciplinary approach from biology to food engineering and social sciences. It addresses the following socio-economic and environmental goals:

- To develop sustainable food systems from production to consumption, to increase food production sustainably while reducing waste in food supply chain and limiting environmental impacts;
- To improve the quality of life by improving food quality in a sustainable way and to ensure the resilience of the food supply chain;
- To encourage sustainable consumer behaviors and food choices;
- To improve competitiveness and economic growth in the European food industry with special attention to SMEs.

04 Network Partners & Governance

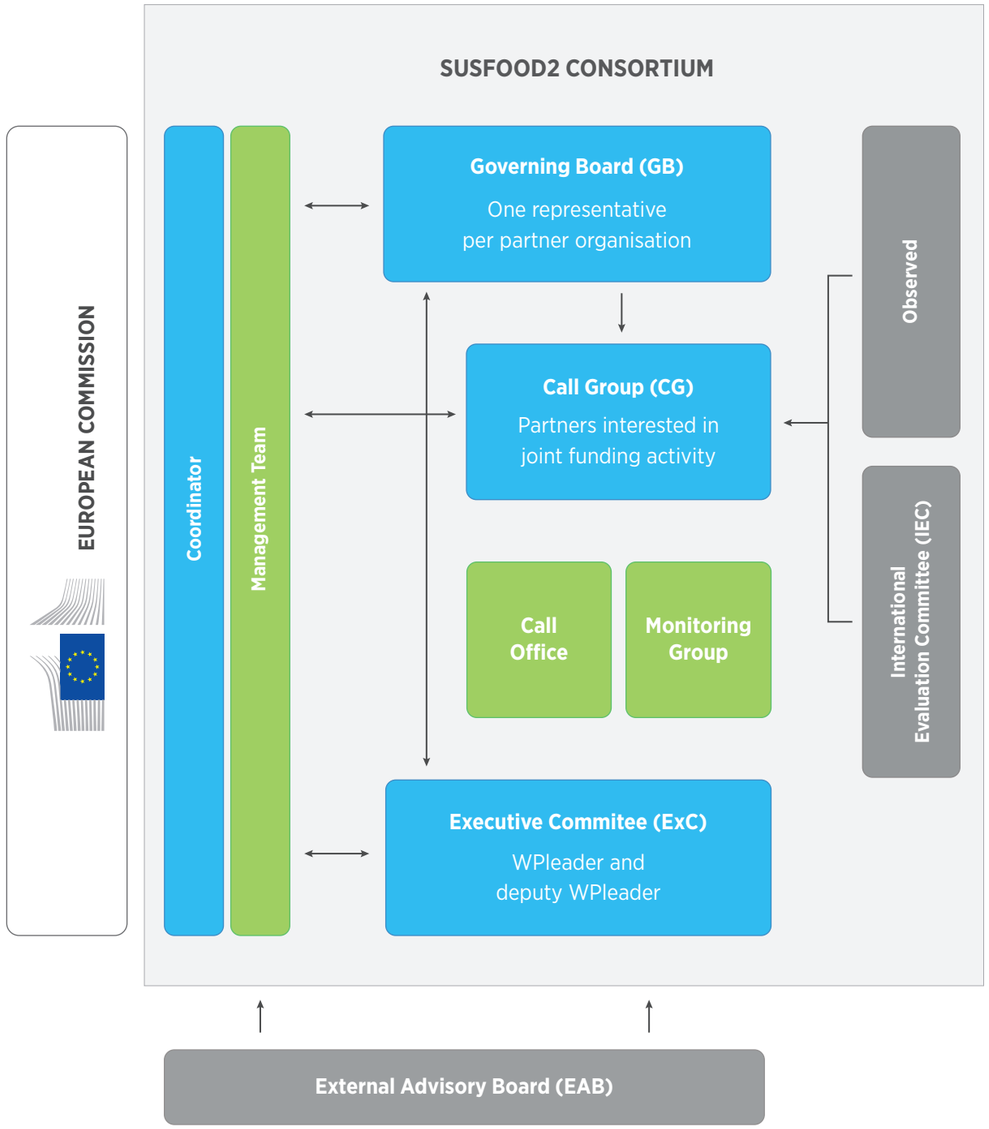
Under FP7, 25 partners from 16 countries joined forces in SUSFOOD. In the second project phase, the partner geometry changed to 26 partners from 15 countries plus two associated partners. Most of the network partners stayed while others left or joined as new participants.



Country	Partners	SUSFOOD1	SUSFOOD2
France	National Research Institute for Agriculture, Food and Environment (INRAE) (SUSFOOD1 Coordinator)	•	
Germany	Research Centre Juelich (SUSFOOD2 Coordinator)	•	•
Belgium	Flanders Research Institute for Agriculture, Fisheries and Food (ILVO)	•	•
	Flanders Innovation and Entrepreneurship / Hermes Funds (VLAIO)	•	•
Denmark	Danish Agency For Science, Technology And Innovation (DASTI)	•	
	University of Copenhagen (UCPH)	•	
Estonia	Ministry of Rural Affairs (MEM)	•	•
Finland	Ministry of Agriculture and Forestry (MMM)	•	•
	Natural resources institute Finland (LUKE)	•	•
France	The French Network of Food Technology Institutes (ACTIA)	•	•
	The French National Research Agency (ANR)	•	•
Germany	Federal Office for Agriculture and Food (BLE)	•	•
	Federal Ministry of Education and Research (BMBF)		•
	Federal Ministry of Food and Agriculture (BMEL)	•	•
Ireland	Federal Office for Agriculture and Food and The Marine (DAFM)		•
Italy	Ministry of Agricultural, Food and Forestry Policies (MIPAAF)	•	•
	Ministry of Education, Universities and Research (MIUR)		•
Lithuania	Ministry of Agriculture of the Republic of Lithuania (MOALIT)		•
Norway	Research Council of Norway (RCN)	•	•
Poland	National Centre for Research and Development (NCBR)	•	
Romania	Executive Agency for Higher Education, Research, Development and Innovation Funding (UEFISCDI)	•	•
Slovenia	Ministry of Education, Science and Sport (MIZS)	•	
Spain	Basque Foundation for Agri-Food Safety (ELIKA)	•	
	Institute of Development of the Region of Murcia (Info Murcia)	•	
	The National Institute for Agricultural and Food Research & Technology (INIA)	•	•
	Centre for the Development of Industrial Technology (CDTI)		•
	Institute for Business Competitiveness of Castilla y León (ICE)		•
	AEI State Research Agency		•
Sweden	The Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning (FORMAS)	•	•
The Netherlands	Ministry of Economic Affairs and Climate Policy (EZK)	•	
	Ministry of Agriculture, Nature and Food Quality (MIN LNV)		•
	The Netherlands Organisation for Scientific Research (NWO)		•
The United Kingdom	The Secretary of State for Environment, Food and Rural Affairs (DEFRA)	•	•
	Innovate UK (The Technology Strategy Board - TSB)	•	
Türkiye	General Directorate of Agricultural Research and Policies (TAGEM)	•	•

Country	Associated partners
Belgium	Flanders' Food
New Zealand	Ministry of Business, Innovation and Employment (MBIE)

In figure below the overall governance structure of SUSFOOD2 is displayed with the Governing Board being the decision making body. More information can be found **at the link.**



From the very start, an External Advisory Board (EAB) was established, helping to ensure coherence and continuity in the overall scientific and strategic steering of SUSFOOD as well as providing external points of view to bring maximum outcomes to the research community and the society. The EAB advised on the scientific strategy and implementation of the action and was involved by various means (consultations, strategic workshops, research seminars and stakeholder events).

The EAB members represent a variety of important stakeholder groups:

Acronym	Organization
EUFIC	European Food Information Council
FAO	Food and Agriculture Organization of the United Nations
FoodDrinkEurope	Food Industry Confederation
NFTP	National Food Technology Platforms
JPI FACCE	Joint Programming Initiative on Agriculture, Food Security and Climate Change
JPI HDHL	Joint Programming Initiative ‘A Healthy Diet for a Healthy Life’
JPI OCEANS	Joint Programming Initiative ‘Healthy and Productive Seas and Oceans”
ETP Food for Life	European Technology Platform “Food for Life“
ETP Organics	European Technology Platform Organics
SCAR SWG Food Systems	Standing Committee on Agricultural Research Strategic Working Group “Food Systems”
EIT FOOD	European Institute of Innovation & Technology „Food“
PRIMA	Partnership for Research and Innovation in the Mediterranean Area
	Food Force Network
JRC-IRMM	Joint Research Center - Institute for Reference Materials and Measurements
Former ERA-Net	Platform (Former ERA-Net)

05 SUSFOOD Strategy

The main purpose of the first SUSFOOD ERA-NET was to establish a common research agenda in the field of sustainable food production and consumption. During the work between 2011 and 2014, the Strategic Research Agenda (SRA) was developed. It identified eight priority research areas and two cross-cutting issues. Those were base for the topics of the first two SUSFOOD calls (2013 and 2014). The SUSFOOD2 calls 2017, 2019 and 2021 put emphasis on adapting, revising and connecting the priority research areas. During SUSFOOD2 two follow up reports of the SUSFOOD SRA were published reviewing the current state strategic scene on the field of sustainable food production and consumption, including relevant movements, agendas and policies in the field. The overall aim of the strategic work within SUSFOOD was to maximize impact, reduce overlap, and identify knowledge gaps and innovation potential.

SUSFOOD Strategic Research Agenda (SRA) and review Reports

The SUSFOOD **Strategic Research Agenda** embraces sustainability within a global context. The global food system is challenged by increased demand for quantity and quality of food to meet the population growth of 7 billion today to 9 billion by 2050, and at the same time to meet changes in the socio-economic and demographic structure of the population. These challenges include increased pressure on the natural resources, water and energy; climate change; demand for more nutritious and safe food for all; and for food to be affordable for all.

The food and drink sector contributes to the global economy in terms of annual turnover and numbers of jobs generated. It is the largest manufacturing sector in Europe. The SUSFOOD SRA takes into account other relevant SRAs for sustainable production and consumption. SUSFOOD SRA focuses on food chain sustainability beyond the farm gate or fishing boat, e.g. processing, packaging, transport, retailing, food services, storage and consumer activities. However, reaches out to the primary production on issues as methods and metrics for assessment and policies. The SUSFOOD SRA strives to have a high impact on

1. food security,
2. pressure on natural resources as water and energy adapting to climate change,

3. innovation and knowledge transfer,
4. food and health
5. sustainable food economy, including employment and job creation.

Challenges for sustainable food production and consumption identified in SUSFOOD SRA:

1. Global food and nutrition security
2. Limited energy, water, natural resources
3. Innovation and knowledge transfer to support sustainable development in the food system
4. Food and health to improve and ensure quality of life of an ageing society
5. Change of markets and approaches, to ensure resilient and sustainable food economy, employment
6. Understanding how food demand can be managed (consumer awareness, food system)

The priority research areas of SUSFOOD strategic research agenda

The strategy for how research can have an impact to address these core challenges has identified the following eight key research areas and two cross-cutting issues where research gaps exist: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The implementation of the SRA was initiated by two SUSFOOD calls, maintenance of the meta knowledge base, and dialogue with national funding bodies, both private and governmental, and with EU institutions.

1. Public policy coherence
2. Innovation in food processing technologies
3. Redesign input, waste and side flow strategies to increase resource efficiency and provide added value in food products and processing, manufacture etc.
4. Interdisciplinary research approach to innovative of food products and use of new raw materials for food products
5. Harmonisation of the methods and metrics for integrated assessment of sustainability of food products and food patterns
6. Connection between stakeholders and food systems
7. Understanding of consumer behavior and food choices
8. Integration of information systems for personalized and sustainable choices

To stress the importance of a holistic approach, the SRA points at the two cross-cutting issues:

1. Localisation of activities
2. Equity and ethics

which both need to be addressed as an integral part of each research area.


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SUSFOOD2 Strategic Scene Reports 2018 - 2020

SUSFOOD2 published two Strategic Scene Reports in 2018 and 2020 describing the current background of research and innovation programming in the field of sustainable food production and consumption in Europe.

The first report complements the SUSFOOD Strategic Research Agenda (SRA) and serves as a tool for its implementation. It summarizes the SRA and the objectives of SUSFOOD2, and give an overview on the main trends and drivers in the field of SUSFOOD.

It also lists other relevant initiatives and takes a look on the first achievements of SUSFOOD funded projects. More information is available in the **Strategic Scene Report**.

The second strategic scene review report shows that the activities of SUSFOOD2 are well in line with recent European policies like the European Green Deal. Sustainable food production and consumption, circularity, and prevention of food waste are at the heart of the Farm to Fork strategy published in May 2020 – and the same themes are the core of SUSFOOD SRA.

SUSFOOD Governing Board and External Advisory Board members were asked in a survey in February 2020 to think about the priority research areas set in SRA and score how important they are in their opinion, according to their national priorities, or European context in 2020's.


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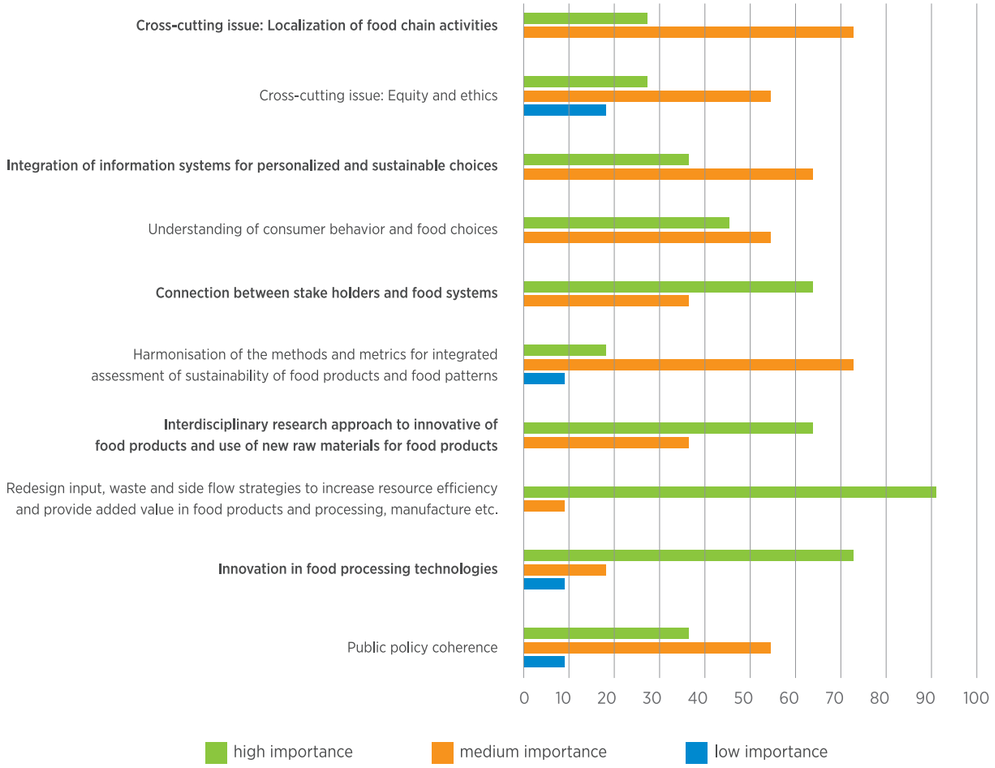
Importance of the SUSFOOD Priority Research Areas in 2020's



The emergence of a novel zoonotic virus such as Covid- 19 has shown that the sustainability and resilience of the food system is more important than ever. The long-term effects of the covid-19 pandemic on the food system remain to be seen but it has already shown that complex supply chains can be a risk for food security.

Localization of food chain activities is seen as a cross-cutting theme in the SUSFOOD SRA, and that will probably be a growing trend in the near future. Sustainability continues as a major trend and challenge in the European and global food field. Consumers have personal preferences, demands and needs resulting in new expectations for diversity of food systems. Research in the food area is active but it needs continuously to be adapted continuously to a changing environment and new boundary conditions. More information is available in the **Second Strategic Scene Report**.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EXAMPLES OF STRATEGIC WORKSHOPS

1. Workshop on Impact of SUSFOOD2 ERA-Net – 14 December 2017

On December 14th 2017, the SUSFOOD2 network invited the EAB for a strategic workshop on "Impact of the SUSFOOD2 ERA-Net Cofund network" in Madrid. Brainstorming on three thematic levels took place via interactive group sessions with 30 participants, of which 8 were EAB members.

First, general challenges and needs of the area of sustainable food were discussed, how to increase the impact of the SUSFOOD2 network and how to secure and increase the importance of food in the European Bioeconomy.

Participants were asked to represent one of the 5 most important SUSFOOD stakeholder groups (researchers, industry, policy makers, funders and general public).

In a 3rd part (Interaction and synergies), the most interesting possibilities for collaboration with existing EU initiatives or actions were considered, to increase the impact of SUSFOOD2 on sustainable food production and consumption in existing food systems. This intense interactive workshop generated many interesting ideas and proposals.

Important messages include the usefulness of ICT technology and big data connected to food systems in order to ensure resource sustainability and more efficient use of resources.

The workshop also touched upon the impression that industry is driven by profits and price is still one of the main drivers in global food consumption (FAO 2015).

Food industry has been going through a massive concentration process over the last decades and the investments of big companies can affect which trends expand. However, the food industry is still mainly SME based (99.1% of the total of EU food and drink companies, **FoodDrinkEurope** Data and Trends, 2017). The SMEs thus also have an important role but there is an insufficient transfer of research results and knowledge.

Research can improve the technological production, but only consumer perception will change the behavior. Other things like sustainability and ethical issues are becoming more important to some consumers.

It was stated that trends change all the time and food has a high cultural value. However, consumers have prejudices towards new technologies and might fear to loose food as a real thing. Advanced technology also changes the way food comes to table.

2. Implementation Workshop – 26 October 2018

More than 30 partners and members of the External Advisory Board gathered on 26 October 2018 in Stockholm. Aim of the workshop was to discuss which activities to follow during the next years in SUSFOOD2 aiming at relevance, added value and feasibility.

The workshop focused on actions within 4 defined fields: Strategic work, Funding activities, Communication, Dissemination and Knowledge Exchange as well as Networking activities.

During an interactive session, participants could share and discuss ideas and also give their preferences during a voting.

The workshop in Stockholm adds to and follows up on various ideas gathered during previous discussions and analysis (workshop in Madrid Dec 2017, Strategic Review Report on the SRA). The outputs of those exercises led to an Implementation plan for SUSFOOD2 summarizing activities for the next years ahead.

The workshop was complemented a thematic keynote speech from Cecilie Mathiesen (RCN) on implementation of Responsible Research and Innovation (RRI) aspects into ERA-Nets.


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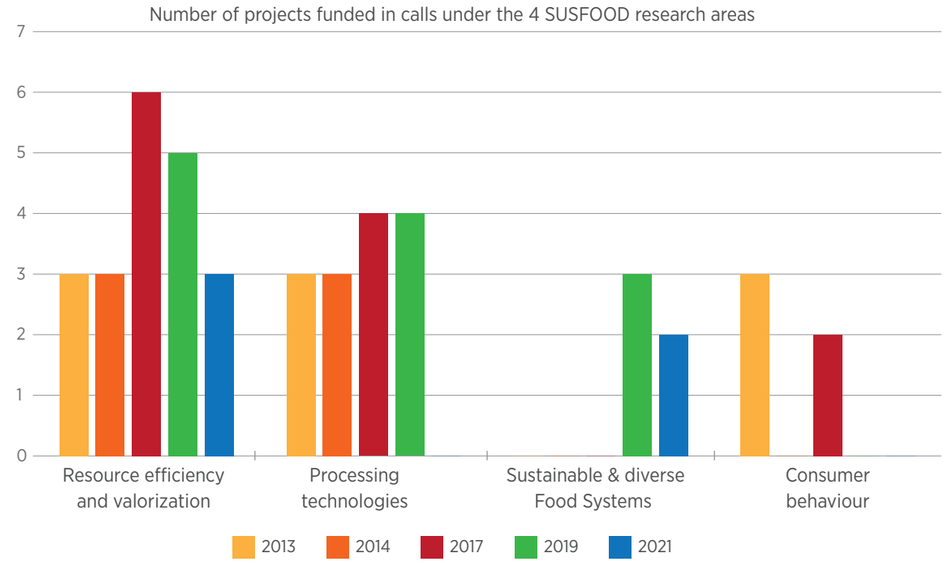
06 Funding of R&I Projects

This action field aims to foster research and innovation in the SUSFOOD area by direct support via public funding as well as follow-up on the projects (monitoring and impact assessment).

The first SUSFOOD ERA-NET lauched two transnational calls in 2013 and 2014. In these calls 15 project were funded and successfully completed. SUSFOOD2 launched 3 calls. The first one is the cofunded call in 2017 followed by two calls jointly conducted together with other ERA-Nets in 2019 and 2021.

SUSFOOD funded projects can be clustered into 4 research areas. The figure below shows the distribution of the 44 projects funded within all 5 calls of SUSFOOD network clustered in four general research areas.

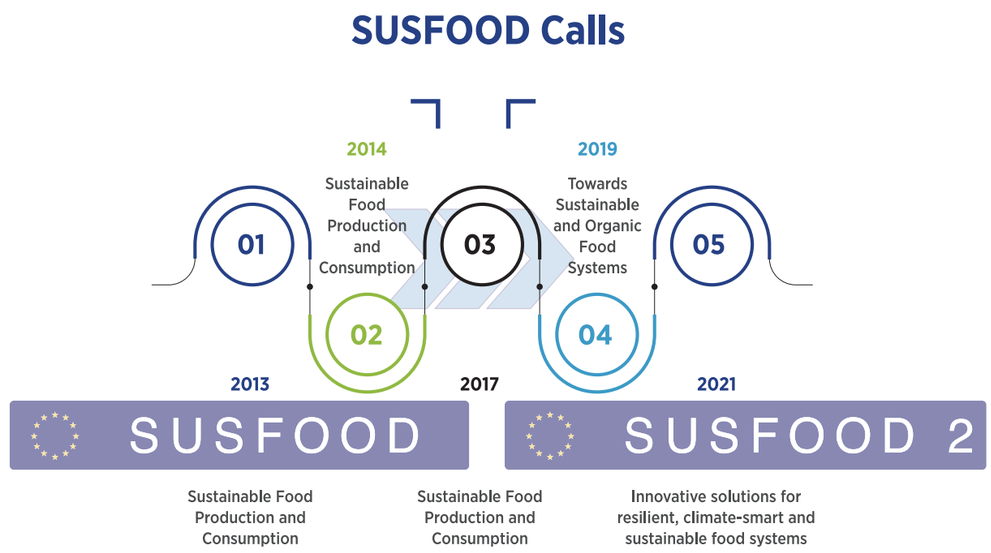


Calls of SUSFOOD

SUSFOOD and SUSFOOD2 launched 5 calls since 2013. In these calls, 44 projects have been selected for funding. The table below gives a brief overview about the calls.

	Call	Year	Nr of funded projects	Status of the projects (mid´22)
1	SUSFOOD 1st Call	2013	9	Completed
2	SUSFOOD 2nd Call	2014	6	Completed
3	SUSFOOD2 Cofunded Call	2017	12	Completed
4	Joint Call of SUSFOOD2 & Core Organic	2019	12	On-going
5	Joint Call of SUSFOOD2 & FOSC	2021	5	On-going

Detailed information related to calls and projects are in following chapters. **SUSFOOD2 webpage** provides information about the projects as well.



1. SUSFOOD 1st Call – 2013

The ERA-Net SUSFOOD launched its first Joint Call for proposals in February 2013.

Call topics:

Topic 1: Improving input, waste and side flow strategies to increase resource efficiency and provide added value in food products and food processing, manufacture, reducing input (energy, water etc.) in the food chain.

Topic 2: Innovation in food processing technologies and food products to support a sustainable food chain.

Topic 3: Understanding consumer behaviour to encourage a (more) sustainable food choice

Below table provides some numeric information about the call.

Information Related to Call	
Funding offered/spent:	9.4 / 9.5 Mio Euro
Number of funders/countries:	17 / 14
Selected projects (full-proposals/pre-proposals):	9 (26 / 98)
Project runtimes:	2014 - 2017
Number of researchers in projects:	66
Percentage of projects with industry participation:	44%
Gender balance projects (f/m)	32 / 68%

All information about the call is in the call document.

List of projects funded in the first call of SUSFOOD

Topic 1: Improving input, waste and side flow strategies to increase resource efficiency and provide added value in food products and food processing, manufacture, reducing input (energy, water etc.) in the food chain.

Cereal: Improved and resource efficiency throughout the post-harvest chain of fresh-cut fruits and vegetables.

Sunniva: Sustainable food production through quality optimized raw material production and processing technologies for premium quality vegetable products and generated by-products.

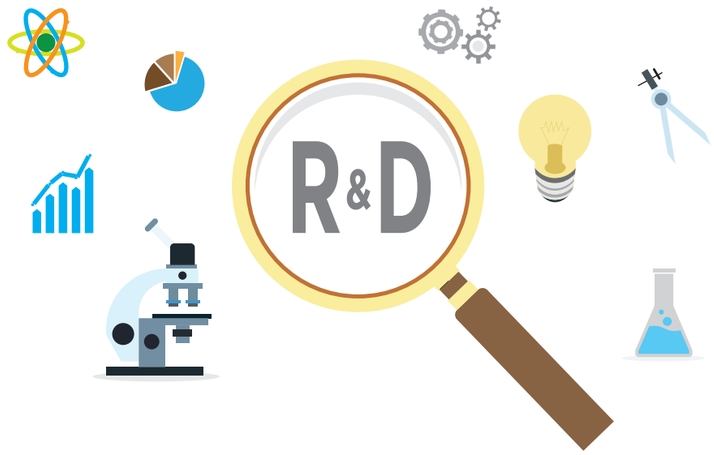
BioSuck: Decision support system on optimized waste collection by vacuum technology with simultaneous production of bioenergy from wastes.

Topic 2: Innovation in food processing technologies and food products to support a sustainable food chain.

Cibus-Food: Computational-design and Innovative Building of Uniquely Structured Food.

Sustainable&Healthy: Development of sustainable processing technologies for converting by-products into healthy, added value ingredients and food products.

Bioprot: Novel multifunctional plant protein ingredients with bioprocessing.



Topic 3: Understanding consumer behaviour to encourage a (more) sustainable food choice

Focas: Food, Convenience and Sustainability

Cosus: Consumers in a sustainable food supply chain: understanding barriers and facilitators for acceptance of visually suboptimal foods

Susdiet: Implementing sustainable diets in Europe

Involved funding bodies:

IWT (Belgium), DASTI (Denmark), EVPM (Estonia), MMM (Finland), BMBF and BMEL (Germany), MIPAAF (Italy), EZ (Netherlands), RCN (Norway), NCBIR (Poland), UEFISCDI (Romania), ELIKA, INFO Murcia and INIA (Spain), FORMAS (Sweden), GDAR (Türkiye), DEFRA (United Kingdom).

2. SUSFOOD 2nd Call – 2014

The ERA-Net SUSFOOD launched its second Joint Call for proposals in February 2014.

Call topics:

Topic 1: Innovation in food processing technologies and food products to support a sustainable food chain

Topic 2: Improving input, waste and side flow strategies to increase resource efficiency and provide added value in food products and food processing, manufacture, reducing input (energy, water etc.) in the food chain

Topic 3: Interdisciplinary research approach to innovative food products and use of new raw materials for food products.

Below table provides some numeric information about the call.

Information Related to Call	
Funding offered/spent:	7.4 / 5.2 Mio Euro
Number of funders/countries:	14 / 13
Selected projects (full-proposals/pre-proposals):	6 (17 / 45)
Project runtimes:	2014 - 2016
Number of researchers in projects:	33
Percentage of projects with industry participation:	50%
Gender balance projects (f/m)	33 / 66%

All information about the call is in the call document.

List of projects funded in the second call of SUSFOOD

Topic 1: Innovation in food processing technologies and food products to support a sustainable food chain.

FreezeWave: Innovative and low energy microwave assisted freezing process for high quality foods

RF-cooking of Ham: Rapid industrial scale cooking of boiled ham using radio frequency electric fields

ProRef: Gentle and resource-efficient refining of vegetable oils for preservation of valuable components and simplified reprocessing of by-products.

Topic 2: Improving input, waste and side flow strategies to increase resource efficiency and provide added value in food products and food processing, manufacture, reducing input (energy, water etc.) in the food chain.

BerryPom: Adding value to fruit processing waste: innovative ways to incorporate fibres from berry pomace in baked and extruded cereal-based foods

Topic 3: Interdisciplinary research approach to innovative food products and use of new raw materials for food products.

SusMeatPro: Sustainable plant ingredients for healthier meat products - proof of concepts

OatPro: Engineering of oat proteins: Consumer driven sustainable food development process

Involved funding bodies:

VLAIO (Belgium), DASTI (Denmark), EVPM (Estonia), MMM (Finland), BMBF (Germany), MIPAAF (Italy), EZ (Netherlands), NCBIR (Poland), UEFISCDI (Romania), MIZS (Slovenia), ELIKA and INIA (Spain), FORMAS (Sweden), GDAR (Türkiye), DEFRA (United Kingdom).

3. SUSFOOD2 Cofunded Call – 2017

The co-funded call within the second project phase of SUSFOOD2 was launched in January 2017. By the start of the ERA-Net, the co-funded call was ready to be launched, the preparation of the evaluation process and the expert's panel were already at an advanced stage and the website was updated.

Call topics:

Topic 1: Innovation in food processing technologies and products

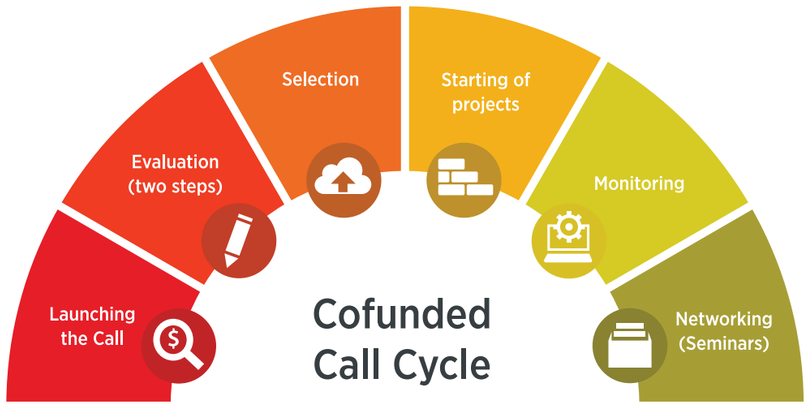
Topic 2: Providing added value, increased resource efficiency and reduction of waste in sustainable food systems

Topic 3: Understanding consumer behaviour and food choices

The co-funded call was implemented successfully with the help of all partners, funding 12 transnational projects with 11.4 Mio Euro total funding. The projects were continuously monitored including regular updates, mid- and final reports. 3 project meetings (kick-off, mid-term and final) were held with the aim to share knowledge, to interact and network.

Information Related to Call	
Funding offered/spent:	14 / 11.5 Mio Euro
Number of funders/countries:	18 / 15
Selected projects (full-proposals/pre-proposals):	12 (30 / 95)
Project runtimes:	2018 - 2021
Number of researchers in projects:	73 (17 countries)
Percentage of projects with industry participation:	50%
Gender balance projects (f / m)	40 / 60%

All information about the call is in the call document.



List of projects funded in the cofunded call of SUSFOOD 2

Topic 1: Innovation in food processing technologies and products

BIOCARB-4-FOOD: Extraction and characterization of BIOactives and CARBohydrates from seaweeds and seagrasses FOR FOOD-related applications

InProVe: Innovative Processing of Vegetables and Potato

FUNBREW: Biotransformation of brewers' spent grain: increased functionality for novel food applications

MEFPROC: Improving Sustainability in Food Processing using Moderate Electric Fields (MEF) for Process Intensification and Smart Processing

DISCOVERY: Disaggregation of conventional vegetable press cakes by novel techniques to receive new products and to increase the yield

ProSeaFood: Innovative processing of seaweed for novel, healthy food products and ingredients

Topic 2: Providing added value, increased resource efficiency and reduction of waste in sustainable food systems

AVARE: Adding value in resource effective food systems

SPAREC: Sustainable Processing of Agrofood Residues to Elicitors and Chemicals

ImPrOVE: Innovative (pre)POmace Valorization process

SUSPUFA: Sustainable production of health-promoting n-3 LC-PUFA using agro food industry by-products through microalgae

Topic 3: Understanding consumer behaviour and food choices

SUSCHOICE: Towards Sustainable Food and Drink Choices among European Young Adults: Drivers, Barriers and Strategical Implications

PLATEFORMS: Sustainable Food Platforms: Enabling sustainable food practices through socio-technical innovation

Involved funding bodies:

VLAIO (Belgium), MEM (Estonia), MMM (Finland), ANR (France), BMEL (Germany), DAFM (Ireland), MIRU and MIPAAF (Italy), MoALit (Lithuania) RCN (Norway), UEFISCDI (Romania), ADE, CDTI, and MINECO (Spain), FORMAS (Sweden), NOW (The Netherlands), GDAR (Türkiye), DEFRA (United Kingdom).

4. JOINT Call of SUSFOOD2 & Core Organic – 2019

In order to address emerging societal challenges, SUSFOOD2 and CORE Organic (Coordination of European Transnational Research in Organic Food and Farming Systems) have joined forces within the transnational Call 'Towards sustainable and organic food systems' launched in 2019.

Call topics:

Topic 1: Resource-efficient, circular and zero-waste food systems

Topic 2: Diversity in food from field to plate

Topic 3: Mild food processing

Topic 4: Sustainable and smart packaging

Below table provides some numeric information about the call.

Information Related to Call	
Funding offered/spent:	9.5 / 7.9 Mio Euro
Number of funders/countries:	21 / 18
Selected projects (full-proposals/pre-proposals):	12 (29 / 60)
Project runtimes:	2019 - 2023
Number of researchers in projects:	67
Percentage of projects with industry participation :	17%
Gender balance projects (f / m)	37 / 63%

All information about the call is in the call document.

List of projects funded in the joint call of SUSFOOD2 & Core Organic

Topic 1: Resource-efficient, circular and zero-waste food systems

FOODLEVERS: Leverage points for organic and sustainable food systems

FERBLEND: Fermentation-induced valorization of side stream blends from oilseed and dairy industry

Bio4Food: High quality and nutrient rich food through crop waste-derived biostimulant and biopesticide

ALL-IN: ALfalfa for sustainable Livestock farming systems: Improve alfalfa -rhizobia symbiosis and New feeding strategy based on ecological leftovers

SysOrg: Organic agro- food systems as models for sustainable food systems in Europe and Northern Africa

Poultrynsect: The use of live insect larvae to improve sustainability and animal welfare of organic chickens production

PROVIDE: PRotein and biOmolecules sources for nutritional security and biodiVersity of bakery products in a cIrcular fooD system

Topic 2: Diversity in food from field to plate

FOOdIVERSE: Diversifying sustainable and organic food systems

SPiwi: Sustainable production of innovative sparkling wine

Topic 3: Mild food processing

MILDSUSFRUIT: Innovative Mild Processing Tailored to Ensure Sustainable and High Quality Organic Fruit Products

HO-FOOD: Innovative High pressure process to increase the preservation of ready-to-eat Organic FOOD

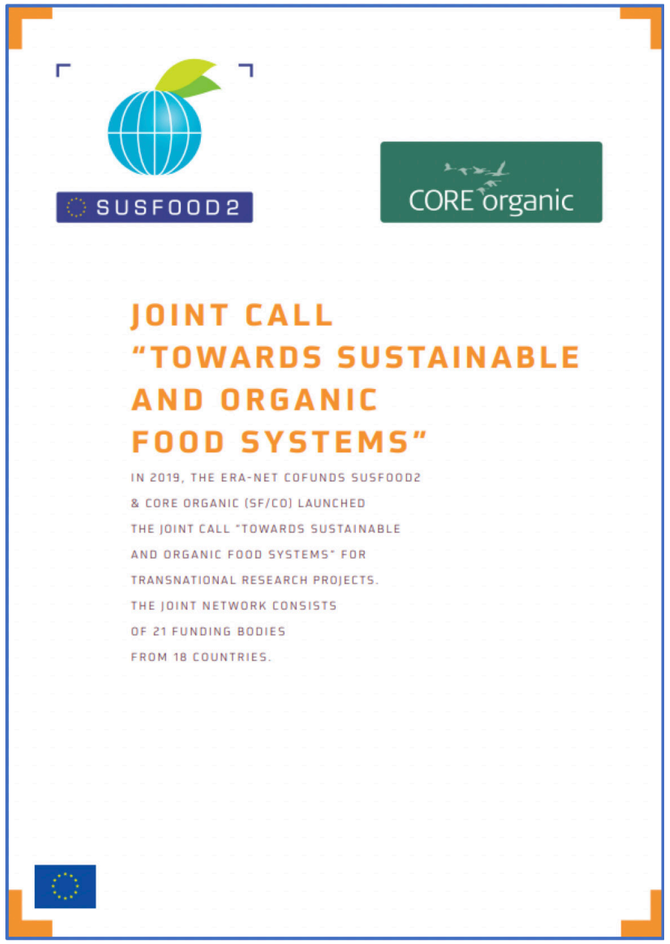
MI-WINE: Mild Innovative Treatment for Wine Stabilisation

Topic 4: Sustainable and smart packaging

No projects were selected in this topic

Involved funding bodies:

MESRS (Algeria), VLAIO and Dep.LV (Belgium), DAFA (Denmark), MEM (Estonia), MMM (Finland), ANR and MAA (France), BMEL (Germany), MIRU and MIPAAF (Italy), AREI (Latvia), CNRS-L (Lebanon), FNR (Luxemburg), MENFPESRS (Morocco), RCN (Norway), NCBR (Poland), UEFISCDI (Romania), ICE (Spain), GDAR (Türkiye), DEFRA (United Kingdom).



5. JOINT Call of SUSFOOD2 & FOSC – 2021

The Joint Call of the ERA-NETs SUSFOOD2 & FOSC (Food Systems and Climate) on "Innovative solutions for resilient, climate-smart and sustainable food systems" was closed on August 16th, 2021.

The scope of the call was to fund projects that facilitate the transition from current linear food systems to resilient circular systems, including optimal use of resources and less vulnerability to shocks under consideration of the interdependencies within the systems and its stakeholders.

Call topics:

Topic 1: Innovations to improve food systems sustainability, with a focus on increasing resource efficiency and reducing waste

Topic 2: Food Systems adaptation and resilience to system shocks

Below table provides some numeric information about the call.

Information Related to Call	
Funding offered/spent:	7.85 / 3.6 Mio Euro
Number of funders/countries:	14 / 13
Selected projects (full-proposals):	5 (31)
Project runtimes:	2021 - 2025
Number of researchers in projects:	34
Percentage of projects with industry participation:	60%
Gender balance projects (f / m)	35 / 65%

All information about the call is in the call document.

List of projects funded in the joint call of SUSFOOD2 & FOSC

Topic 1: Innovations to improve food systems sustainability, with a focus on increasing resource efficiency and reducing waste

MedAgriFoodResilience: Socio-environmental shocks assessment and resilience empowerment in Mediterranean agri-food heritage systems: Italy, Morocco, Algeria FAO GIAHS sites

IPSUS: Climate smart food innovation using plant and seaweed proteins from upcycled sources

SmartDairy: Climate-smart Dairy: Assessing Challenges, Innovations, and Solutions

AlgaeBrew: Unlocking the potential of microalgae for the valorisation of brewery waste products into omega-3 rich animal feed and fertilisers.

Topic 2: Food Systems adaptation and resilience to system shocks

Olive3P: Innovative sustainable food system for olive oil production converting solid and liquid by-products into edible yeast and biopesticide.

Involved funding bodies:

MESRS (Algeria), INTA (Argentina), FNRS and VLAIO (Belgium), MEM (Estonia), MMM (Finland), ANR (France), DAFM (Ireland), MIPAAF (Italy), MENFPESRS (Morocco), RCN (Norway), UEFISCDI (Romania), TÜBİTAK (Türkiye), DEFRA (United Kingdom).

07 Communication & Dissemination and Knowledge Transfer

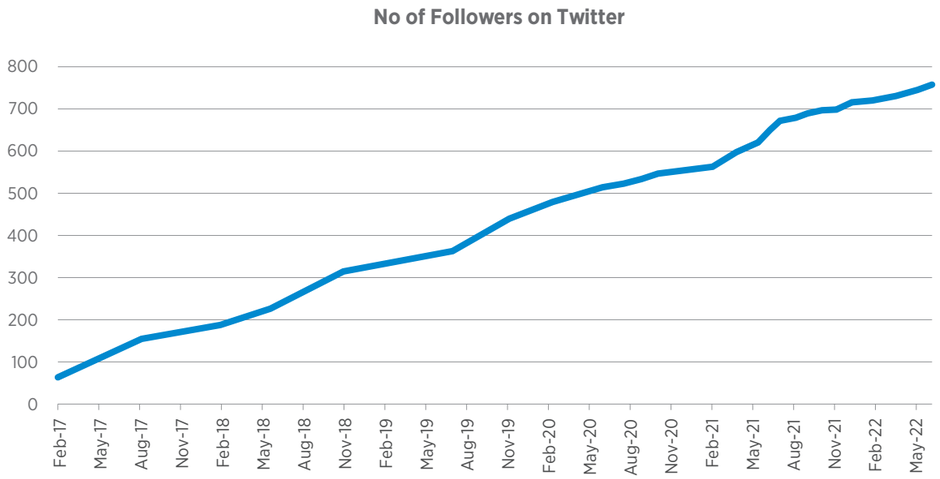
SUSFOOD has put in place several actions to promote aims, objectives and outcomes on project and network level. The main C&D activities under the first SUSFOOD project phase were dedicated to sharing of information, common vision and agenda. A mapping exercise has been performed and an online database called the Meta Knowledge Base or MKB, was developed. The results thereof were summarized in the **SUSFOOD Country Report** to highlight the possibilities for national funding in food research and the research institutes working within the food research landscape in the SUSFOOD countries in 2014.

Under SUSFOOD2, great emphasis has been laid on capacity building, e.g. offering trainings for researchers on C&D, valorization, Responsible Research and Innovation (RRI) etc. Following the SUSFOOD2 C&D Strategy, Twitter was used as additional social media platform next to the website and the biannual Newsletters.

Examples of C&D measures:

1. Twitter

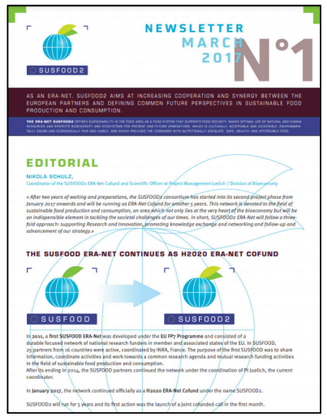
The @susfood_eranet Twitter account has become an important outreach tool for the communication and has gained content due to the inter-linkages with the funded projects. There has been a steady rise in followers from the end of the first year (end of 2017) with ~160 followers to ~280 by end of 2018 and ~440 followers in November 2019. In the communication strategy, we aimed at 500 followers and reach that number in the beginning of 2020. By the beginning of June 2022 SUSFOOD2 had 759 followers on Twitter and send out over 900 tweets.



2. Newsletter

In total, we sent out 11 newsletters, 2 of which were dedicated to the Joint Calls with Core Organic and FOSC to inform all stakeholders of the ERA-Net. Which means that during the runtime of SUSFOOD2, the Newsletter was sent out every six months. It gave an overview of the publications and other relevant events that have occurred during this time period and a meet the SUSFOOD2 partners part. The newsletter provides also a compact overview of the funded projects and it is a good way to summarize the project to its followers. Everybody could sign up for the newsletter on the link in the newsletter. The newsletters are also displayed on the website https://susfood-db-era.net/main/content/newsletter.

By December 2019 the newsletter had 736 subscribers. The number of subscriptions to the newsletter has remained status quo in recent years from December 2019 until now. The opening rate of the newsletter is about 300 people per newsletter and click rate is 36 percent.


NEWSLETTER
MARCH 2017 N°1
SUSFOOD2
AS AN ERA-NET, SUSFOOD2 AIMS AT INCREASING COOPERATION AND SYNERGY BETWEEN THE EUROPEAN PARTNERS AND DEFINING COMMON FUTURE PERSPECTIVES IN SUSTAINABLE FOOD PRODUCTION AND CONSUMPTION
EDITORIAL
NIKOLA SCHULZ,
THE SUSFOOD ERA-NET CONTINUES AS H2020 ERA-NET COFUND
SUSFOOD
SUSFOOD2


CORE organic
SUSFOOD2
Joint Newsletter n°1
November 2021
SUSFOOD2 PRIVACY POLICY
EDITORIAL
Sustainable organic food production and farming systems


FOSC
ERA-NET Cofund on Food Systems and Climate
SUSFOOD2
JOINT SUSFOOD2/FOSC CALL
First Newsletter - February 2022
Innovative solutions for resilient, climate-smart and sustainable food systems
Editorial
Dear Reader,

Photo competition with the Cofunded call projects

We passed the photo competition challenge to our 12 SUSFOOD2 cofunded call projects and asked them to visually display “How they are contributing to increase sustainability in the food system” by a photo labelled with a slogan.

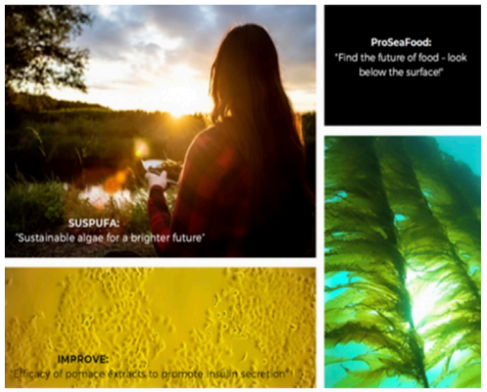
The main goal was to increase visibility and highlight the objective of each special project. Creativity and ability to engage your audience were the main criteria used to select a winner.

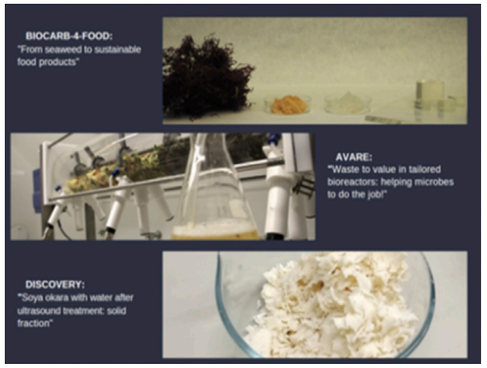
We received **27 pictures**, the researchers were very creative in producing beautiful pictures capturing their work or the idea they want to achieve. All the SUSFOOD2 partners and some volunteering EAB members had the difficult task to select a winner.

The winner of the photo competition was FUNBREW. They use the waste streams of beer to make new healthy products. FUNBREW received a web based video of their project together with guidance to communicate it broadly by the company Hague.

Postcards and Stamp

4 postcards with pictures from the research projects were used as promotion material during the project mid-term seminar to draw attention to the network and the funded research projects. All seminar invitees also had the opportunity to send one or more postcards. A SUSFOOD2 stamp was developed for this purpose.





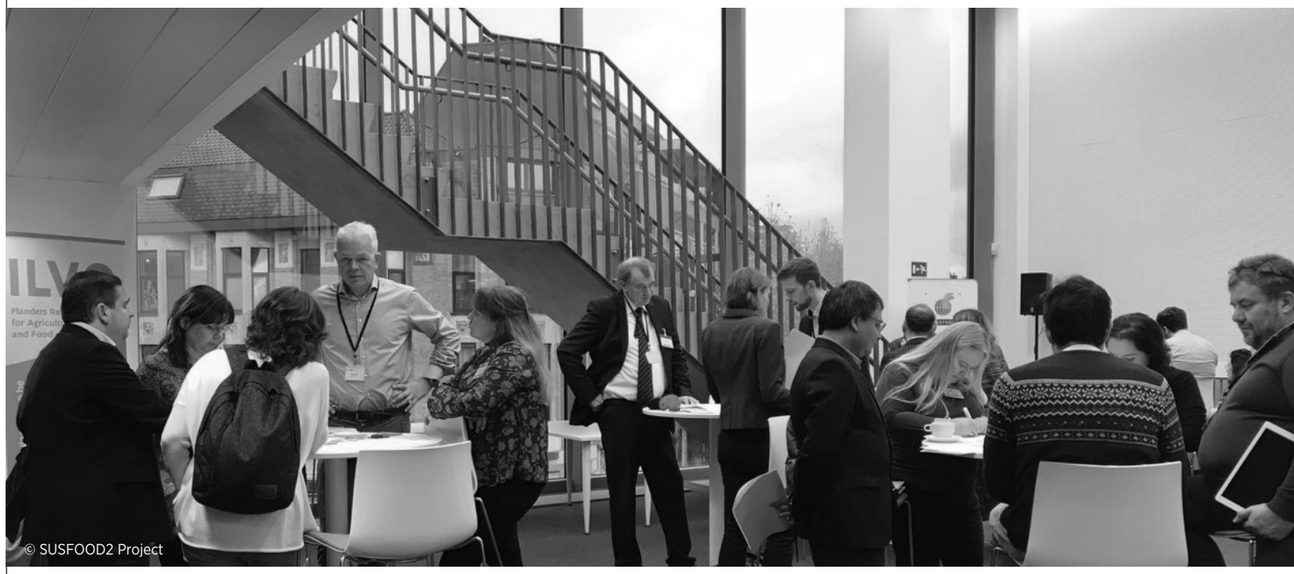
Examples of trainings and workshops/webinars for capacity building

1. Responsible Research and Innovation Workshop – 28 November 2019

During the mid-term seminar in Ghent the SUSFOOD 2 Consortium held an interactive workshop with an emphasis on Responsible Research and Innovation and Stakeholder engagement. The aim was to develop a concept for transnational Research and Innovation support focusing on stakeholder engagement in a European network.

Researchers, network partners, and External Advisory Board members took part in an interactive morning session including a mapping and a linked interview exercise with the main objectives to share knowledge and experiences and to collect suggestions and ideas.

The afternoon session involved the network partners and external advisory board and targeted the possible indications for SUSFOOD2 as well as potential future activities. **The NewHoRRIzon Project** supported the pilot action by providing facilitators, who helped preparing and implementing the sessions.



2. Valorization Workshop – 28 November 2019

Organized by Flanders' Food in close collaboration with ACTIA, this workshop dedicated to the projects partners supported by SUSFOOD2 was aiming to give them tips tools and contacts to better valorize projects results towards stakeholders and practitioners.

First, examples of success stories as well as presentation of examples of existing financial supporting measures in Belgium and France have been introduced.

Then, 3 working tables debating around valorization towards industry, practitioners and public authorities as well as problems related to patents and licensing have been organized.

This successful workshop has allowed participants and projects partners to better conduct valorization of projects results.

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3. Webinar on packaging – 02 December 2020

The webinar titled as "New solutions for innovative and sustainable food packaging" was conducted to offer knowledge and capacity building to projects partners supported by SUSFOOD2 in the field of food packaging on the 2nd of December 2020 (2 hours).

Coordinators and partners of projects funded or cofunded by SUSFOOD2 and also by CORE Organic were targeted (total 24 projects).

Through the presentation of MyPack EU running project coordinated by ACTIA and illustrated by different successful applications in the packaging sector, this webinar allowed to the participants to get an overview of potential solutions responding to the specification of the products and services studied in their project.

MyPack introduced various solutions of packaging (biofilms, Blow®technology) with different potential applications as well as studies results on sustainable packaging definition and features and consumers expectations.

At the end, a fruitful and interactive debate allowed the audience (36 participants) to get information about potential solutions responding to their needs and expectations.


© Suha Dinçer

4. Workshop for young researchers on impactful Communication – 15 January 2021

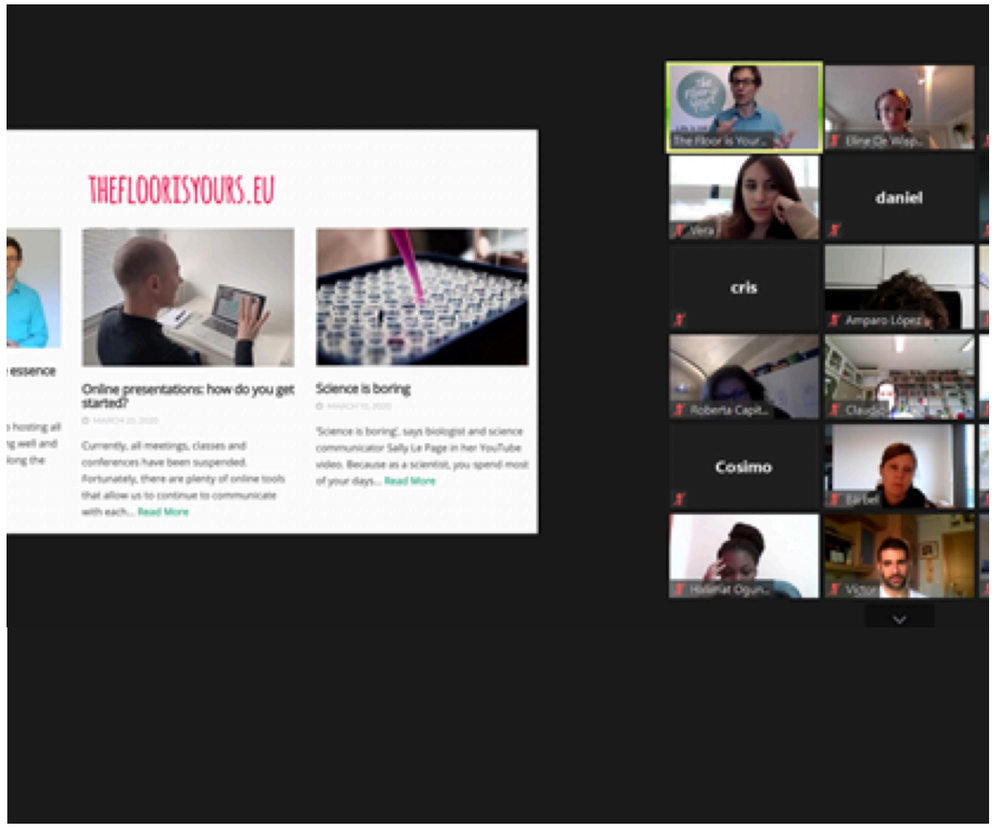
We invited our project coordinators and especially young researchers in the projects, to learn to present their research or project, in a clear and convincing manner, tailored to the needs of the target groups. With the goal to help us increase the visibility and awareness for the field of SUSFOOD2.

To reach this objective, SUSFOOD2 collaborated with The Floor is Yours for organizing the online workshop: Presenting with impact.

We structured the workshop into two sessions. The morning session was organised with a combination of theory, practical exercises and inspiring cases. We were using research or project examples from the 30 participants themselves, which we had requested beforehand and incorporated in the workshop. During the workshop, the participants gave a 1-minute presentation of their research.

During the try-out sessions in the afternoon, we delved deeper into the different presentation techniques and there was more room for practice. The participants each gave their 1-minute presentation a second time, allowing them to apply the tips and tricks from the workshop and receive more personalised feedback.

After the workshop, we asked the participants to share their experience with us. 11 participants (who represented 40% of the total) evaluated the content of the morning and the try-out sessions as well as the duration and organisational aspects of the workshop, all aspects were found to be excellent and very good. Overall, the workshop was evaluated excellent.



5. Policy online workshop with Cofunded call projects – 02 July 2021

The policy workshop was held online with the 12 SUSFOOD2 Cofunded call projects. The aim was to discuss and practice how to reach out and communicate with key stakeholder groups (e.g. policy makers, industry, public). The recommendations of the projects were clustered in order to be further developed into a joint policy brief on EU-level in order to speak with one strong voice. The SUSFOOD2 team has worked further on the policy brief and it was released in June 2022.

The headline of the policy brief is given below.

"Research on food production and consumption yields sustainable solutions but food system transition needs incentives!"

08 Networking and Connecting Stakeholders Within and Beyond Europe

This action field is closely related to Communication & Dissemination, yet stresses the need for joint undertakings through networking. Collaboration with related initiatives (alignment) is aimed at, as well as the creation of connections and partnerships within and beyond Europe.

From the very beginning, SUSFOOD has worked with the External Advisory Board, in which several organisations and also projects exist. The Joint Programming Initiatives (JPIs) given below are represented to advise and give input from an external point of view.

- **FACCE (Agriculture, Food Security and Climate Change)**
- **HDHL (A Healthy Diet for a Healthy Life)**
- **OCEANS**

Beyond this, interaction with other thematically related ERA-Nets has been achieved, e.g. close interaction with;

- **CORE Organic (Coordination of European Transnational Research in Organic Food and Farming Systems)**
- **FOSC (Food Systems and Climate)**
- **Blue Bio (Blue Bioeconomy)**

Networking is important, both on SUSFOOD level but also on project level and the research seminars of funded projects brought together actors from all across Europe to share their achievements, results, expertise and experiences. Achieved networks and connections stay viable also beyond the projects runtime.

Seminars of Research Projects

1. Cofunded Call Kick-off seminar – 24&25 October 2018 – Stockholm

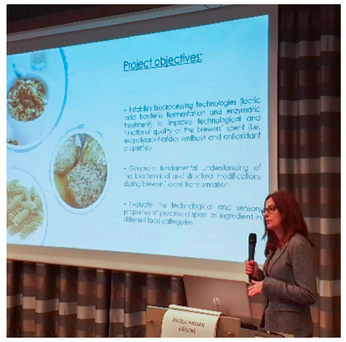
In October 2018, the SUSFOOD2 ERA-NET held the kick-off seminar of the 12 research projects funded under the cofunded call. This seminar took place in Stockholm, Sweden with 76 participants including network partners, members of the External Advisory Board and invited Swedish projects representatives.

The SUSFOOD2 projects were asked to apply various forms of presentations; a marketplace pitch, a classic power-point presentation and a debate.

During the seminar, the invited Swedish projects representatives also had their turn to present themselves.

Two keynote speeches gave further inspiration: Line Gordon (Stockholm Resilience Center) explained the concept of planetary boundaries and Clare Shelley-Egan (Oslo Metropolitan University) emphasized the need for Responsible Research and Innovation.

At the kick-off seminar, a training on Communication & Dissemination, facilitated by Rhonda Smith (Minerva), was offered for the support and to strengthen communication skills.



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2. Cofunded Call Mid-term seminar – 28&29 November 2019 – Ghent

The SUSFOOD consortium, 56 participants large, was present in Ghent, for the Cofunded Call Mid-term seminar hosted by the Flemish Research Institute for Agriculture, Fisheries and Food (ILVO) from 28th to 29th of November 2019. Several activities were organized for the SUSFOOD2 partners, the research project coordinators (or representatives) and the SUSFOOD2 External Advisory board, with a focus on the first results of the projects, Responsible Research and Innovation and “tips and tricks to valorise research”.

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On the first day of the Mid-term we made a visit to the Food Pilot, an application and analysis center, with facilities that can mimic all sorts of food production lines (meat, vegies, fruits, dairy, …) cofounded by ILVO and Flanders’ FOOD.

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The next day, the second part of the mid-term with presentations of the results of the projects was held in co-organisation with the Flanders’ FOOD Inspiration Days and EIT FOOD. This doubled the number of participants and gave researchers the opportunity to mingle with industry and get their results communicated broader.

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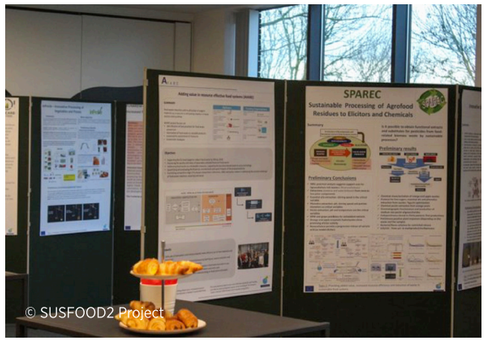
During lunch, a postermarket of all SUSFOOD2 research projects was organized.



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3. Cofunded call Final project seminar – 26 October 2021 – İstanbul

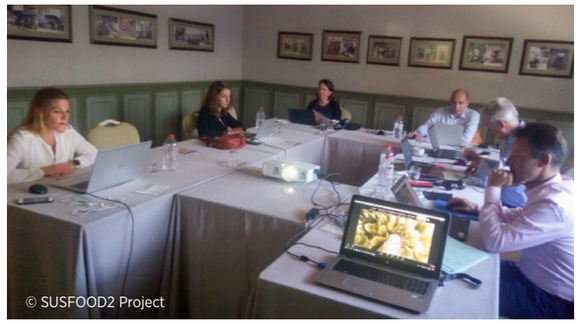
SUSFOOD2 conducted a final seminar for the 12 cofunded projects on 26 October 2021 in Istanbul as a hybrid meeting to reveal the findings of the projects three-year studies, which had the mission to work towards more sustainable, resilient and secure food systems, by reinforcing the cooperation in research, development and innovation between EU Member and associated States.

There were 41 participants in the seminar, including members of SUSFOOD2 Governing Board and External Advisory Board, project representatives and invited guests. Although the number of registered people was higher than the actual attendance, the majority of people joined online, whereas 7 of the participants joined the seminar physically in Istanbul (due to Covid-19 pandemic).

The final seminar started with welcoming words and presentations of the SUSFOOD2 coordination (Nikola Hassan) and TAGEM, the host of the seminar represented by Ahmet Budaklıer. The main part of the seminar was composed of two pitches and two open discussion sessions of the projects.

Since the 12 project presentations needed to be short, we invited the participants to already get an overview of the work achieved by watching the videos that each project has prepared which are still available at https://susfood-db-era.net/main/projects-presentation.

More information about this final seminar can be found in the **SUSFOOD2 Final Seminar Report.**



Examples of Networking Events

1. SUSFOOD session @ EFFoST – 14 November 2017

Every year the **European Federation of Food Science & Technology (EFFoST)** organizes an international food science and technology conference, an important scientific event that brings together world-renowned researchers, scientists, policy makers, professionals and students from multidisciplinary food-related fields to share the latest developments.

The 31st edition of the International EFFoST conference took place on 13-16th November 2017 in Sitges (Spain) under the theme Food Science and Technology Challenges for the 21st Century - Research to Progress Society.

This was a perfect opportunity for 10 projects funded under the FP7 ERA-Net SUSFOOD calls in 2013 and 2014 to share their outcomes to the research community and stakeholders which were numerously present in a special SUSFOOD meets EFFOST session on November 14th 2017 in Sitges (Barcelona).

After a general presentation on SUSFOOD by our Coordinator Nikola Hassan, the presenters of the 10 following projects took the stage, which were BERRYPOM, OATPRO, Sustainable&Healthy, SUSDIET, SUNNIVA, SUSMEATPRO, BIOPROT, FOCAS, RF Cooking Ham, FREEZEWAVE.

More information about the event is available here.

2. ERA-NETs SUSFOOD2 and BlueBio networking event – 23 September 2021

In September 2021, the ERA-Net programmes SUSFOOD2 and BlueBio jointly organised an online workshop on market pathways for sustainable algae products. The goal of the workshop was to bring research and industry together to discuss the future of sustainable algae products and especially about market issues like regulation, pilot scale infrastructure, techno-economic feasibility and sustainability.

Algae were chosen as topic of the joint workshop since they are a natural, innovative and sustainable resource of fatty acids, proteins, carbohydrates, antioxidants and colorants. They will play an important role in the blue bio-economy of the future as resource for food, feed, chemical and material applications. In both ERA-Net programmes, several research projects based on algae as resource are funded.

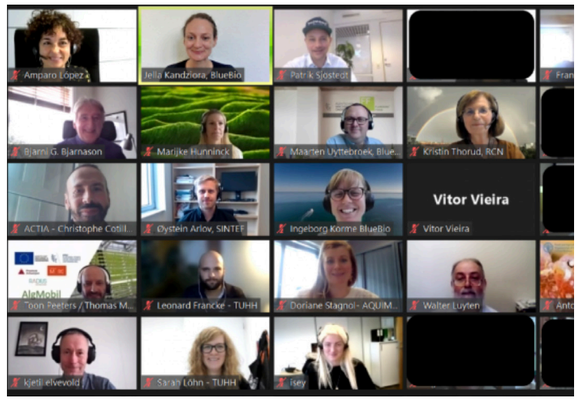
After an introduction by Frank Hensgen (SUSFOOD2) and Kristin Thorud (BlueBio), the following two keynotes from a company perspective were given:

1) Astaxanthin made in Schleswig-Holstein: key points for sustainable algae products (Stefan Hindersin, Sea & Sun Technology)

2) The power of seaweed: a sustainable raw material (Angela Garcia Agis, CEAMSA)

After the four flash project presentations from the SUSFOOD2 and BlueBio programmes discussions were held in 4 different break-out groups as regulation, pilot testing and upscaling, economics and sustainability.

More information can be found in the event report.



3. Stakeholders workshop – 27 October 2021

SUSFOOD2 organised the Stakeholders workshop to inform a wider interested audience on the progress made by SUSFOOD2 funded projects and to explore the next steps to enable interaction between the research teams and stakeholders. The workshop was mainly an online event, due to Covid 19 pandemic and the still strict travel restrictions in many countries.

Of 110 registered persons, 60 attended the stakeholders workshop. The main group of participants came from academia and research institutes, followed by policymakers and funding agencies as well as a few participants from industry and NGOs.

During the event, we discuss three different topics in breakout sessions. These are:

- "Smart" consumers: How can R&I lead to well-informed consumers?
- Value from waste: Food losses and waste in the context of sustainable food systems
- Bringing new sustainable technologies to the market- chances and barriers:
- Acceptance and adoption–bottlenecks for new food technology?

In order to have an overview of the work done by the 12 projects, everyone was invited to watch the **videos** that each project had prepared:

The coordinators first gave a short presentation of their project, focusing on the applicability of the results and what future research needs remain. In addition, a message was formulated for the stakeholders and the end-users. Many substantive discussions were held, in which the questions were motivated through the use of Slido. The discussions also touched upon important other new research themes, missing actors to advance R&I even faster in future projects, next steps towards innovation.

Finally, an evaluation of sorts was made and questions were asked as to how SUSFOOD2could further support the research and researchers in the field of sustainable food systems.

More information can be found on the Stakeholders workshop summary report.

4. 10 year anniversary and final event - “Looking back – moving forward” - 16/17 June 2022

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During the days of 16th and 17th of June 2022, SUSFOOD celebrated its **10th anniversary** at the German representation of the State of Northrhine-Westphalia. The meeting from Lunch to Lunch was also streamed online to allow participants to follow the event remotely. 54 participants joined the live event and 18 participants followed the livestream. Nikola Hassan, Frank Hengen (Juelich) and Hendrik de Ruyck (ILVO) welcomed the participants and opened the meeting. At first, the achievements and lessons learned were presented by Nikola Hassan and Marijke Hunninck (ILVO), who displayed that a number of significant impacts have already been achieved.

One very important part of SUSFOOD are of course the research projects and a selection of projects representatives for the diversity of SUSFOOD were present during the meeting. The projects were asked to pitch their project using a unique object they brought along.

The keynotes on the first day were held by Florence Tartanac (FAO) and Daniela Lüth (DG RTD, European Commission). Florence Tartanac presented a keynote on “Food systems as holistic approach”, an approach SUSFOOD tried to promote during the whole lifetime of the project. Daniela Lüth presented the “mid- and longterm goals from Farm2Fork and Food2030“. Both presentations can be downloaded. A panel discussion, led by Wim Haentjens (ILVO), on “Impact of R&I on the transition of food systems, and future R&I needs” featuring the panelists Daniela Lüth, Sirpa Kurppa (Luke), Minna Huttunnen (MMM), Susanne Braun (FoodForce) and Inge Arents (Flanders´Food) tried to answer the question “did SUSFOOD make an impact”. Important achievements mentioned were the prosperous networking, the importance of the transnational projects for industry and “EU-new comers”, the strong strategic basis from FP7, clear relevance and followed systems approach. For the future, biodiversity, place-based solutions and citizen engagement will be important aspects, among others.

The second day marked the transition from looking at the past to the way forward. A discussion round with the SUSFOOD projects showed interesting lessons to learn (e.g. how to cooperate with the industry and achieve technology transfer,

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importance of providing continuity in research and also options for follow-up projects or longer project durations, controversy of multidisciplinarity and academic pressure for excellence, very different levels of the understanding of who or what is a food system, the role of policy etc.)

A presentation by Dorri te Boekhorst (WUR) showcased the Green ERA HUB CSA and conveyed the importance of this initiative for the future of the SUSFOOD community. GEH is perserving on the achievements of different ERA-NETS, and will further explore how to valorise the projects results (see presentation). Another presentation by Hugo de Vries (INRAE) introduced the CSA « FOODPathS » and how this CSA helps to lead the way towards the Sustainable Food Systems partnership. A panel discussion moderated by Nikola Hassan took up the topic of transition by discussing under the headline “From ERA-Nets to Partnerships — transition of the collaborative framework and practices”. The panelists were Ivana Trkulja (ICROFS/ CORE Organic), Hugo de Vries and Niels Gotke (UFM). Important insights were the strong strategic and co-creation approach towards the partnerships which also leads to new dialogues on all levels as well as challenges and opportunities for the new instrument, which the networks as living organisms will tackle. The meeting closed with a look forward, expectations from SUSFOOD partners and many thanks from the coordination team.


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International outreach

In 2012 the EU Commission proposed a strategic approach to enhance and focus the Union's international cooperation activities in research and innovation. In this framework, ERA-Net Cofunds, named as instruments contributing to the outreach of the EU research and innovation area, were asked to support the ERA priorities also by improving international connectivity both across agencies and countries as well as research communities.

SUSFOOD2, in line with the objectives of the ERA strategy, has always been keen to realize the common vision of a sustainable food production and consumption in Europe and beyond, therefore promoting knowledge exchange and the visibility of SUSFOOD2 in and outside of Europe, and supporting the enhancement of a multidisciplinary research community working in the field of food sustainability with a multi-actor approach and at all geographical scales.

Based on the Strategic research Agenda statement "All food chain partners contribute to achieving sustainable, secure and resilient food systems which feed the world and make sustainable choices the easy and preferable choices for consumers", the network has implemented focussed activities, which include: a mapping exercise, in order to identify potential new partners active in the scope of SUSFOOD2, participation to international food events attended by industry representatives, researchers from different parts of the world, and other key stakeholders, joint calls with partnerships including non-EU partners, exchanges on vision and strategies with other networks, invitation of international food network representatives in SF meetings and workshops, enlargement of the External Advisory Board with inclusion of international key-players.

Europe and the involved R&I actors, including ERA-Nets, have reached some first results in terms of global transformation of the research area and its impact on our societies, but everyone is fully aware that the pathway will take much more than one EU R&I funding programme...SUSFOOD2 partners are now contributing to framing the new opportunities proposed under Horizon Europe, and are ready to further cooperate in an international context.

09 Projects funded by SUSFOOD

SUSFOOD network has launched 5 calls and funded 44 projects from 4 thematic research area. The funded projects are one of the most important outputs of SUSFOOD network. This chapter is prepared to provide detailed information about these projects.

These 4 thematic research areas are:

- Resource Efficieny and Valorization
- Processing Technologies
- Sustainable and Diverse Food Systems
- Consumer Behaviour

Below table demonstrates the calls and related pages. Detailed information about the funded projects are given under each call.

PROJECTS BY RESEARCH AREA

Resource Efficieny and Valorization

Acronym	Title	Call	Page
CEREAL	Improved and resource efficiency throughout the post-harvest chain of fresh-cut fruits and vegetables	2013	70
SUNNIVA	Sustainable food production through quality optimized raw material production and processing technologies for premium quality vegetable products and generated by-products	2013	75
BIOSUCK	Decision support system on optimized waste collection by vacuum technology with simultaneous production of bioenergy from wastes	2013	80
BERRYPOM	Adding value to fruit processing waste: innovative ways to incorporate fibres from berry pomace in baked and extruded cereal-based foods	2014	124
SUSMEATPRO	Sustainable plant ingredients for healthier meat products - proof of concepts	2014	129
OATPRO	Engineering of oat proteins: Consumer driven sustainable food development process	2014	134
FUNBREW	Biotransformation of brewers' spent grain: increased functionality for novel food applications	2017	147
DISCOVERY	Disaggregation of conventional vegetable press cakes by novel techniques to receive new products and to increase the yield	2017	156
AVARE	Adding value in resource effective food systems	2017	164
SPAREC	Sustainable Processing of Agrofood Residues to Elicitors and Chemicals	2017	168
ImPrOVe	Innovative (pre)POmace Valorization procEss	2017	171
SUSPUFA	Sustainable production of health-promoting n-3 LC-PUFA using agro food industry by-products through microalgae	2017	176
FERBLEND	Fermentation-induced valorization of side stream blends from oilseed and dairy industry	2019	195
Bio4Food	High quality and nutrient rich food through crop waste-derived biostimulant and biopesticide	2019	197
ALL-IN	ALfalfa for sustainable Livestock farming systems: Improve alfalfa -rhizobia symbiosis and New feeding strategy based on ecological leftovers	2019	199
Poultrynsect	The use of live insect larvae to improve sustainability and animal welfare of organic chickens production	2019	203
PROVIDE	PRotein and biOmolecules sources for nutritional security and biodiVersity of bakery products in a cIrcular fooD system	2019	204
AlgaeBrew	Unlocking the potential of microalgae for the valorisation of brewery waste products into omega-3 rich animal feed and fertilisers	2021	215
IPSUS	Climate smart food innovation using plant and seaweed proteins from upcycled sources	2021	219
Olive3P	Innovative sustainable food system for olive oil production converting solid and liquid by-products into edible yeast and biopesticide	2021	221

Processing Technologies

Acronym	Title	Call	Page
CIBUS-FOOD	Computational-design and Innovative Building of Uniquely Structured Food	2013	84
Sustainable & Healthy	Development of sustainable processing technologies for converting by-products into healthy, added value ingredients and food products	2013	89
BIOPROT	Novel multifunctional plant protein ingredients with bioprocessing	2013	95
FREEZEWAVE	Innovative and low energy microwave assisted freezing process for high quality foods	2014	110
RF-cooking of Ham	Rapid industrial scale cooking of boiled ham using radio frequency electric fields	2014	116
ProRef	Gentle and resource-efficient refining of vegetable oils for preservation of valuable components and simplified reprocessing of by-products	2014	120
BIOCARB-4-FOOD	Extraction and characterization of BIOactives and CARBohydrates from seaweeds and seagrasses FOR FOOD-related applications	2017	139
InProVe	Innovative Processing of Vegetables and Potato	2017	143

MEFPROC	Improving Sustainability in Food Processing using Moderate Electric Fields (MEF) for Process Intensification and Smart Processing	2017	151
ProSeaFood	Innovative processing of seaweed for novel, healthy food products and ingredients	2017	159
SPiwi	Sustainable production of innovative sparkling wine	2019	207
MILDSUSFRUIT	Innovative Mild Processing Tailored to Ensure Sustainable and High Quality Organic Fruit Products	2019	209
HO-FOOD	Innovative High pressure process to increase the preservation of ready-to-eat Organic FOOD	2019	211
MI-WINE	Mild Innovative Treatment for Wine Stabilisation	2019	212

Sustainable and diverse Food Systems

Acronym	Title	Call	Page
FOODLEVERS	Leverage points for organic and sustainable food systems	2019	193
SysOrg	Organic agro- food systems as models for sustainable food systems in Europe and Northern Africa	2019	201
FOOdIVERSE	Diversifying sustainable and organic food systems	2019	206
MedAgriFood Resilience	Socio-environmental shocks assessment and resilience empowerment in Mediterranean agri-food heritage systems: Italy, Morocco, Algeria FAO GIAHS sites	2021	217
SmartDairy	Climate-smart Dairy: Assessing Challenges, Innovations, and Solutions	2021	222

Consumer behaviour

Acronym	Title	Call	Page
FOCAS	Food, Convenience and Sustainability	2013	98
COSUS	Consumers in a sustainable food supply chain: understanding barriers and facilitators for acceptance of visually suboptimal foods	2013	103
SUSDIET	Implementing sustainable diets in Europe	2013	105
SUSCHOICE	Towards Sustainable Food and Drink Choices among European Young Adults: Drivers, Barriers and Strategical Implications	2017	182
PLATEFORMS	Sustainable Food Platforms: Enabling sustainable food practices through socio-technical innovation	2017	188

PROJECTS FUNDED IN THE FIRST CALL OF SUSFOOD (2013)

There are 9 projects funded in the first call. Detailed information about the projects listed below is provided in this section.

Nr	Acronym	Project Title
1	CEREAL	Improved and resource efficiency throughout the post-harvest chain of fresh-cut fruits and vegetables
2	Sunniva	Sustainable food production through quality optimized raw material production and processing tech-nologies for premium quality vegetable products and generated by-products
3	BioSuck	Decision support system on optimized waste collection by vacuum technology with simultaneous production of bioenergy from wastes
4	CIBUS-FOOD	Computational-design and Innovative Building of Uniquely Structured Food
5	Sustainable&Healthy	Development of sustainable processing technologies for converting by-products into healthy, added value ingredients and food products
6	BIOPROT	Novel multifunctional plant protein ingredients with bioprocessing
7	FOCAS	Food, Convenience and Sustainability
8	COSUS	Consumers in a sustainable food supply chain: understanding barriers and facilitators for acceptance of visually suboptimal foods
9	SUSDIET	Implementing sustainable diets in Europe

1. CEREAL

CALL 2013

Improved resource efficiency throughout the post-harvest chain of fresh-cut and vegetables

PROJECT TEAM

Coordinator:

Amadeo R. Fernández-Alba, University of Almeria, Spain

Partners:

Roberto Rosal, UAH, Spain

Mª Dolores Hernando, INIA, Spain

Clara Silvestre, CNR, Italy

Aji P. Mathe, LTU/SU, Sweden

Peter Muranyi, IVV, Germany

Mika Manttari, LUT, Finland

Yuece Sueleyman, RWTH, Germany

Summary

EU agricultural industry sustainability depends to a major extent on its capability to introduce new, ready-to-eat fresh and composite fruit and vegetable products. This, in turn, requires significant improvement in produce cleaning and packaging technologies to ensure food quality and safety, reduced input of water/energy and enhancing waste recyclability.

The improvements in resource efficiency were achieved by exploring solutions provided by advances in nanotechnology. A new generation of ultra and nanofiltration membranes with biocidal functionalization reduced the dose of disinfectant agents and saving water by improving recyclability. Residues from food processing (cellulose) were also used to produce nanomembranes. The incorporation of nanoparticle-based active coatings in ceramic modules allowed operation under strong oxidizing conditions with the production of ozone by pulsed corona discharge (PCD), which is an energy efficient process. The water purification process based on the use of the developed membranes combined with filtration and oxidation process shown that nanofiltration with polymeric membranes produced better quality in the treated water than using the PCD oxidation. Acceptable removal rate of contaminants (>50%) was achieved in few minutes of treatment by filtration processes. PCD treatment was effective for the elimination of by-products of pesticides in few minutes. The nanocellulose membranes were effective by limiting microbial growth and biofouling.

According to the life cycle impact assessment (LCIA), the use of the four technologies reduced environmental impacts by approximately 50% for all categories at midpoint level. The single score ReCiPe (H/H) showed an overall reduction of the environmental burdens of 55% by the use of nanofiltration, 56% by ultrafiltration and 47% for the scenario of PCD. Sensitivity analysis showed net environmental benefits even when water recirculation was reduced up to 20% from the reference scenario. The reference scenario for the eco-sustainable packaging options confirmed that lettuce production entails by far the larger environmental burden, followed by the PPR bag production and the washing stage (considering current-use technology with sodium hypochlorite). Single score ReCiPe (H/H) shown that the use of PLA+ZnO reduced the environmental impact of lettuce consumption by 10% while the package made from PPR+ZnO entailed reductions of a 9%.

Results and Achievements

Nanocomposite membranes were prepared with polylactic acid (PLA), polyacrylic acid (PAA), polyvinyl alcohol (PVA), polymers cellulose acetate (CA), polyurethanes (PS), polyvinylpyrrolidone (PVP) and nanoparticles (supported and unsupported metals and metals oxides) in order to evaluate selective removal of contaminants from water in food processing by ultrafiltration and nanofiltration methods. The CA polymers surface were coated with chitin nanocrystals (ChNC) or cellulose nanocrystals (CNC) to obtain water filtration membranes.

Dynamic and static tests methods were used to determine the integrity of membrane systems through the study of liberation efficiency of new active materials from manufactured membranes for the water treatment processes in the food sector. In the case of formulations containing only PS-AgNPs release was higher for those containing a higher content of Ag (5%). For the membranes containing PS-PVP-NPs, both formulations (Ag & AgCu) shown a similar rate of release silver ions.

A new membrane module was developed and evaluated to reclaim water from the washing process of fresh-cut produce investigated. Experiments shown that mainly bacteria were retained and removed from the process cycle therefore, bacteria were not accumulated in the process water. A test with commercial membranes shown that the application of static mixers improves the filtration. Fouling was reduced and the permeate flux increased. Thus, the process was more energy-efficient and required less use of chemicals for membrane cleaning. A simulation model shown that the ultrafiltration of the process water is possible and a high recovery rate can be reached so that a saving of more than 50% of the process water could be achievable. Recycled material membranes (CA) also shown excellent improvement in mechanical properties, flux, contact angle and surface morphology as well as antifouling performance.

The water purification process based on the use of the developed membranes combined with filtration and oxidation process shown that nanofiltration with polymeric membranes produced better quality in the treated water than the PCD oxidation. The oxidation did not seen to improve the flux in short-period of filtrations and it decreased a bit retention of organic compounds.

Regarding the chemical evaluation to determine removal efficacy of the developed membranes, good results were observed for membranes using NPs (Ag & Cu), in treatment times of up to 80 minutes. Nanocrystal membranes provided an acceptable removal rate of pesticides (>50%) in 5 minutes of treatment. In terms of effectiveness, the use of ozone provided a removal percentage higher than 50% for the targeted pesticides, in a time of 30 minutes of treatment. The elimination of contaminants was slower when the test was carried out in salad washing water.

Antibiofouling properties were studied using different strains of bacteria and fungi selected from the ISO Standards BS ISO 16869 (Assessment of the effectiveness of fungistatic compounds in plastics formulations) and ISO 22196 (Measurement of antibacterial activity on plastics and other non-porous surfaces). The results obtained shown that microbial growth was significantly impaired by all metal-containing particles. Ag/SBA and Cu/SBA membranes had led to a reduction of about 40% and 65% with respect to SBA and controls. Cu/SEP configuration was efficient in reducing fungal growth and metabolic activity. The bacterial growth was significantly impaired by PAA/PVA membranes containing > 35 wt.% PAA. CA fibers shown rejection of 20-56% for particles of 0.5-2.0 μm, indicating potential of these membranes in rejecting microorganisms from water. PS-membranes proved to exhibit an antimicrobial effect against Pseudomonas fluorescens as well as E. coli. However, immediate blockage of membranes during filtration of bacterial suspensions enabled permeation of only few ml, even at high pressure of 5 bar. Regarding the films made of CA, retention capacity was very low. In this case, no pressure was necessary for filtration of bacterial suspensions.

According to the life cycle impact assessment (LCIA), the use of the four technologies reduced

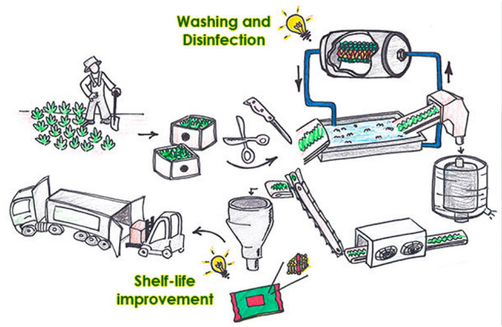
environmental impacts by approximately 50% for all categories at midpoint level but Ozone process, where both scenarios of nanofiltration (the one with AgNP and the one assisted by PCD) scored higher. The single score ReCiPe (H/H) showed an overall reduction of the environmental burdens of 55% by the use of nanofiltration+AgNP or the recycled materials membrane, 56% when process water was treated with ultrafiltration and 47% for the scenario of nanofiltration+PCD. Sensitivity analysis showed net environmental benefits even when water recirculation was reduced up to 20% from the reference scenario.

On the other hand, a new generation of packaging materials based on nanotechnology were prepared using polypropylene (PPR), polylimonene (PL), polylactic acid (PLA) and nanoparticles (ZnO), in order to extend the shelf-life of fresh produces and to reduce wastes. The addition of polylimonene (PL) to PPR has a great effect to reduce the O_2 and CO_2 permeability, although a small increase of WV permeability was also found. Films with plain ZnO present good tensile mechanical properties and lower permeability to O_2 and CO_2. The investigation demonstrated that the modified ZnO particles must not be used because their presence worsen of the tensile mechanical properties of the film.

Regarding chemical evaluation for determining safety of packing materials, in the PPR+PL+ZnO based films, 5 compounds (non-intentionally added substances, NIAS) were tentatively identified as migrating species under the experimental conditions with the simulant B (3% acetic acid), while 3 with simulant A (10% ethanol). In the PL+PLA+ZnO based films, 3 GC-amenable NIAS were tentatively identified in simulant A. Four LC-amenable NIAS were tentatively identified in simulant B. The nanopolymer composed of PLA+ZnO, provided to be the most suitable food contact material with improved functionality, based on the migration test; PL additive appears to stimulate the migration of organic compounds and Zn2+ release.

Different packaging films with incorporated ZnO and PL were evaluated for their antimicrobial efficiency. The films made of PPR and PL with incorporated ZnO exhibited significant antimicrobial properties when tested according to the procedure of ISO 22196 against E. coli, Listeria innocua or S. aureus. PL films showed very low antimicrobial effects.

The reference scenario for the eco-sustainable packaging options confirmed that lettuce production entails by far the larger environmental burden, followed by the PPR bag production and the washing stage (considering current-use technology with sodium hypochlorite). Single score ReCiPe (H/H) shown that the use of PLA+ZnO reduced the environmental impact of lettuce consumption by 10% while the package made from PPR+ZnO entailed reductions of a 9%.



Impact

The transnational cooperation was basic and essential for the achievements and knowledge.

The partners 2 (UAH) and 5 (LTU-SU) developed membranes functionalized with different materials and nanoparticles, tasks involved in WP1. The partners 2 and 5 provided membranes and they were evaluated in modules in WP2 (RWTH). The evaluation of membranes and processes was performed in WP4 (chemical, UAL) and WP5 (antimicrobial, IVV). The international collaboration with Partner 8 (RWTH), 7 (LUT), 1 (UAL) and 5 (IVV-Fraunhofer) was essential. Developed membranes achieved an acceptable removal for all the pesticides studied (>50%) in few minutes of treatment by filtration processes. A reduction rate higher than 50% was obtained for targeted pesticides in 30 minutes using ozone. The water ultrafiltration process was feasible and high recovery rates could be reached so that a saving of more than 50% of the process water was achievable. PS-membranes proved to exhibit an antimicrobial effect against Pseudomonas fluorescens as well as E. coli.

The partner 4 (CNR) developed PPR based film (with polylimonene and ZnO) and PLA based film (with ZnO) that have been shown to possess excellent mechanical properties (barrier and tensile). The international collaboration with Partner 1(UAL), 3 (INIA) and 5 (IVV-Fraunhofer) was essential to demonstrate the properties of such films as solutions to increase the performance of the polymers further adding safety, economical and environmental advantages. The partner 3 (INIA) was in charge for the Evaluation of the developed technologies/materials for post-harvest chain processing of fresh-cut fruits and vegetables by a life cycle assessment study (LCA) and life cycle impact assessment impact assessment (LCIA), with a view to achieving a more sustainable production.

Conclusion and Recommendations

Electrospun membranes functionalized with nanoparticles and recycled materials developed in CEREAL project shown to possess excellent mechanical properties. They achieved an acceptable removal for pesticides (>50%) in few minutes of treatment by filtration processes and in 30 minutes of treatment by PCD treatment. They proved to exhibit an antimicrobial effect against Pseudomonas fluorescens as well as E. coli. Furthermore, a significant amount of the water used to washing process of fresh-cut vegetables and fruits was saveable (around 50% in some cases). Based on the findings of CEREAL project, the results highlighted an overall reduction of the environmental burdens of 55% and 56% when process water was treated with nanofiltration or ultrafiltration, respectively (in combination with AgNP or recycled material membranes), whereas 47% was the reduction obtained using nanofiltration process combined with PCD treatment. Sensitivity analysis showed net environmental benefits even when water

recirculation is reduced up to 20% from the reference scenario. In summary, it can be concluded that membrane filtration is a safe and reliable solution to save water, chemicals, and energy in the washing processes of fresh-cut fruits and vegetables. For the eco-sustainable packaging options for the results shown that the use of PLA+ZnONP reduces the environmental impact of lettuce consumption by 10% while the package made from PP+ZnONP entails reductions of a 9%. During the project, several partners were in contact with different food processing companies interested in installing a membrane plant for the reuse of the water used to washing process of fresh-cut vegetables/fruit. This together with the transnational cooperation of the different research groups involved in the project was basic and essential for the transfer knowledge and achievements of the project.

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2. SUNNIVA

CALL 2013

Sustainable food production through quality optimized raw material production and processing technologies for premium quality vegetable products and generated by-products

PROJECT TEAM

Coordinator:

Trond Løvdal, NOFIMA, Norway

Partners:

Ingunn Vågen, NIBIO, Norway

Agnieszka Bartoszek, GUT, Poland

Giovanni Agati, CNR-IFAC, Italy

Bart Van Droogenbroeck, ILVO, Belgium

Ferruh Erdogdu, AU, Türkiye

Inge Hanssen, DCM, Belgium

Christophe Robin, INRA, France

Mustafa Tutar, MGEP, Spain

Christine Vos, KU Leuven, Belgium

Stanisław Kaniszewski, InHort Research Intitute of Horticulture, Poland

Caglar Eroglu, Alata Horticultural Research Institute, Türkiye

Bernd Lambrechts , Greenyard Prepared, Belgium

Marek Krajczynski, Enbio Technology, Poland

Øivind Winther Fosvold, Fjordland AS, Norway

Dorota Piasecka, Company Nowak, Poland

Martin Sunde, Fjordkjøkken AS, Norway

Summary

The project Sustainable food production through quality optimized raw-material production and processing technologies for premium quality vegetable products and generated by-products [SUNNIVA] was funded under the framework of the Era-Net SusFood Call (2014-2017). SUNNIVA aimed at the development of a sustainable food system from production to consumption, addressing the entire food supply chain for the vegetables tomato and Brassicae. The goal was better utilisation of the vegetable raw materials, reduced energy and water consumption, higher profitability and healthier food. This was achieved by providing various valorisation strategies to reduce waste and limiting environmental impact. Preservation of the intrinsic health-beneficial phytochemicals (HBPC) present in the raw material in order to improve the nutritional properties of vegetable food products was central in the project. The project contained optimization of harvest time and pre-processing storage conditions, development of novel mild processing design based on modelling, and a two-track valorisation strategy.

Non-destructive optical tools to estimate in situ flavonols and chlorophyll of Brassicae, and lycopene content of tomatoes were developed. These tools enable many samplings in a very short time compared to conventional wet chemistry and allows for rapid and inexpensive monitoring of HBPC content in the vegetables. The spectrometers can be used when the fruit is still attached to the plant, either in the field or in the greenhouse, for a fast selection of products before harvesting, or during storage for selection before processing. Elicitor treatment of cabbage and tomato to improve storability of the raw material prior to processing and at the same time preserve or increase HBPC was investigated aided by the optical tools developed.

Energy efficient processing designs for novel food products based on fresh and pre-processed tomato and Brassicae raw material were developed. This resulted in prototype sausage and meatloaf comminute products with 18% (w/w) cabbage. These novel products have a high nutritional value relative to the conventional meat products and comparable sensory quality.

Microwave flow pasteurization was demonstrated a feasible processing strategy for the prefabrication of cabbage, and also in combination with the oxygen-free spiral filter press for the processing of tomato and apple juices. Moreover, numerical models for heat-transfer and heat distribution in agitated retort systems and industrial type over-pressure microwave ovens were derived. Compared to the traditional industrial static autoclaves, the novel technologies demonstrated a large potential in energy- and water saving. Reduced thermal processing times enabled by in-pack microwave cooking significantly improved sensory properties (especially texture and colour) of cauliflower and broccoli.

Research has been performed to develop valorisation strategies for underutilized vegetable biomass and processing side-streams. This was pursued through two tracks: first the recycling of these fractions back into the food chain. Second, the fractions not suitable for recycling into the food chain were assessed for their potential as raw material for organic fertilizer or soil amendment products. Using mild, cost- and energy efficient processing technologies, several different high-quality vegetable side-stream fractions could be processed into juices, smoothies and purees, or otherwise be applied as functional ingredients in food products. It was thus demonstrated that vegetable by-products and side streams could be successfully transformed into tasteful and healthy food products by the use of energy- and cost-efficient technologies. Biomass left over from this production, like press cakes, peel, and scales, was finally incorporated as raw material for organic fertilizer products and the effect on plant growth promotion was investigated.

Results and Achievements

WP1: Initial properties of cabbage and tomato and their waste fractions were determined, to form a basis for further activities. A range of elicitor treatments were tested in post-harvest trials to identify efficient elicitor treatments as tools to influence the content of HBPC in tomatoes and cabbage raw material and their waste fractions. Vegetables both for industry use and fresh market use were targeted. Results showed that the waste fractions of tomato and cabbage could be utilized as valuable sources of HBPC, and also provide better raw material utilization when subjected to efficient post-harvest elicitor treatments. Among the most promising elicitor treatments were ethylene treatments for pink and waste fraction tomatoes, and light/UV-B treatments for cabbage waste fractions. An important part of WP1 was to optimize non-destructive optical tools to facilitate more frequent and inexpensive monitoring of HBPC content of vegetable raw material. A LED reflectance sensor was optimized for in situ measurements on tomato fruits and subsequent estimation of lycopene content. This tool can be used to predict the best harvest time to obtain the highest level of lycopene in tomatoes. For cabbage, fluorescence-based sensors were proved to be able to detect flavonols and chlorophyll in leaves and cabbage heads directly in the field, as well as after harvest. This could be a useful tool to predict cabbage storability.

As a result of realization of WP2, three types of healthy food products were designed, prepared, and evaluated. All of them were based on tomatoes and cabbage cultivated in the framework of WP1. Two types of foods were studied only at laboratory scale: fresh tomato-based sauce to be served with fish and lyophilizate based vegetable instant smoothie-like drink combining tomatoes, cabbage and herbs. The third type of food products, namely meat sausage and pate enriched with cabbage prefabrication was realized in cooperation with two industrial partners. The first stage dedicated to the preparation of cabbage prefabrication was carried out with the aid of microwave flow steriliator EnbioJet at Enbio Technology. The cabbage prefabrication was then used at Meat Company Nowak to prepare meat products.

The results of WP3 suggested an optimal reciprocal agitation rate for low-viscosity Newtonian liquids at 80 rpm with respect to the average temperature increase and temperature distribution uniformity. For the non-Newtonian case, a certain inertial force was demonstrated to be imposed (over 80 rpm) to start gaining an effect for high viscosity which might even have possible negative effects on the temperature evolution during agitation. Average temperature increase due to the effect of 20 and 80 rpm agitation was very similar due to high viscosity and resulting viscous forces. It was pointed out that the increasing rotational forces in a high viscous range lead to higher centrifugal forces overcoming the gravitational forces. This prevents the natural convection, and heat transfer tends to be conduction-like with well-formed kernel-like temperature contours by slowing down the temperature increase.

WP4: A data collection focusing on the availability (in time and space) of vegetable by-products throughout the agrifood chain was performed. From this exercise it became clear that these biomass fractions truly represent a valuable feedstock for improved valorisation strategies toward food, feed, fertilizer, soil improvement etc. Specific by-products are present in significant volumes (e.g., >1000 tonnes/year) in a single location, relatively pure and of good quality (either raw or processed). The most relevant vegetable by-products were characterized for the nutritionally relevant parameters. A biorefinery process scheme was developed centred around the use of the low-oxygen spiral-filter press as fractionation technology. This technology allows to fractionate the wet vegetable by-products into a liquid fraction and a press cake, without the need to add antioxidants. The liquid fraction can be directly valorised as a juice, smoothie or puree after a conservation treatment (pasteurization) or as an ingredient in such preparations. In the project, spiral-filter processing and the subsequent pasteurization was optimized for tomatoes, cauliflower, carrots, peas, beans, red beetroot, celeriac, stalk celery and


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black salsify. A pilot line was built up in an industrial context and process and product development resulted in 4 selected recipes that were subjected to taste-trials. In addition, the spiral-filter press technology was combined with the microwave-based pasteurization technology of EnbioJet. As was done for the other products developed, chemical and microbial safety was checked, together with a shelf-life study of the end-products. From this work it became clear that the technologies used have the potential to turn vegetable by-products into tasteful products, appreciated by consumers, that can be marketed as clean label, natural and healthy products.

WP5: Twenty vegetable waste streams, mainly generated by the Belgian partners of the Sunniva project, were analysed to evaluate their potential as input source for De Ceuster Meststoffen in products such as organic fertilisers, soil amendments, or biostimulants. All streams were characterized for nutrient content, dry matter content, percentage organic material, lignin, hemicellulose, cellulose and soluble fraction. The main secondary metabolites such as flavonoids and alkaloids and their relative concentration were also determined. These analyses resulted in a complete overview of the characteristics of each stream and indicated a selection of streams with further valorisation potential.

- A series of plant bioassays was optimized in WP5 to characterize the effect of the materials on seed germination, plant shoot growth, plant root growth and root phenotype. The bio-assays span a scale from in vitro tests up to greenhouse tests, so the most suitable test could be selected in each situation. These bioassays form a valuable portfolio for future testing.
- The use of the vegetable waste streams resulted in a multitude of plant effects, ranging from growth suppression to growth promotion, either above- or belowground, or effects on root architecture. Especially bean, cauliflower, celery, apple peel and salsify waste streams showed significant (positive or negative) plant effects.
- A test batch of a solid soil improver formulation was produced for bean, cauliflower, celery and apple peel. Bioassays validated their potential agricultural value.
- A cost-effective industrial drying method is crucial for valorisation of the waste streams as raw material in soil improvers or fertilisers. A first large batch was dried at industrial scale, the plant bioassays with this product are still ongoing.
- A test batch to investigate the potential as biostimulant in solid formulation was also produced. Promising trends of plant growth promotion were observed with specific vegetable streams.
- The biostimulant effect of watery extracts of the materials was also evaluated in different bioassays. A strong effect on root phenotype was observed for specific streams, but additional characterisation is still needed.

Impact

The Research institutions involved in SUNNIVA have benefitted from the knowledge transferred between leading food technology institutes, and European food industry. SUNNIVA has contributed to the training of researchers on cutting-edge methodology, and mobility of students through internships between partners. The access to facilities for processing and field trials, and new methods has facilitated research of a high standard throughout Europe. The project has contributed to reinforced cooperation in research, development, and innovation between European countries in order to maximize the contribution of research to the development of more sustainable food systems from production to consumption, and the creation of a European network on sustainability in the vegetable food supply chain. The project resulted in significant dissemination and communication with diverse target groups as illustrated by the publication of 11 papers in international peer-reviewed journals, over 20 presentations at international conferences, five MSc theses, and several popular science publications.

Norwegian (Fjordland, Fjordkjøkken), Polish (Meat Company Nowak), and Belgian (Greenyard Prepared) food companies have all been involved and benefitted from the project through research on the innovative technologies and product development. To some extent, novel technologies were implemented, at least on a pilot scale.

A Polish equipment supplier (EnBio Technology) was given the opportunity to display their innovative microwave technology to a broad audience of European Industry and Research institutions. The technology was used for production of new cabbage/meat food products, and combined with oxygen-free juice pressing for the production of tomato and apple juice. The Enbio Technology was demonstrated on a workshop at ILVO's Food Pilot Plant initiated through the SUNNIVA project.


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The Belgian company De Ceuster Meststoffen are one of Europe's largest producer of organic fertilizers and biocontrol companies. They have been, in close collaboration with INRA and KU Leuven, performing research on the use of novel raw material based on side-streams in their production.

Conclusion and Recommendations

In conclusion, SUNNIVA has undertaken a life-cycle approach by analysing the vegetable food supply loop rather than the chain, in terms of sustainability. By doing so, the various residual raw materials can be exploited to the full: Either directly for sustainable production of healthy food (as a refined product or an ingredient), or indirectly by bringing it back into the food chain (as organic fertilizers and soil amendment products) in order to generate renewed primary production with minimal environmental impact.

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3. BIOSUCK

CALL 2013

Decision support system on optimized waste collection by vacuum technology with simultaneous production of bioenergy from wastes

PROJECT TEAM

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Summary

The project BioSuck is an ERA-Net SUSFOOD project that ran from September 2013 until December 2017. The BioSuck consortium consists of three scientific partners, one industry partner as well as an additional associated industry partner. The project aim was the establishment of a decision support system (DSS) that forces a re-design of the food processing industry with regard to an optimized waste collection system that is able to distinguish waste streams of differently contaminated streams in order to use them in the most efficient way. This can be realized via vacuum lines and subsequent processing of concentrated waste streams into bioenergy or recycling of nutrients. The redesign will save a significant quantity of water, because it requires considerably less water for cleaning purposes when waste is sucked off. This will accordingly decrease the disposed wastewater and thus reduce costs. The concentrated waste (high organic load fraction) can further be used for a self-supply with nutrients (fertilizer, food or feeding purposes) and/or bioenergy generated by subsequent processes (biogas, bioethanol, hydrothermal carbonization).

The final project outcome is an MS-Excel® based decision support system (DSS) with a complementary guideline for the redesign of the food processing industry. Therefore, several intermediate results where worked out and achieved throughout the project, namely:

- data collection and database creation
- LCA, environmental Impact Assessment (EIA) and sustainability analysis of the BioSuck concept and technology
- the realization of a test unit and a case study of the vacuum collection system
- the DSS itself

Finally, a first version of the DSS was successfully developed in the course of the project. The LCA and sustainability analysis revealed that the BioSuck concept is highly positive in terms of environmental and social impacts. Positive economic impacts are also likely, but these are also highly dependent on the food processing facility itself. The overall outcome is positive, but the DSS needs to be

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improved by implementing more data from many different sectors of the food processing industry. The realization of a big pilot demonstration unit of the vacuum sewer system in the food processing industry and its communication within this sector is helpful to facilitate the implementation of the BioSuck ideas and results in the future.

The consortium offers food-processing companies the possibility to test the DSS on their individual facility and to propose possible improvement options with regard to their wastewater management system.

Results and Achievements

The final project outcome is an MS-Excel® based decision support system (DSS) with a complementary guideline for the redesign of the food processing industry. Therefore, several intermediate results where worked out and achieved throughout the project, namely:

- data collection and database creation of

1. waste accumulation scenarios,
2. waste stream characteristics,
3. vacuum system performance depending on different food processing industries,
4. information, which waste streams are suitable for the different proposed bioenergy production routes (biocoal, biogas, bioethanol),
5. the estimation of the potential bioenergy yield.

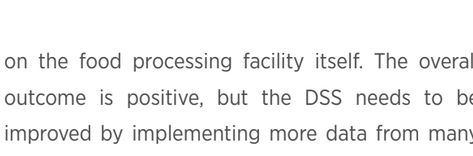
- LCA, environmental Impact Assessment (EIA) and sustainability analysis of the BioSuck concept and technology
- the realization of a test unit and a case study of the vacuum collection system in a food processing company to collect information and gain real life experiences to be transferred into the DSS
- the DSS itself

Finally, a first version of the DSS was successfully developed in the course of the project. The LCA and sustainability analysis revealed that the BioSuck concept is highly positive in terms of environmental and social impacts. Positive economic impacts are also likely, but these are also highly dependent

on the food processing facility itself. The overall outcome is positive, but the DSS needs to be improved by implementing more data from many different sectors of the food processing industry. The realization of a big pilot demonstration unit of the vacuum sewer system in the food processing industry and its communication within this sector is helpful to facilitate the implementation of the BioSuck ideas and results in the future.

Impact

The added value results from respecting the experiences, opinions and views of partners from different countries that have different cultural backgrounds. In addition, the food processing as well as waste(water) management systems in Europe have different foci and practices depending on the country. Thus, it was possible to work on those issues in a holistic way and to generate an output that is not only usable in a single national context. This becomes even more important as Europe is merging closer.



In addition, the network of all partners has been widened. This allows also to be more competitive in the future and to spread innovations widely. Furthermore, the uptake and implementation of the technology behind the idea of the BioSuck concept became more likely as it would be in a national context.

Conclusion and Recommendations

Many food processing companies could improve their waste (water) management system and gain benefits in terms of money and resource efficiency. Unfortunately, this problem or the potential improvements are not within the focus of most of the companies or they are not aware of its relevance. The focus lies understandably on the production process itself and the products. Wastewater and waste occur, but those are disposed or sold in established ways. The installation of a vacuum system, which could bring many potential improvements, is far out of the understanding or scope of food processing companies. Especially SMEs are not able or willing to spent resources in improving the waste management system. First, the production process does not have to stop. Thus, the communication of the BioSuck concept is difficult. The “right” people need to be met in order to pursue this innovative concept.

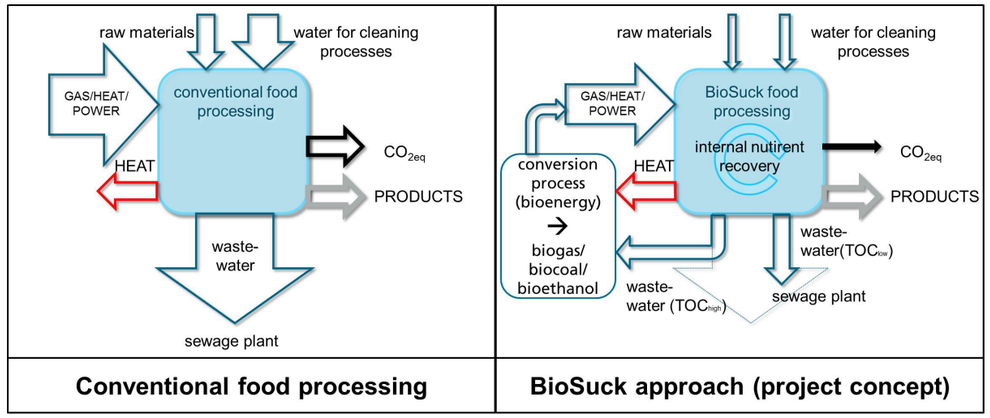
The recommendations of the BioSuck consortium to facilitate the uptake of the concepts are:

- Put pressure on the (food) processing industry to save energy and water, currently water and waste water is too cheap
- Cost savings are not attractive enough, set political framework
- Take up of vacuum sewer systems as Best Available Technique (BAT), already established technology, but not widely implemented in this sector, Food processing companies are restrictive with regard to innovative technology, the production process need to run continuously
- More/additional funding to disseminate project results professionally, marketing campaign and widely recognized demonstration project

The implementation of the BioSuck concept and vacuum technology depends on the individual situation of a company. In the following, some beneficial condition and barriers are summarized with regard to the likeliness of implementing the concept:

Pro:

- Necessity to reconstruct the sewage system



Conventional food processing | **BioSuck approach (project concept)**

- Connected sewage plant reached its limits
- Tightened regulations (e.g. with regard to maximum contamination of waste water)
- Large distance to existing sewage plant infrastructure
- Wastewater streams of different composition within the production facility

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Contra:

- High remaining depreciation costs of the sewer system or of the own sewage plant.
- Connected sewage plant has unused capacitiesno necessity for improvements
- Legal uncertainties
- Missing demonstration pilot plants (in the food processing industry)
- Low acceptance for new technologies.
- Unqualified personnel to understand the innovative concept/technology

All in all BioSuck made the first step of improving the waste(water) management and reuse in the food processing industry. The envisaged DSS has been created, but need to be adjusted in the future when more real life data becomes available. Water and costs savings potential exist. The LCA showed clear indication of positive impacts with regard to social and environmental key indicators. Positive economic impacts are also likely, but are subject to individual analysis. Here, the BioSuck consortium is willing to assists companies to check their improvement potentials

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4. CIBUS-FOOD

CALL 2013

Computational-design and Innovative Building of Uniquely Structured Food

PROJECT TEAM

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Summary

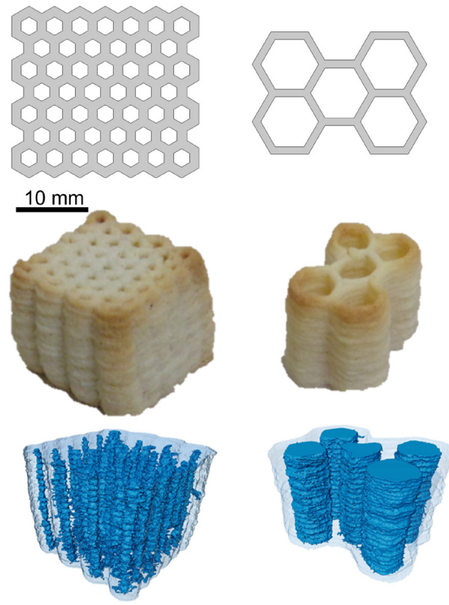
The goal of CIBUS-Food was to investigate Additive Manufacturing (AM) as a novel and sustainable production process for food products with dedicated structures and textures.

AM, popularly known as 3D printing, has been called the next industrial revolution and is currently employed for many manufacturing steps using traditional materials like plastics and metals. AM of food will be the next big step, allowing a completely new method of production. Within this transnational project, research was carried out that enabled the in silico design of complete food products (a cookie and meat replacement product) based on knowledge from existing food products and structures. Suitable food materials were be selected or produced that could be used in the AM process. The food products were characterized with state of the art 3D imaging using X-ray micro-CT and mechanical characterization technologies to validate the design and product properties.

Computational software was applied to propose printed structures based on the mechanical properties of 3D structural designs. It was found that a range of textures could be achieved by manipulating the geometrical characteristics of simple as well as more complex 3D shapes. The technology that was employed for the printing of the cookies and meat replacement products is the Fused Deposition Modeling (FDM) or extrusion printing technology, as this technology is expected to provide the highest degree of control over structure design.

For the cookie product, baking stability was a key parameter required for the successful creation of the final cookies. The material formulation was optimized to be “liquid” enough to be extrudable, whereas it must have enough stand-up in order to allow printing without loss of the desired shape. Additionally, the material must be formulated such as to allow shape retention during the baking process. Using the optimized dough formulations, baking of the cookies without loss of the design proved possible. Baking was carried out directly after printing, as well as after various periods of drying, aimed at decreasing the water content and thus increasing the baking stability.

The project has shown that the in silico designed model of the food is as good as it represents the actual printed structure. The printing process was optimized to create structures that resembled as accurately as possible the design. Different cookie shapes of moderate design complexity as well as of high design complexity were successfully printed. We found differences between the model design structures and those actually achieved by 3D printing. Using the actual printed structure in the in silico model for mechanical analysis improved correspondence between model and measurement proving the design approach. The mechanical properties of the matrix material after baking determines the effective texture properties of the printed cookie. We have found that for the material studied in this project, there is a large effect of the moisture content of the material after baking. So accurate control of the baking process to target a uniform moisture content will be required for effective texture design.



For the meat replacement products various formulations were investigated. Overall it can be concluded that products based on various meat replacement recipes with various distinct designs can be successfully printed. Additionally, it proved possible to print coaxially, employing different formulations for the core and shell of the extruded filament. This opens up the way to create complex, texturized food products where the properties of both formulations contribute to the overall textural experience. The first mechanical analysis of the printed samples showed that designs with overall identical shapes but with different internal layouts displayed different mechanical properties. Additionally, coaxially printed designs again differed with respect to their mechanical properties. This shows that the 3D printing route has great potential for the creation and tuning of textures and textural attributes.

In addition, the project comprised consumer acceptance studies to get insights in consumer attitudes towards the technology and its resulting food products. For many people, 3D-printing in general and 3D-food printing is generally unknown: approximately 66% of all interview respondents say they have very little knowledge on 3D-printing of food. However, the more people know about it, the more receptive they are towards 3D-printing of food. People expect it mostly in high-end eating establishments or at special events at home. There clearly were differences in appreciation of the technology between correspondents of the three countries Germany, The Netherlands and Belgium which had a relation to level of knowledge of the technology. Looking at meat replacement products and biscuits in particular, it can be concluded that 3D-printed meat replacement products appear to have greater potential than 3D-printed biscuits, and there is willingness to pay more for 3D printed food.

Results and Achievements

Texture and structure of cookies produced with conventional methods and of cooked chicken breast meat were analysed in detail to determine influential parameters in the microstructure for texture properties. For cookies it was found that porosity and, more pronounced, material structure thickness had a considerable influence on mechanical properties. For meat, it was more difficult to make analysis of the relationships because of the high 3D variability in structure and mechanical properties

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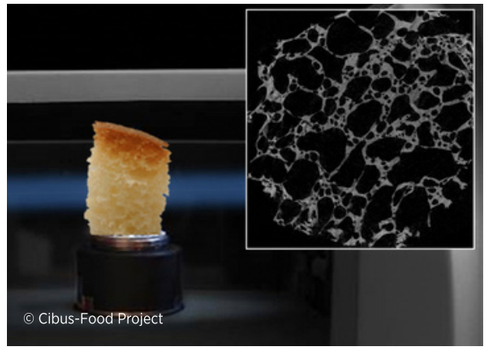
observed. The microstructure of the fibrous material was composed of clearly separated and interacting phases (fat, connective tissue and muscle fibers) using advanced visualization in high resolution and explained the difficulty of structure-texture analysis because of the local variation in orientation and composition of the meat. Nonetheless, the results showed that a key to achieve printed meat like texture lies in a achieving the printing of a multiphase fibrous matrix.

Computer aided design (CAD) structure models of both designed and measured 3D structures were created using dedicated CAD software. Models for mechanical deformation of the structures were developed and implemented to analyse the effects of structure on effective mechanical properties. The simulations were used to suggest different structures for printing that were consequently analysed for structure and texture properties.

The most suitable 3D printing processes for the creation of the selected food products was selected and optimized. FDM, or rather extrusion printing, requires the ingredients to be present as a paste or dough, which fits very well with cookie formulations. The use of doughs allows the use of mechanical action and thus the formation of a gluten network when needed, thus allowing for a much larger range of mechanical properties. In addition, FDM is a technology that allows the creation of closed, hollow cavities and where removal of excess material is not needed, making it easier to create complex porous and other network structures. Furthermore, the use of doughs (rather than powders as with some other technologies) allows the creation of dense, strong walls with defined thicknesses. One known issue with FDM-based printing of cookies is the fact that a printed 3D structure may somewhat deform or may even complete loose its shape upon baking as the structures are freestanding. Particularly the last requirement necessitated specific (re)formulation steps. After a series of experiments considering printing and baking quality it was concluded that cookies with intricate designs can be successfully printed. The developed formulation allowed not only the successful printing of the design, but also provided baking stability. FDM is also suitable for the paste and gel type formulations that are likely to be used for the printing of meat-type products. It allows the curing of materials prior to, during, or after the printing process, thus offering great flexibility for the production process. In addition FDM by its very nature produces extruded fibers making it inherently suitable for the printing of meat-type structures. A selection of suitable plant proteins for the preparation of first printable formulations for the use in 3D printed meat replacement products. For this purpose a screening approach was selected and carried for all protein preparations. The screening consisted of a test for gelation and the evaluation of the most relevant attributes using a virtual scale. To develop the virtual scale a standard cooking process for a real meat reference product was established and the real meat product was characterised using textural analysis. Overall it was concluded that products based on various meat replacement recipes with various distinct designs can be successfully printed. Additionally, it proved possible to print coaxially, employing different formulations for the core and shell of the extruded filament. This opens up the way to create complex, texturized food products where the properties of both formulations contribute to the overall textural experience. The first mechanical analyses of the printed samples showed that designs with overall identical shapes but with different internal layouts displayed different mechanical properties. Additionally, coaxially printed designs again differed with respect to their mechanical properties. This shows that the 3D printing route has great potential for the creation and tuning of textures and textural attributes.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The characterization of AM foods comprised the determination of the texture of the food samples made by means of force-deformation measurements and X-ray micro-tomography analysis with respect to food structure, allowing optimization of the novel processes. The main emphasis was on printed cookies at this stage. It was observed that the cookies having similar Young's modulus value have also similar porosity. From the earlier model-based design study, we concluded that printed food Young's modulus increases with a decrease of the porosity. However, this fact was not always observed. Moisture content may be the predominant factor responsible of this deviation. Further deviations were due to Systematically, the measured results deviated from the predicted results. These deviations can be due to internal cracks occurring during the baking process that were observed in the micro-CT scans and spreading of the dough during the FDM process resulting in a spread cubic shape and smaller pores. Indeed, using the actual cookie structure (obtained from X-ray micro-CT) in the model analysis considerably improved the prediction of the effective E-modulus of some of the investigated structures. The actual porosity of the printed structure was significantly lower than those of the model designs. As a result, the effective E-modulus increases and comes in range much more comparable to the measured values. The project has shown that first models can be created that allow the description and prediction of mechanical properties of printed (cookie) products based on their structure and porosity (as determined by μmCT scans). The strategy of designing and printing shapes with controlled porosity clearly allows the tuning of the mechanical properties and offers opportunities hitherto unknown in food science. Some observations, however, could not be explained fully based on this model, which indicates that a full understanding of the structure-mechanical properties relationships for (printed) food objects is still lacking. This, however, is to be expected given the novelty of this field.

It is clear that significant further research is needed in order to be able to print food products with tunable and predictable mechanical and thus organoleptic properties. As part of the move towards the printing of complex, typically multimaterial food products with specifically designed structures the approach followed in this projects will be followed; however, additional material deposition technology developments are foreseen. Having more possibilities for the controlled and localized deposition of food materials will allow the creation

of more complex food structures and textures but will make the modeling and understanding even more complex.

To study the consumer acceptance of AM in general and of food in particular, a small desk research was executed. The aim of this small desk research was to retrieve a topic list to be used in the survey on consumer acceptance of AM of food, to be held among consumers in Germany, Belgium and The Netherlands. Results of desk research were briefly discussed with two scientific experts (a food technologist and a social scientist) to confirm these topics. Consumer acceptance of AM in general and/or AM of food is not (yet) an issue; it is not yet a topic of great interest in scientific literature and/or news articles. The main focus is on AM in general, very few articles on AM of food like meat. General focus in literature is on exploring techniques of (food) printing (scientific literature) and introducing the possibility of AM of both food and non-food products (news articles). Often the possibilities of AM are mentioned, but there is also much discussion about the downside of AM, such as high costs, uncertainty about IP etc. The main application domain is in the industry, less in literature on out-of-home or home situation. The results of the interviews with consumers (WP6) showed that, for many people, 3D-printing in general and 3D-food printing is generally unknown: approximately 66% of all respondents say they have very little knowledge on 3D-printing of food. However, the more people know about it, the more receptive they are towards 3D-printing of food. At the moment, 3D-printed food products are considered exclusive, original and surprising. People expect it mostly in high-end eating establishments or at special events at home. There clearly are differences between the three countries. The Dutch appear to be most sceptical, with relatively little knowledge of 3D-food printing. The Belgians have more knowledge and have more positive scores on key factors like price and ease of preparation. There also are major differences concerning the extent of individual contribution: The Belgians do not want to contribute much, while the Germans prefer to create the 3D-printed food product entirely by themselves. In addition, the Germans consider it more relevant than average, but have their doubts about sustainability and safety. Snacks, desserts and pasta are the most popular 3D-printed food products. Ice cream might be a possible future product to consider. Looking at meat replacement products and biscuits in particular, it can be concluded that 3D-printed meat replacement products appear to have greater potential than 3D-printed biscuits. More people are willing to pay more for a 3D-printed meat replacement product (compared to a traditional meat replacement product) than for a 3D-printed biscuit.

Impact

The uniqueness of the consortium bringing together experts in 3D imaging, modelling, additive food manufacturing and food and consumer science is difficult to achieve on a national level. It has allowed us to analyse and further develop the new technology using a multidisciplinary approach.

Conclusion and Recommendations

The project showed that it was possible to 3D print different cookie shapes and meat replacement products with distinct designs, incorporating extruded filaments with different formulations for the core and shell. Designs with overall identical shapes but with different internal layouts had different mechanical properties, indicating that 3D printing has great potential for the creation and tuning of textures and textural attributes. As postprocessing steps such as baking and cooking further change texture, future computer aided design methodologies should also include models of them to better predict texture properties. Also, the throughput of the 3D printing process needs to be increased.

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5. SUSTAINABLE & HEALTHY

CALL 2013

Development of sustainable processing technologies for converting by-products into healthy, added value ingredients and food products

PROJECT TEAM

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Summary

Fruit and vegetable processing industry generates a number of by-products (e.g. Press cake/skins/seeds) that contain bioactive compounds. Despite its valuable content, most of these by-products are discarded as waste. The objective of the Sustainable&Healthy project was to i) extract phenols and bioactive oils from berry press-cakes using supercritical fluid extraction (SFE), ii) stabilize extracts by encapsulation using spray drying or PGSS (Particles from Gas Saturated Solutions) and develop added value food products using iii) non-thermal emulsification or iv) osmotic dehydration.

SFE was applied on bilberry press-cake and optimized to extract non-polar compounds (bioactive oils) as well as water soluble bioactive compounds (anthocyanins). It was possible to obtain a bilberry seed oil with enhanced vitamin E content, and antioxidant activity, by optimization of the extraction conditions. The choice of co-solvent percentage highly influences the anthocyanin extraction efficiency and it was found that the selection and combination of pre-treatment techniques (drying, fractionation and milling) highly influence the anthocyanin extraction recovery. When using moderate ground and unground bilberries, PEF has a considerable effect on the membrane integrity and total anthocyanin recovery in a two-stage extraction process consisting of watery and high pressure carbon dioxide extraction/SFE resulting in an elevated anthocyanin yield. In finely ground bilberry pomace, PEF led to no significant raise in anthocyanin yield.

Spray drying and the high-pressure process Particles from Gas Saturated Solutions (PGSS) experiments were carried out to stabilize the bilberry extract. It was shown that encapsulation of bilberry extract in different shell materials, such as maltodextrin, the copolymer Eudragit and the palm fat Revel A is possible. It was found that different process parameters like pressure, temperature, specific gas ratio, respectively mass flow and nozzle type or nozzle size have influence on the particle properties such as particle size, moisture content and morphology. These properties are analyzed and correlated with the process parameters.

A new non-thermal emulsification method (o/w/o) was developed in order to generate microcapsules where the bilberry seed oil was dispersed in a continuous aqueous phase of anthocyanins stabilized by whey protein isolate. The effect of pH (3 or 4.5), concentration of anthocyanins and

emulsifier on structure forming properties and resulting microstructure was investigated. It was found that for samples with a final pH of 4.5 the gelling process was slow and which resulted in agglomeration of the bilberry seed oil. The samples with final pH of 3 experienced significantly weak gels after the gelling process. However, as the gelling process started within minutes, this still generated a more even distribution of small BSO droplets and consequently a more stable structure. The storage stability of the systems was also investigated by establishing the protective effect from anthocyanins on the oxidation of berry seed oil.

Finally, dried food products with added value from anthocyanins were generated by using osmotic dehydration pre-treatment combined with a two-step convection and microwave-vacuum method. This method was then compared to reference samples obtained by freeze-drying. Droughts generated by initial osmotic dehydration combined with optimized parameters for drying convection-microwave-vacuum exhibited favourable organoleptic properties and with enhanced levels of health promoting ingredients. Thus, using the bioactive compounds (anthocyanins) during osmotic dehydration as a pre-treatment is a new way of enhancing the attractiveness of dried fruit products.

Results and Achievements

Extraction of bioactive compounds from by-product

Supercritical fluid extraction (SFE) or High pressure carbon dioxide extraction (HPCDE) was applied on a by-product from fruit processing industry (bilberry press-cake) and optimized to extract both water soluble bioactive compounds (anthocyanins) and non-polar compunds (bioactive oils). The choice of co-solvent percentage highly influences the anthocyanin extraction efficiency from bilberry press cake.

It is possible to obtain a bilberry seed oil with enhanced vitamin E content, and antioxidant activity, by optimization of the extraction conditions. The applied temperature and pressure conditions affected the yield and the effect of temperature was more pronounced at lower pressures. The fatty acid composition was similar independently on the pressure or temperature used, while the content of vitamin E and the antioxidant activity varied between extracts.

The selection and combination of pre-treatment techniques (drying, fractionation, milling and PEF-pulsed electric field) highly influenced the anthocyanin extraction recovery. For combination of drying, fractionation and milling, a higher anthocyanin content was achieved in the large size fraction (>710 μm). However, the small size fraction (<710 μm) was more beneficial for a high anthocyanin recovery when using high pressure carbon dioxide, independently of the drying technique applied.

There was a significant increase in the anthocyanin extraction yield when PEF was applied on unground pomace if the complete process is laid out as a two-stage process, with the PEF-treatment as first extraction step and HPCDE as a subsequent extraction step. The outcome was highly influenced by the degree of grinding prior to pomace production.

Stabilization of extracts rich in anthocyanins

The project started in October 2014 and at that time, the bilberries for that season were already harvested. Unfortunately, no fresh bilberry material was available. Because of that, preliminary tests were carried out with an alternative organic material; tormentil (potentiall erecta).

CPF technology caused extreme stickiness of the gained products and it was not possible to produce stable and storable powders. Because of that the process was replaced by spray drying and successful pulverization experiments were done instead. Tormentil extract could be processed using spray drying technology.

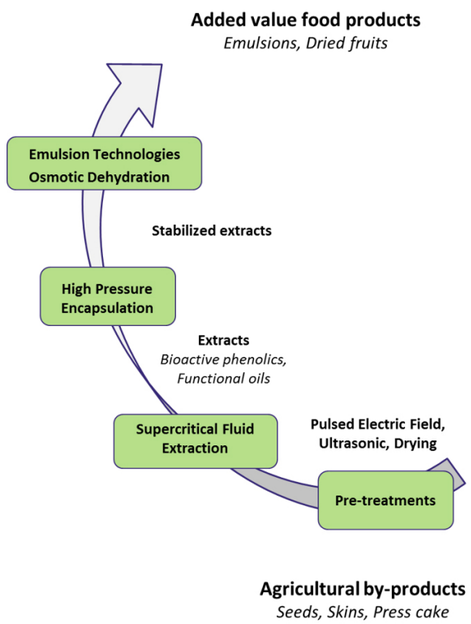
Tormentil extract was also sprayed by using PGSS technology. In difference to spray drying technology it is possible to operate with much lower temperatures by using PGSS and the experiments are carried out in an inert gas atmosphere. This is of importance when thermal or oxygen sensitive substances have to be processed. With these experiments it could be proven, that the extract`s viscosity is of higher importance for successful PGSS experiments than for spray drying. The experiments also showed that the relative amount of gas which is sprayed together with the extract through the nozzle, has a major influence on the powder`s properties. The higher the gas fraction the smaller the particles are.

After gaining experience with the tormentil plant extract, experiments with bilberry extract were carried out. Physical properties of the extract were needed to optimize the spraying processes. Therefore, the viscosity and the density of different extracts were measured with an acoustic levitator system. The density was compared to measurements by a pycnometer while the viscosity was verified by a rotational viscometer. From these experiments it could be concluded that small changes in extraction conditions lead to changes of the composition of the extract. These changes in the composition are likely to cause remarkably changes in the viscosity of the extract. This will in turn complicate the extract`s further processing. Because of the variations of the physical properties between the small bilberry batches, it was decided to go on with a big batch of bilberry extract, with constant physical properties for all experiments.

Added value emulsions by non-thermal emulsification with both anthocyanins and bilberry seed oil

A new non-thermal emulsification method (o/w/o) was developed in order to generate microcapsules where the extracted bilberry seed oil was dispersed in a continuous aqueous phase of anthocyanins stabilized by whey protein isolate. To avoid lipid oxidation of the bilberry seed oil and thermal degradation of the anthocyanins during encapsulation, a cold gelation process was adapted. It was found that for samples with a final pH of 4.5 the gelling process was slow which resulted in agglomeration of the BSO. The samples with final pH of 3 experienced significantly weak gels after the gelling process. However, as the

gelling process started within minutes, this still generated a more even distribution of small berry seed oil droplets and consequently a more stable structureThe storage stability of the systems was also investigated and gas chromatography–mass spectrometry measurements of the fatty acid profile of BSO during storage displayed that AC had a protective effect against lipid oxidation in the emulsions.



Added value food products by osmotic dehydration with anthocyanins

Dried food products, droughts, with added value enriched with anthocyanins were developed. All droughts, had long durability, because the obtained values of water activity were less value of 0.50. Droughts were obtained by using osmotic dehydration pre-treatment and thereafter dried by a two-step convection and microwave-vacuum method.. In addition, in the two-step method convection drying was shortened to 1-2 h and used mainly for surface drying of osmo-dehydrated fruit. It has been shown that long time fruit osmotic dehydration (24 h) could be combined with reduced puffing temperature (approximately 55°C) during microwave-vacuum drying.. In order to attain a high quality product, focus was also paid on attractive appearance and crispiness which could be controlled by the puffing and colour derived from the enrichment substances. The results were also compared with freeze-dried drought obtained by puffing (in two-stage drying) which exhibited preferred features associated with the reduced hygroscopicity. Studies on the chemical composition of drought, obtained by a two-stage drying process showed less degradation of biocomponents compared with the drought created by freeze drying. Droughts generated by initial osmotic dehydration combined with optimized parameters for drying convection-microwave-vacuum exhibited favourable organoleptic properties and enhanced levels of anthocyanins. The resulting products have potential as an alternative for snacks and additives in processing.

Impact

The project contribute to increase the research collaboration between three European countries (Sweden, Germany and Poland) and 4 research institutions (one institute and three universities) in a relevant area of development of sustainable technologies to produce high quality healthy foods. By a transnational collaboration, the project has reached further compared to national initiatives, since novel technologies throughout the entire food chain could be developed, from collecting and extraction of by-products, stabilization of extracts to development of new added-value food products. The World Health Organisation (WHO) and the European Commission's Eurodiet project recommends a daily intake of fruit and vegetables of around 600g, to take advantage of these health benefits, but very few people incorporate this into their diet. To address this challenge, a large variety of attractive food products containing the natural bioactives compounds extracted from fruits and vegetables needs to be developed. This project contributed to this through the partnerships identified making it strategic and necessary to operate at a European level.

Many berries as well as fruits and vegetables are grown within the entire European Union, often by SME's. The innovative SFE technologies for extraction of bioactives can be adapted by juice producing companies that will be able to sell their by-products to a higher price or even invest in similar extraction technologies and in this way have a new unique product in their portfolio. Several companies working with berries from the north of Sweden have shown interest in the technology and in other parts of Scandinavia e.g. Finland, SFE is today an established technique for collecting bioactive compounds from berries and by-products. The results from this project will facilitate this development further and there is an established connection between RISE and the stakeholders through the "Berry network".

By implementing the PEF technology in extraction processes of berry pomaces it seems possible to enhance the yield of those valuable, bioactive compounds without using excessive mechanical disintegration procedures or harmful extraction chemicals, producing a clean and energy and time efficient process that in turn will produce new and cost competitive products for the food, food supplement and pharmaceutical industry. The high-pressure technology PGSS, which was used to preserve the natural extracts is until today not established in food industry. Driven by the project different food-processing companies were showing interest in this technology.

This in turn will enhance the competitiveness of European fruit and vegetable production locally in each country, and help campaigns for promotion on the internal market.

Fortifying fruit with biologically active compounds such as anthocyanins during osmotic dehydration is a new way of enhancing the attractiveness of dried fruit products. It is also possible to use fruit juice or extracts obtained e.g. from fruit by-products, which is an effective factor in the sustainable processing of plant materials.

Conclusion and Recommendations

It is possible to obtain a bilberry seed oil with enhanced vitamin E content, and antioxidant activity, by optimization of the extraction conditions. The fatty acid composition was similar independently on the pressure or temperature used, while the content of vitamin E and the antioxidant activity varied between extracts. There was a significant increase in the anthocyanin extraction yield when PEF was applied on unground pomace if the complete process is laid out as a two-stage process, with the PEF-treatment as first extraction step and HPCDE as a subsequent extraction step.

The PGSS and spay drying experiments, showed that encapsulation of bilberry extract in maltodextrin is possible. The experimental series also displayed that it was possible to encapsulate bilberry extract in Eudragit with spray drying and in Revel A with PGSS. It was found that different process parameters like pressure, temperature, specific gas ratio, respectively mass flow and nozzle type or nozzle size influence on the particle properties such as particle size, moisture content and morphology. This influence has been analysed and a correlation between those process parameters and resulting particle properties were visible. These results are valuable for many branches of the food industry for designing custom-made particles.

Added value emulsions by non-thermal emulsification with both anthocyanins and bilberry seed oil coud be produced. Final pH of the stabilizing continuous whey protein gel had significant impact of structure stability and product shelf-life during storage. Furthermore, anthocyanins had a protective effect against lipid oxidation in the emulsions during storage.

It was established that the fruits subjected to pre-osmotic dehydration, and then freeze-drying had a higher content of polyphenols compared with samples dried by convection and microwave vacuum. However, the ability to bind radical DPPH• varied depending on the technological process and the type of osmotic solution. Furthermore, a trend to a higher antioxidant activity was observed in the case of osmo-dehydrated products combined with convection and microwave-vacuum drying in comparison to the freeze drying. The results display the possibility of using process of osmotic dehydration concentrate of berry extract to enrich the product with ingredients that are health promoting i.e. anthocyanins.

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6. BIOPROT

CALL 2013

Novel multifunctional plant protein ingredients with bioprocessing

PROJECT TEAM

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Summary

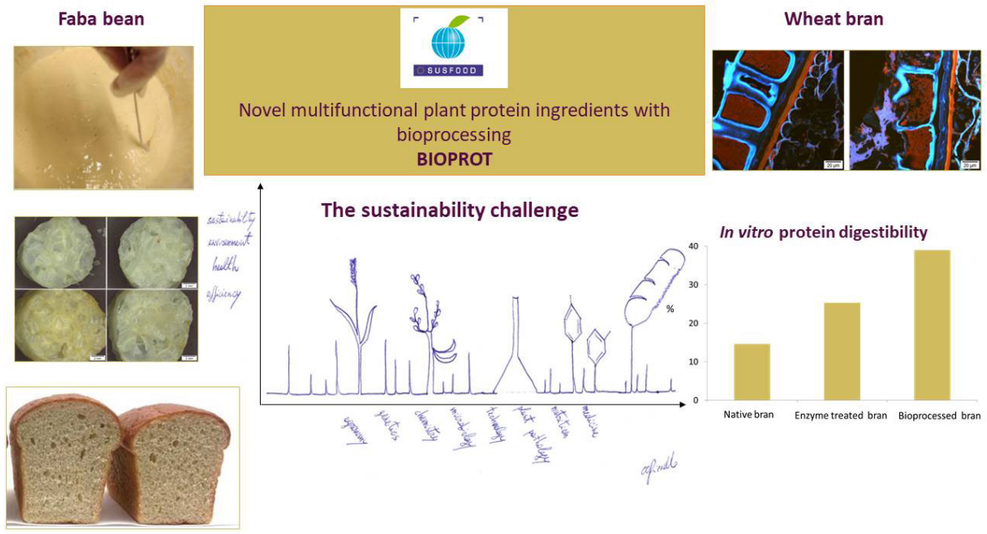
Finding new sources of plant proteins is a necessity to obtain sustainable and affordable foods for the growing global population since the production of animal protein is not a feasible option in the future. Two major solutions to increase plant based protein sources are: increased cultivation of protein rich crops and efficient utilization of protein rich side streams of food production.

Several current processes such as wheat flour production generate significant amounts of side streams like bran, which are mainly used as feed or incinerated. Furthermore, there are potential leguminous crops such as faba bean, which could provide protein if presence of anti-nutritional factors would be diminished. Both of these versatile plant materials have high content of nutrients and bioactive compounds, e.g. proteins, dietary fibres (DF), minerals, vitamins and other phytochemicals. The protein rich materials, however, consist of recalcitrant cell walls which are rich in insoluble heterogeneous polymers or presence of anti-nutritional factors. Availability of bioactive compounds and proteins is restricted as they are often entrapped in the complex cell wall matrices which limit their exploitation. Bioprocessing (fermentation with lactic acid bacteria and yeasts with or without added enzymes) of cereal raw materials has shown great potential to improve nutritional and technological properties of plant materials.

Fermentation is also potential mean to detoxify faba bean by significantly reducing content of anti-nutritional compounds such as convicine, vicine and tannin and improving bioavailability of bean protein for food use. As protein degradation is also determining structure and flavour formation in most foods, bioprocessing has to be tuned to take into account both nutritional and technological functionality.

BIOPROT focused on developing multifunctional, novel protein enriched bran and faba bean ingredients, with high potential to be used in several food categories (bread, pasta, extruded products). This was obtained by developing tailored fermentation technology for matrix modification resulting in diminished anti-nutritional factors and upgraded nutritional and technological protein quality. Selected microbial starters allowed to release proteins and modified amino acid profiles, to reduce antinutritional compounds and to suppress the growth of unwanted microbes (biocontrol).

The results will promote cultivation of faba beans in Europe and valorise both bran and bean as protein sources for food and feed use.



Results and Achievements

Selected LAB starters and enzymatic treatments enriched the nutritional value of bran and faba bean. They increased the composition of essential amino acids and GABA in both the raw materials and decreased the content of faba bean antinutritional compounds, e.g. pyrimidine glycosides, involved in favism, and the flatulence causing α-galactosidase. LAB fermentation provided a natural bioprocessing tool for modification of nutritional and technological properties of faba bean flours that could be applied in the development of novel plant-protein based products.

The solubilization of wheat bran proteins could be improved from 14% to 50% by using tailored fermentation, especially in combination with cell-wall hydrolyzing enzymes. Significant changes in Mw of proteins were observed depending on the bioprocessing type. Improved in vitro digestibility of bran proteins was also obtained (from 14.6% to 39%).

Faba beans, as well as other legumes, are considered a good source of proteins. By improving the protein digestibility through the reduction of phytic acid it was possible to enhance the good properties of faba. Phytase treatment with commercial food-grade enzyme was a fast tool to increase protein solubility and mineral availability. Similarly, faba bean sourdough fermentation was able to enhance the nutritional profile of wheat bread. The free amino acid profile, protein chemical score, and biological value index were the highest in faba bean sourdough bread compared to common wheat bread and wheat bread containing native faba bean flour. In addition, the predicted glycemic index was the lowest in faba bean sourdough bread. Similar results were obtained for faba-bean enriched pasta, which had acceptable technological performance, overall improved nutritional profile and, in the case of fermented faba bean, also sensory score.

Faba bean flour provides an excellent base for in situ production of microbial exopolysaccharides (EPS). EPS technology improved the quality of the composite faba-wheat bread, allowing better sensory properties. In extruded snacks, additional benefits were not observed with EPS-containing ingredients. Browning of bean matrix in high temperatures applied in extrusion was observed due to Maillard reactions, especially for EPS fermented samples. Novel EPS containing faba bean ingredients could be applied in baked products or in vegetable pastes.

Impact

Cereal and legume grains are a strategically important crops in Europe, and cereal foods represent a main component of our diet. The cereal industry comprises a large part of the European food market. Wheat milling process is focused on flour extraction and, other parts of the kernel are commonly considered as milling by-products used as animal feed. Those by-products, coming from outer layers of kernel (bran layers and aleuron) and the germ, store components with high nutritional value (e.g. dietary fibre, minerals, vitamins, lipids, phenolic compounds). Due to their feed destination, those components are “lost” for the human nutrition due to consumer preference of products made with endosperm flour. This loss represents a reduction of efficiency in the capacity of the wheat production chain to supply nutrition to society.

The transformation technologies and food processes developed in BIOPROT focused on valorizing the lost nutritional potential, implementing simple up-scalable technologies. This will allow better raw material usage producing innovative, healthy ingredients to be used in products with both high nutritional and sensory value.

Compared to animal proteins, plant proteins e.g. from legumes are typically of lower quality because they lack one or more of the essential amino acids. Furthermore, they often pose challenges in terms of technological functionality and flavor. However, the growing global population cannot be fed only with animal originated proteins making technologies to upgrade plant protein quality utmost important for their full utilization in the future. Tailored fermentation processes developed in BIOPROT showed great potential to improve AA composition, in vitro protein digestibility and other nutritional indexes of the raw material. Bioprocessed bran or faba bean can be used directly as ingredient in a variety of foods, reducing energy and water cost otherwise required for isolation. This approach will also benefit other health promoting compounds present in bran and bean such as fibre.

The BIOPROT project contributed to the competitiveness of European grain and legumes production, particularly wheat bran and faba bean, and corresponding processing industry by providing knowledge and tools for targeted processing of foods of high protein and overall nutritional quality. The project also addressed the challenge to combine food nutritional value with high sensory performance, which is required to increase consumers´ acceptance.

Conclusion and Recommendations

Upgrading wheat bran and faba bean technological and nutritional properties is an ambitious but required factor to increase their consumption. This, together with efforts to improve their sensory quality, will contribute to make bran and faba bean superior protein rich ingredients. The market for protein ingredients is expected to dramatically increase in coming years, so project results can be commercialized by European enterprises in a long rung. The possibility to create these innovative upgrading technologies for bran and faba bean will represent an opportunity for European research to gain world scientific leadership in the field. Within this project we had the important opportunity to explore different ways to modify plant proteins, and to develop new plant protein enriched foods with positive health effects designed to fit in the European consumption pattern. We used international background information to develop internationally competitive know-how and products for Europe. In the last 10 years industries and consumers have been showing a growing interest in novel protein sources which will increase in near future. Therefore, for these results to be promptly up taken, awareness of both professionals and consumers in Europe about the technological possibilities and benefits of consuming plant protein-based food should be promoted and disseminated.

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7. FOCAS

CALL 2013

Food, Convenience and Sustainability

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Summary

The FOCAS project (Food, Convenience and Sustainability) was part of the SUSFOOD programme's research strand on understanding consumer behaviour to encourage more sustainable food choice.

The four work packages focused on processed baby-food and everyday feeding practices; the healthiness and sustainability of supermarket ready-meals; canteen food and work-place food geographies; and the convenience and sustainability of meal-box schemes.

The FOCAS project aimed to answer four research questions: how 'convenience food' is understood by consumers and how its use relates to understandings of 'healthy eating' and environmental sustainability; with what specific practices (shopping, cooking, eating, disposing) convenience food is associated; how such foods are incorporated within different household contexts and domestic routines; and to what extent current practices are subject to change (towards more sustainable and healthier practices).

Rather than assuming that 'convenience food' is a single unified category, we used the somewhat awkward neologism 'conveniencization' to study the processes and practices through which some kinds of food come to be considered more convenient that others, whether in terms of acquisition, appropriation or appreciation.

The research adopted a 'theories of practice' approach, emphasising the meanings that consumers attach to convenience food; the practices with which convenience food is associated; the embeddedness of convenience foods in the routines and rhythms of everyday life; and the 'do-ability' of convenience food in terms of practicality and cultural appropriateness.

Convenience foods are often regarded as among the least healthy and most unsustainable of dietary options in terms of their low nutritional value and heavy environmental impact.

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The growth of the sector since the 1970s was associated with increased female participation in the labour force and was encouraged by a series of socio-technological innovations including domestic refrigeration and the development of the 'cold-chain' in food manufacturing and retailing.

The use of convenience foods is often described as providing meal solutions to time-pressed consumers, helping them deal with busy domestic routines and workplace schedules. These pressures can be felt at different points: when planning a meal, purchasing food, cooking or cleaning up.

The contrast between 'convenience' food and 'home-made' food, cooked from scratch using fresh ingredients, remains widespread and has led to the negative moralization of convenience food. This is particularly problematic for mothers who face social disapprobation for relying on convenience foods, given the persistence of gender stereotypes about 'feeding the family' as predominantly women's work.

Rather than blanket condemnation of convenience foods for their adverse impacts on environment and health, our research sought to understand why consumers adopt practices that depart from expert opinion and official advice on 'health eating', food waste and sustainability, challenging the conventional 'deficit' approach (where consumers are assumed to lack the knowledge or skill to make informed choice). By contrast, a practice-based approach focuses on the institutions and infrastructures that shape their choices.

The research included a systematic literature review, published in the peer-reviewed journal Appetite (Jackson & Viehoff 2016). Our main research findings were published in a series of articles and in a jointly-authored book: Reframing Convenience Food (Palgrave Macmillan 2018).

Two PhD theses have also been completed. One (Wenzl) is already published: https://opendata.uni-halle.de/bitstream/1981185920/70830/1/Wenzl_Dissertation_final.pdf, the other (Hertz) is to be submitted shortly.

Results and Achievements

WP1: Processed baby-food and everyday feeding practices

What is considered convenient food for weaning is sometimes home-cooked and sometimes readymade and dependant on factors such as the baby's food preferences, the family's food preferences, daily meal rhythms and ideologies of eating together.

Companies' web marketing challenges the conventional distinction between convenience and care, and equates convenience food products, which often carry qualities considered negative or even harmful, with care.

Marketing and web material on baby food and weaning involves a range of images offering discursive resources which support consumers in negotiating actual and ideal practices linked to cultural ideals on consumption.

Comparing the riskscapes of weaning and baby food of public health, Swedish-born and Somali-born mothers shows that inadequate weaning practices are a major concern only for public health officials, while mothers' riskscapes are assembled around matters of the baby, food and everyday life. For the Swedish-born women also, the conflicting information on weaning practice they receive from public health is a big concern. Taste preferences of the baby and other everyday concerns matter most when it comes to choice of food for the baby. Good nutritional quality and price is also important, but sustainability is not a big concern, although locally produced food is preferred.

Environmental sustainability is primarily addressed in reference to eco-labelled products and notions of locally produced products. Price is more important than organic, but the taste preferences of the baby and other everyday concerns matter most.

WP2: The healthiness and sustainability of supermarket ready-meals

Rather than seeing 'convenience' and 'homemade' food as mutually exclusive categories, our research demonstrates how participants combine convenience foods with other kinds of food in their everyday domestic practices.

The use of convenience foods such as ready-meals is often contrasted negatively with 'cooking from scratch' and is subject to moral disapprobation within the gendered discourse of 'feeding the family'. Participants justified their choices as providing the opportunity to cater for the tastes and culinary preferences of different family members, to provide food at times that suit the disharmonious domestic routines of parents and children, to allow children to cook for themselves when parents are out, or to enable more 'quality' time to be spent with family members. The moral ambiguities of convenience food are often negotiated through the use of irony and self-deprecating humour (Jackson & Meah, Food, Culture and Society 2019).

While many participants struggled to make a link between food and environmental issues, some argued that their use of convenience food reduced food waste rather than buying fresh ingredients that might spoil before use (particularly among older people, those living alone and households with no dependent children).

Consumer practice often departed from official guidance (on 'correct' refrigeration and storage instructions, or washing poultry prior to cooking). This suggests a need to understand the logic that informs people's everyday practice rather than assuming them to be ignorant or careless in their domestic routines.

WP3: Canteen food and work-place food geographies

Lunch in a canteen is as much a social event as an opportunity to satisfy appetite and this should be taken into account in the discourse of healthy eating. Apart from the meal choices made by canteen guests, key decisions are also made in the supply chain which affect the meals served in canteens. These include:

- EU food safety regulations and HACCP systems
- National legal frameworks, including dietary recommendations (in calls for tender) and policies which favour highly industrialised large-scale food production
- Whether a canteen is subsidized or not which affects the budget to be spent on food. This has direct impact on the range and quality of meals offered. Catering businesses operate in a very price-competitive environment.

Where available, consumers often combine different side-dishes with elements from the salad bar or buffet in order to create a dish which meets their individual demands. This is especially evident for vegetarians or people who do not eat pork. When interviewed, caterers were aware of the special dietary regulations in Jewish or Muslim religions.

The research concluded that:

- Consumption of fresh meals in canteens is dependent on prices. The budget of canteens needs to be improved.
- Documentation and observation of certification, regulations and standards is very time-consuming and keeps canteen staff from concentrating on sourcing and preparing healthy and fresh meals. Bureaucratic tasks for canteens need to be reduced and simplified.
- Meat dishes are still the most common lunch-time meals when served at reasonable prices. Canteen customers are very price sensitive. Subsidizing vegetarian dishes could make them a more competitive and compelling choice.

WP4: Meal-box schemes: convenience and sustainability

Meal box-schemes are a good example of the kind of food provisioning which is experienced as convenient by parents, because the food-work involved in planning, shopping and preparation of meals is made 'more simple'. Meal-box schemes help to maintain the everyday logistics of family life. When families use meal box-schemes, they switch to a highly planned way of providing food and cooking.

Meal-box schemes function as a convenient way to avoid traditional convenience foods, associated with unhealthy and unsustainable food. Parents can claim that they cook their meals from scratch, which then enables them to live up to the normatively acceptable ways of preparing home-made meals. The boxes also enable them to meet the criteria for 'proper' food, such as variety, freshness, locality, satiety, nutritional composition, and not least, sustainability through organic food and reduced food waste.

Providing for, cooking and eating family meals is thus a constant attempt to balance a number of different, sometimes contradictory, social expectations about cooking in a sufficiently healthy, varied and loving way.

The institutional arrangements of websites and the supply of meal boxes draw on a common discourse that equated meal-boxes with convenience, where the consumer is constructed as in need of help to make daily life easier. At the same time, there are clear differences where organic meal-boxes tend to stress sustainability the non-organic meal-boxes tend to stress nutrition.

Impact

The final chapter of our book, Reframing Convenience Food (2018), draws out the implications of our research for policy and practice offering an alternative to the deficit approach (that focuses on consumers' alleged lack of knowledge and skills); a critique of simplistic ideas about 'food miles' that inform attitudes to food waste and sustainability; and a reframing of the links between health and sustainability (highlighting what lessons can be learnt from the popularity of convenience food that might be relevant to the consumption of healthier and more sustainable alternatives).

The findings of WP1 were discussed with Swedish food retailers and health authorities. Researcher Maria Fuentes has worked on a second SUSFOOD project, 'Sustainable platforms: enabling sustainable food practices through socio-technical innovation' (PLATEFORMS), and on the 'Alternative

food markets' project, promoting new modes of food provisioning and consumption' (including vegan alternatives, local markets, and consumer-to-consumer markets), funded by Swedish research council FORMAS.

The results of WP2 were presented to the Department for Environment, Food and Rural Affairs (Defra) in London in 2014 and again in 2016. Presentations were also made to the Food Standards Agency's Science Summit in 2016. Following the FOCAS project, Jackson chaired a SAPEA working group on the transition to a more sustainable food system for the EU, informing the European Commission's 'Farm to Fork' strategy: https://sapea.info/topic/food/. Jackson currently serves on Defra's Social Science Expert Group, providing advice and challenge to Government. He also provided oversight for the public engagement phase of the National Food Strategy.

The outputs of WP3 include an outstanding PhD thesis (summa cum laude) by Christine Wenzl on canteen food consumption practices, published in 2022. Dr Wenzl now works as network coordinator of the Food Agency of the Bavarian Ministry of Food, Agriculture and Forestry, responsible for 'Organic Food from Bavaria'.

Building on the findings of WP4, Halkier has been working on a project about 'Social drivers and barriers for climate-friendly diet'. This is impacting on the societal development of transition processes towards more plant-based and sustainable diets in Denmark, working closely with the Danish green think-tank CONCITO. Halkier became a member of the Danish Climate Council in 2020. The Climate Council is an independent institution of experts who advise the Danish government on strategies by which to reach the climate-related goal of 70% reduction by 2030.

Finally, our researchers have gone on to careers in academia (Fuentes), teaching (Viehoff), government (Wenzl), consultancy (Herrtz) and business (Meah), demonstrating the value of the FOCAS project in terms of their career development.

Conclusion and Recommendations

Our research concludes that 'convenience foods' do not stand alone as a separate category in terms of everyday consumption, frequently being combined with other kinds of food. While definitions are multiple and contested, 'convenience foods' conventionally encompass a wide variety of processed or semi-processed foods which can be classified as 'ready to cook', 'ready to heat' or 'ready to eat'. A useful typology is provided by Daniels and Glorieux (Appetite 2015).

Different kinds of convenience food can be compared and contrasted in terms of their methods of acquisition, appropriation and appreciation as summarised in Jackson et al. Reframing convenience food, 2018.

Our project focused on four key themes concerning: the normalization of convenience food, its moralization, temporalities and spatial organization. We also highlighted the way that convenience food is caught up in public discourse about the alleged decline in cooking skills and culinary competence. By contrast, our project drew attention to the way that convenience food provides practical solutions to the temporal and other constraints of people's daily lives. Our recommendations suggest that a practice-based approach offers a preferable alternative to the moralization of convenience food in popular and policy discourse, repudiating the assumption of a deficit (of skills and competence) in those who use them. The reasons that have made various kinds of convenience food so popular can then be used to promote foods that are considered healthier and more environmentally sustainable.

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8. COSUS

CALL 2013

Consumers in a sustainable food supply chain: understanding barriers and facilitators for acceptance of visually suboptimal foods

PROJECT TEAM

Coordinator:

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Summary

A large share of edible food is wasted because it deviates from what consumers consider 'optimal': they are close to best-before date, have an odd shape, or have other visual imperfections. COSUS (2014-2017) aimed to:

1. Understand the barriers and facilitators for acceptance of suboptimal foods
2. Investigate how strategies that stimulate consumer acceptance of suboptimal foods can be successfully implemented into the food supply chain
3. Design and test strategies that promote the consumption of suboptimal foods.

The project resulted in increased knowledge, successful strategies, and opportunities identified in the food supply chain for producing, selling, and consuming suboptimal foods.

Results and Achievements

This project indicates that suboptimal foods can be accepted by consumers under certain conditions: more likely in the home than in the store, unless for a large discount; depending on the product type, whether the product is easy to handle, whether it will be served to guests or children, and depending on personal characteristics. Potential target groups for suboptimal food are households without children, women, younger individuals, individuals with lower education, those with strong environmental commitment, and individuals who are price conscious. Consumers seem to be

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sensitive to discounts on suboptimal products, but in some cases, the discount needed in order to accept suboptimal foods is high. Repeated exposure of consumers to suboptimal products might generate increased purchase likelihoods of such products over time, as does communication that suboptimal foods are still tasty. Ideally, children should become familiar with suboptimal foods, thus making suboptimal foods move from being suboptimal, to foods that are considered acceptable for consumption.

Impact

The project has generated scientific (20+) and popular scientific articles and conference presentations, as well as new project proposals at national and international level. In Norway, the project Sustainable Eaters: Consumers in a sustainable Norwegian food system (Research Council of Norway, nr. 320800) aims to develop new solutions for boosting consumers' contribution to a sustainable future.

Conclusion and Recommendations

This project shows that there is potential for increasing purchase and consumption of suboptimal foods under the right conditions. It also unveiled a need for tools to increase European consumers' awareness and accountability in food waste reduction, beyond standard communication pathways.

Collaboration between stakeholders, timing and sequence of initiatives, competencies that the initiative is built on, and a large scale of operations are key success factors. Future initiatives should take inspiration from existing initiatives, especially in considering the right partners that are trusted by consumers, the competencies involved, and timing. Collaboration is also key to ensuring that future initiatives are acceptable and economically viable for all actors in the supply chain.

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9. SUSDIET

CALL 2013

Implementing sustainable diets in Europe

PROJECT TEAM

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C. Revoredo, SRUC, United Kingdom

P. Scarborough, University of Oxford, United Kingdom

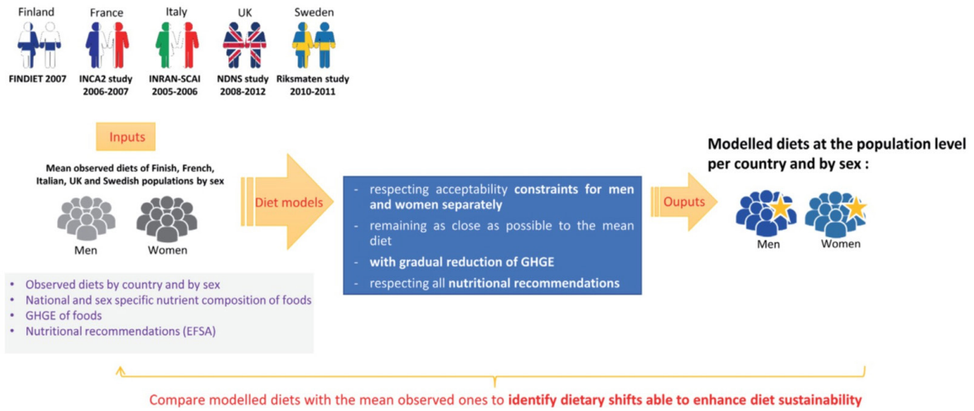
Summary

The SUSDIET project aimed at identifying sustainable diets compatible with consumers' preferences in Europe and analysing the public and private policies that could favour their adoption. The SUSDIET consortium was composed of 15 research teams from 8 European countries (Finland, France, Germany, Italy, Norway, Spain, Sweden and the UK). The approach was multi-disciplinary, encompassing researchers in consumer studies, environmental science, economics, nutrition, and public health.

There is broad agreement that current consumption patterns are unsustainable in the sense that the multi-dimensional problems that they entail threaten the functioning of the entire food system. However, despite this agreement, the dietary patterns to be targeted and the way of achieving them remain unclear. To get a better understanding of these issues, the following questions were addressed: what impact on health, the environment and consumer welfare may we expect from changes in dietary patterns? To what extent do consumers take into account sustainability issues in their decisions? To what extent information, labelling and fiscal policies may affect the consumers' trade-offs and contribute to the adoption of more sustainable diets?

Results and Achievements

A first set of results provided new insights into the sustainability of current and alternative diets, considering different sustainability dimensions (i.e., health, environment, economic) simultaneously. Some important sustainability



Sustainable claim	Product attribute
Carbon neutral (CN)	Certified pack featuring CO_2 Neutral Carbon Neutral Certified Logo
Ethical – Animal (EA)	• Free range eggs (custard, mayonnaise pasta) • Free range pork • Free range chicken • Milk from free range cows • Free range Beef / reared with care by British farmers • Responsibly managed farms and fisheries • Approved by freedom food to strict RSPCA standards
Ethical – Charity (EC)	• The manufacturer works with charity (environmental) • Manufacturer supports rural communities • Recyclable carbon bearing the FSC logo
Ethical – Environmentally Friendly Packgage (EEFPCK)	• Partly-recyclable, recyclable or biodegradable pack • Recyclable bottle • Recyclable pack
Ethical – Environmentally Friendly Product (EEFPR)	• Sustainable sources of production (e.g. palm oil) • Grown to Leaf Marque Standard (integrated production) • UTZ certified to support cocoa farmers • FSC and Rain Forest Alliance Certified logos
Ethical – Human (EH)	• Support British farmers • Fairtrade logo • The manufacturer works with charity (human)
Organic (O)	Organic certified

properties of alternative patterns of consumption were assessed, such as the trade-offs between greenhouse gas emissions (GHGE) and nutritional quality. Moreover, while previous studies had focused on substitutions between food categories (e.g., plant vs. animal products), the project provided new results to substitutions within food categories (e.g., between different types of meat).

A second set of results was related to the identification of major barriers preventing consumers from making sustainable dietary choices. A better understanding of consumer trade-offs between sustainable attributes was achieved and the role of motivations, values, price, taste, convenience, and other attributes that can influence food consumption was better explained.

A third set of results was related to policy instruments that may influence consumers' decisions towards choosing more sustainable diets. Two main public policies were considered: those supporting better choices through information campaigns and food labelling; and those aiming at changing the market environment, mainly through fiscal policies. Using state-of-the art methods and data collected at the European level, the project provided original insights about the economic, public health and environmental impact of these policies.

Impact

- Participation in European conferences, scientific publications and national reports.
- Presentation of the main results in several countries, with representatives of ministries and actors of food chains.
- Policy recommendations on sustainable diets to be prioritized at European level.
- Policy recommendations on the potential impact of various instruments for change at the consumer level.

The willingness to consider different sustainability dimensions (health, environment, economic) simultaneously, and to conduct cross-country comparisons at the European level, raised several methodological challenges. In particular, it was important to collect and harmonize food dietary survey data and food composition databases, as well as to harmonize climate impact assessment of food categories. It was also required to estimate food demand parameters in several countries by using, as much as possible, the same methodology. All of this work provides results (datasets) that can be used in future research. Methodological advances were also needed to better estimate the health effects of dietary changes, to carry out the benefit-cost assessment of dietary recommendations, and to progress in the ex-ante evaluation of carbon taxes. It will also be possible to use these methods in future research.

Conclusion and Recommendations

1. Healthier diets are not necessarily the most climate-friendly. However, it is possible to reduce the climate impact of one's diet without compromising nutrition. Compared with average consumers, individuals who have more sustainable dietary patterns, consume more vegetables, grains, fruits, meat imitates, fish, dairy milk product imitates, vegetables fats, water and vegetable composite dishes and less livestock meat, processed meat, cheese, sugar & confectionary, animal fats, juices, soft drinks, alcoholic beverages, animal composite dishes and snack and desserts. Thus, overall they clearly consume more plant-based products and less animal products.
2. To achieve nutritional adequacy with a 30% reduction in GHG emissions impose significant modifications in average current dietary patterns, but it is possible without suppressing any food group. Overall, achieving a diet that meets nutritional recommendations leads to substantial population health gains.

   Even more health gains can be achieved with diets that are additionally designed to reduce GHG emissions. A large proportion of the health benefits are from reductions in cases of colorectal cancer and diabetes. This is primarily due to the big reductions in red and processed meat intake that occur in the diet scenarios with the largest health benefits. Reductions in CHD, stomach cancer, lung cancer, breast cancer and stroke, also contribute to the modelled health gain.

3. Even for health-aware consumers, the adoption of nutritional recommendations is difficult. Consumers may incur an adoption cost, which weakens their willingness to comply with recommendations. However, even when one takes into account this cost, it turns out that most of the sustainable diet recommendations are highly cost-effective. General conclusions regarding sustainability of diets hold in all countries. However, the variability of current dietary patterns, food products composition, and consumers' preferences across countries may require adapting dietary targets according to the national contexts.
4. Consumers are sensitive to sustainability issues. However, consumers' sensitivity to sustainability issues has positive – albeit modest – effects on food purchases. Overall, values related to intrinsic product properties such as taste, safety, appearance, and nutrition are seen as most important by consumers, while values related to production like fairness, sustainability and environmental impact are seen as less important. However there are significant differences with respect to food groups and environmental values between countries.
5. Perceived consumer effectiveness, subjective knowledge, altruistic attitudes and time preferences have an important influence on climate-friendly behavior. Beliefs about meat and environment play an important role in diet choices. Social image concerns have been shown to influence the WTP for sustainable foods.
6. Substitution patterns induced by healthy-eating policies are key in determining environmental outcomes. Regarding 5-a-day campaigns, it turns out that they may have positive impacts on the consumption of fruit, fruit products and fruit and vegetable juices, and favor a reduction in the consumption of meats, ceteris paribus. This effect leads to an overall improvement in GHGE emissions and suggests consistency between nutritional policy objectives and environmental outcomes.
7. Product labelling facilitates consideration of health and environmental dimensions by consumers, especially if labels are associated with more information. The association of environmental and health labels may generate more confusion, which affects consumers' wiilingness-to-pay. Labels generally increase consumers' awareness, but do not always affect food choices.
8. Cross-country investigation of food demand confirms that consumers respond to prices. However, most own-price elasticity estimates are smaller than unity in absolute value, which establishes that food demand, even for reasonably disaggregated categories, is inelastic. The analysis indicates that demand relationships remain highly specific to each country. A consequence is that the potential effects of carbon taxes on food products strongly vary across countries. Overall, carbon taxes on food products would have modest impacts on GHG emissions, and depend a lot on tax schemes and rates. In general, carbon taxes on food products would not damage the nutritional quality of individuals' diets, but they induce moderate losses of welfare for consumers. The consumer's welfare loss is minimized if only the beef category is taxed.

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PROJECTS FUNDED IN THE 2nd CALL OF SUSFOOD - 2014

There are 6 projects funded in the second call. Detailed information about the projects listed below is provided in this section.

Nr	Acronym	Project Title
1	FREEZEWAVE	Innovative and low energy microwave assisted freezing process for high quality foods
2	RF-cooking of Ham	Rapid industrial scale cooking of boiled ham using radio frequency electric fields
3	ProRef	Gentle and resource-efficient refining of vegetable oils for preservation of valuable components and simplified reprocessing of by-products.
4	BerryPom	Adding value to fruit processing waste: innovative ways to incorporate fibres from berry pomace in baked and extruded cereal-based foods
5	SUSMEATPRO	Sustainable plant ingredients for healthier meat products - proof of concepts
6	OATPRO	Engineering of oat proteins: Consumer driven sustainable food development process

1. FREEZEWAVE

CALL 2014

Innovative and low energy microwave assisted freezing process for high quality foods

PROJECT TEAM

Coordinator:

Prof. Alain LE-BAIL, ONIRIS

Partners:

Epameinondas XANTHAKIS

Marie SHRESTHA

Jean-Paul BERNARD

Summary

FREEZEWAVE project concerns the freezing of foods using a highly innovative technique combining freezing at slow rate with part time emission of microwaves (2450 MHz); this innovative concept has been investigated recently by ONIRIS and results showed that a 62% decrease of the average ice crystal size was acquired when samples were frozen under microwave irradiation compared to the control (Xanthakis et al., 2014, IFSET - study on pork meat). Freezing offers a quasi-infinite shelf life of food regarding the microbial risk and it is environmental friendly in that it reduces food wastes and offers convenience to the consumer (cook just what you need). Limitations in shelf life rather come from the deterioration of the quality of food which is due to: i) mechanical damage caused by ice crystals formation and ii) exposition of the matrix to concentrated solution caused by cryoconcentration.

To improve the quality of frozen foods, fast freezing is usually recommended, resulting in a reduction of the ice crystals. However, a fast freezing increases the energy demand: low ambient temperature & high air velocity to enhance the rate of heat transfer are needed to achieve a fast freezing. This project proposes a highly innovative technique which showed that a small amount of emitted microwave energy combined to a slow freezing rate is able to refine ice crystal size in frozen meat. FREEZEWAVE project aims at expanding & optimizing the concept to several foods (sauce, meat, vegetable & ready to eat meals) and also at designing industrial equipment.

The novel concept is expected to concern the freezing equipment sector thanks to a French SME partner of the project and the global frozen food sector. FREEZEWAVE will provide scientific knowledge and new scientific insights in food freezing. Project's outcomes may also be of interest for non-food applications such as biotechnology.

Results and Achievements

FREEZEWAVE's main outcomes are presented in this summary. It concerns the equipment, the methodology to assess freeze damage and the results related to the MAF process (Microwave Assisted Freezing).

MICROWAVE ASSISTED FREEZING TECHNOLOGY & EQUIPMENT:

Regarding the equipment's, a 200 Watts-2.45 GHz solid state emitter has been constructed by SAIREM company (France). This emitter is able to deliver a continuous micro waves emission at low power,

which is impossible to do with a conventional magnetron. ONIRIS has developed a controller, which was connected to the emitter in order to control the duty ratio of power emission. For the very low power, a mechanical switch has been constructed by ONIRIS; indeed, even when a zero power was programmed to the solid state emitter, a residual power was still emitted. As a conclusion from FREEZEWAVE, ONIRIS, RISE (former SP) and TTZ are equipped with different freezing equipment that could be used to continue the research related to MAF (table 1). At RISE (former SP) the dielectric properties of a variety of foodstuffs were measured during freezing and thawing conditions and they were presented as functions of temperature. A specific model accommodating the amount of frozen water in the food sample as a function of temperature was used and compared to experimental results. The mass fraction of each component was coupled to the dielectric properties of each fraction to evaluate the effective dielectric properties based on a two phases Maxwell-Wagner model considering ice as a dispersed fraction and food as a continuous fraction. The unknown dielectric properties of dry matter and an adjusting coefficient were used to optimize the fitting between experimental data and calculated data.

FREEZE DAMAGE ASSESSMENT:

FREEZEWAVE partners have developed specific skills related to the assessment of freeze damage in different matrices. Apart from the conventional techniques such as texture, drip loss, NMR, in depth research has been done to benchmark different model foods and different under used technics. A model gel (Tylose – commercial name, a gel of methylcellulose that has similar properties to meat) has been used successfully by ONIRIS. The gel was freeze-dried progressively to prevent any collapse of the structure. X-Rays computed tomography was used by ONIRIS to analyze the size of the ghosts of ice crystals left in the matrice in Tylose and also in other food systems. This technic was very successful and allowed a very precise determination of the size of ice crystals. Other techniques such as CLSM (Confocal Laser Scanning Calorimetry) have been very helpful for fruits and vegetables. Carnoy fixation technique was well adapted to seafood and meat tissues; this technique is a bit complex to use. Besides, it gives access to the observation of the ghosts of ice crystals with the possibility to determine intra and extra cellular ice.

CONTRIBUTION TO MAF APPLIED TO A METHYLCELLULOSE GEL & MODELING

This research is related to the PhD of M SADOT (held 24th Sept 2018), which manuscript (in French) is available on the website of the University of Nantes-France. A 3D heat transfer model coupling heat transfer with phase change and electromagnetic waves heat generation has been developed. The importance of the dielectric properties reduction

on resonance phenomena, leading to the moving of “hot spots”, and on the generated heat has been pointed out. A methylcellulose gel was used and X ray tomography was used to quantify the size of ice crystals in 3D using freeze-dried samples. Aa a main result, a clear decrease in ice crystal size was observed for MAF compared to conventional freezing. Finally, it has been shown that the ice crystal size reduction was more reduced for pulsed microwave emission (duty ration 1/3) than for constant MW power emission. However, the differences were not significant from a statistical point of view.

CONTRIBUTION TO MAF APPLIED TO FRUITS & VEGETABLES

This research is related to the P.K. JHA (held 9th Nov. 2018), which manuscript (in English) is available on the website of the University of Nantes-France. The impact of MAF on freezing time, quality attributes (microstructure, texture, drip loss and colour) of apple and potato. MAF was performed by applying constant microwave power (167 W/kg) and pulsed microwave power (500 and 667 W/kg with 10 s pulse width and 20 s pulse interval making an average power of 166 & 222 W/kg during freezing. The freezing time was not much affected by the MAF process. MAF yielded a superior microstructure (examined using X-ray tomography and

EQUIPMENT POWER (MW) 2 450 MHz FREEZING CAPACITY Contact Person Single mode wave guide SAIREM solid state 0-200 W + power control (ONIRIS) 10 g T: – 20°C/- 80°C Prof A. Le-Bail - ONIRIS Alain.lebail@oniris-nantes.fr Multi mode cavity (domestic type modified). Turn table. Air flow inlet-outlet through cavity (1-3 m/s) SAIREM solid state 0-200 W + power control (ONIRIS) 100 g / 200 g T: -20°C/-40°C Prof A. Le-Bail - ONIRIS Alain.lebail@oniris-nantes.fr Multi mode cavity (domestic type modified). Turn table. Air flow inlet-outlet through cavity (1-3 m/s) SAIREM solid state 0-200 W + power control (ONIRIS) 100 g / 500 g T: -20°C/-40°C Dr E Xanthakis - RISE (former SP) epameinondas.xanthakis@ri.se Multi mode cavity (domestic type modified). Turn table. Air flow inlet-outlet through cavity (1-3 m/s) SAIREM solid state 0-200 W + power control (ONIRIS) 100 g / 200 g T -20°C/-40°C J. HUen – TTZ jhuen@ttz-bremerhaven.de Solid state Emitter 0-200 W D. Vennin SAIREM CEO dvennin@sairem.com cryo-SEM techniques) than the control sample with a significant reduction (ca 15 to 20% in dimension) of the mean ice crystal size in apple and potato sample, a lower drip loss, a lower reduction in firmness/hardness and Young’s modulus value compared to control sample. The 667 W/kg pulsed microwave condition yielded the best result in terms of reduction in ice crystals size and retention of other quality parameters. As a conclusion MAF resulted in higher quality frozen products.

CONTRIBUTION TO MAF APPLIED TO MEAT (RISE (former SP))

This part of the project was focused on the application of MAF to pork meat. For the freezing of meat further than the conventional freezing, pulsed MAF conditions such as long pulse low power (LPLP: 8 s /6 W – 8 s /0 W) and short pulse high power (SPHP: 4 s /12 W – 4 s /0 W), as well as freezing under low constant microwave power (3W) were applied.

The acquired results indicated that conventional and constant power MAF freezing led to greater ice crystal average size, while the SPHP seemed to result in slightly smaller ice crystals. From all the tested conditions long pulsed low power (LPLP) gave the best results regarding the ice crystal size where the average size was ca. 20% lower than that of the conventionally frozen samples. These results confirm the previously acquired results by Xanthakis et al. (2014) for MAF of pork meat where the ice crystal size was decreased when was frozen under similar length of microwave pulses. In that study the authors explained that the impact of microwave application during freezing on the ice crystal size can be related to the oscillation of temperature at both stages of nucleation and crystal growth. The limited oscillation of the temperature during the genesis of the ice nuclei and crystal growth could be responsible for instantaneous recurring melting and regeneration of ice crystals which in turn prohibited the crystal growth and might led to the numerous and smaller ice crystals which were observed (NITOM phenomenon).

CONTRIBUTION TO MAF APPLIED TO SEAFOOD BASED READY TO EAT MEAL (TTZ)

This research was carried out by TTZ on cod samples. It was decided to work with relatively large samples of approx. 100 g each as cod is mainly commercialized as filets, not small pieces. The work conducted at ttz allowed defining process parameters that lead to a significant absorption of the microwave without inhibiting the freezing process. These parameters are: 1 W per 100 g of sample, continuous microwave radiation, 2450 MHz. The experiments were performed with an air temperature of -25°C and -35°C. Histological investigations showed that a significant reduction of the number and of the size of intracellular ice crystals could be achieved in comparison with conventional freezing. This provided evidence of the applicability of MAF-freezing to fish products, as the expected effect on nucleation and crystal growth was observed. On the other hand, the migration of liquid from the intracellular to the extracellular space could not be prevented by microwave application. At a macroscopic level, the loss of product weight observed during thawing was not reduced by microwave application. Both observations may be linked with one another and could possibly be addressed by using a higher velocity of air circulation around the sample, which would lead to a higher freezing rate.

SENSORY EVALUATION OF FOOD FROZEN WITH MAF PROCESS (TTZ)

Note: A detailled report is proposed in Annexe of this main report

The research has been conducted with potatoes, fish and chicken breast and the main objective was to identify the impact of different freezing technologies on the sensory qualities of the food samples. In detail, the study investigated MAF-freezing technology in direct comparison to existing technologies and to fresh samples. The results of the study show that MAF technologies have no significant superior impact on sensory quality than existing technologies. The freezing step in general have much more impact on the sensory perception than how it is frozen. However, even though the study could not proof at this stage that MAF have positive impact on sensory product quality, it must be stressed that there could be a very positive effect on products which are frozen at several process and logistic steps along the food chain. There could be a very positive effect on fish filet e.g. which is traded as double or even triple frozen. Thus, further research is needed to investigate the positive impact on sensory quality in food that is processed with several freezing steps before it is consumed (e.g. fish, fruits). Detailed results are described in a separate report and is under preparation for publication in 2019.

TOWARDS INDUSTRIAL EQUIPMENT

The information’s gathered during FREEZEWAVE gave access to specifications and requirements needed to design an industrial batch of conveying Microwave Assisted freezing equipment. A concept has been sketched by ONIRIS considering the case of apple freezing.

The freezing time has been determined using the PLANK equation with the following assumptions:

- Apple as a slab installation, 3 cm thick, Heat transfer coefficient 30 $W/m^2/K$
- Freezing enthalpy 233 kJ/kg, initial freezing temperature -1°C
- Apple density 1000 kg/m^3, thermal conductivity 1 W/m/K

- Flow rate 30 kg/h, width of the freezer 1 m
- Ambient temperature -20°C/-60°C
- Air ventilation energy = 25% of the freezing energy (for the product)
- Micro wave energy = 3.5% of the freezing energy (for the product)

Based on these assumptions, the freezing time was 99.7 min and 32.1 min for -20°C and - 60°C respectively. This correspond to a freezer length of 166 m and 54 m respectively. In the case of spiral freezer with a spire diameter of 6m, this represents ca 9 turns (spires) and 3 spires respectively. By considering a COP (coefficient of performance) of the refrigeration unit based on the electric power of 1 and 0.3 for -20°C and -60°C respectively, this would make 1.5 kW and 15.5 kW of electric power for -20°C and -60°C respectively. The lower COP of the -60°C option was very impacting on the power consumption, despite a much shorter freezing.

Impact

ENVIRONMENTAL IMPACT OF MAF COMPARED TO CLASSICAL FREEZING

The environmental performances of the innovative process developed were assessed in comparison with conventional freezing, based on LCA methodology. Calculations are made for the case of apple freezing. The computation have been done I the case of apple, based on the following assumptions:

-The quality of frozen product by MAF at -20°C is similar to the quality of product frozen in a blast air freezer working at -60°C.

-The comparison is based on energy consumption of MAF versus 3 others processes at -40°C, -60°C and -80°C in equipment designed to handle slabs of 3 cm thickness and a flow rate of 30 kg/h.

Two impact categories were studied: global warming potential and energy consumption. Methods used for impact assessment are: Cumulative Energy Demand and Recipe midpoint. These results are based on French electricity mix and energy consists of 95%of non-renewable energy (85% nuclear and 10% fossil origin) and 5% of renewable energy (water, wind, solar). Total primary energy use for MAF -20°C corresponds to one third of energy for freezing at -60°C which gives the same product quality (1.1 MJ/kg apple vs 3.6 MJ/kg). The total potential contribution of MAF is approximately 12g CO_2-equivalent per kg of apple whereas this potential reached 40g CO_2-eq in the case of freezing at -60°C. Freezing step is critical for environmental impact due to energy consumption but also to the use of refrigerant. Indeed, refrigerants are important pollutants contributing to global warming and ozone layer depletion. New European regulations have been put in place since 2000 to prevent emissions and ozone layer depletion (progressive prohibition of the use of CFCs and HCFCs) and to reduce the use of higher global warming potential of f-gases in order to decrease the environmental impact of refrigerants. In food industry, the most used refrigerants are (from most used to least used): R-717 (NH3), R-404A, HCFC-22, HFC-134A and R-744 (CO_2). Refrigerants with the lowest contribution are CO_2 and NH3: their use is increasing while that of HCFCs is decreasing. Cryogenics is promising in terms of its impact on global warming but requires powerful equipment. Most current refrigerants are to be avoided for the environment. MAF used with low GWP refrigerant could be a great alternative to reduce energy consumption and increase product quality.

Conclusion and Recommendations

FREEZEWAVE has confirmed that MAF was efficient way to reduced the size of ice crystals in food matrices following the freezing process. Two concepts are proposed to explain the observed ice crystal size reduction in frozen systems by using microwaves.

- The “NITOM” concept (Nucleation Induced by Temperature Oscillation caused by Microwaves) is based on the fact that under specific duty ratio, the temperature of the sample undergoing freezing will oscillate (Xanthakis et al., 2014). The fluctuating temperature is expected to favor secondary nucleation, which, in turn, suppresses the crystal growth.
- The second concept is called “NIMIW” (Nucleation Induced by constant or pulsed MWs power) and it is based on constant or pulsed (short time emission) emission. NIMIW can be explained by the impact of MW on the hydrogen bonds between water molecules, which may affect the water cluster structures during freezing. It is expected that MWs could exert a torque and displace the water molecules from their equilibrium relationships in the ice cluster resulting in fragmentation of existing ice crystals when ice crystals are under the form of nuclei. The fragmented ice crystals nuclei may act as new nucleation sites and promote the secondarynucleation, thus, causing ice crystal size reduction. Further research is needed to conclude even though the NITOM effect appears as the most logical explanation.

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2. RF COOKING OF HAM

CALL 2014

Rapid industrial scale cooking of boiled ham using radio frequency electric fields

PROJECT TEAM

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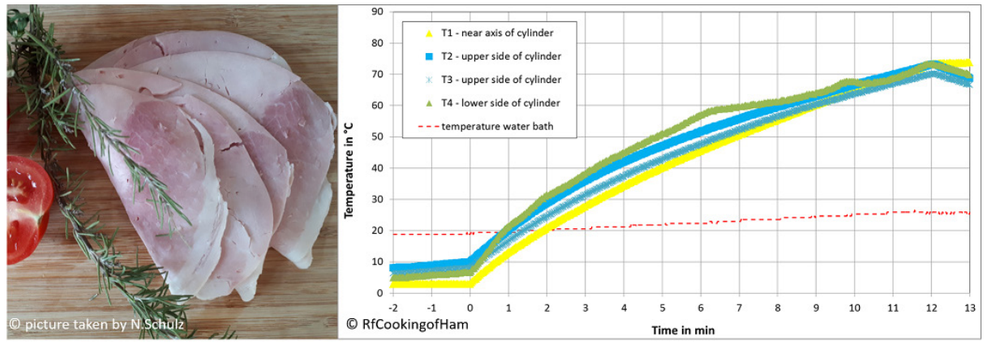
Summary

Cooked ham production is an important part of industrial meat processing and industrial food production in general. More than 220,000 tons worth 950 million EUR of ham is produced alone in Germany, about 120,000 tons of which are boiled ham (German federal statistical office, 2013). A cautious estimate of ham production for the whole of EU_28 amounts to at least 1 million tons worth 4 billion EUR 600,000 tons of which are cooked ham. Ham is also an example of a product category with high added value and significant relevance to trade of processed foods inside the EU. Though automation and large-scale production has been introduced into industrial ham cooking, the thermal unit operation is still a conventional hot water tub or steam-cooker cabinet. Both processes are time consuming and require cooking times up to 12 hours, depending on the size of the ham. Therefore, large-scale production units consume ample floor space and high amounts of energy. By using the volume heating effect of radio frequency (RF) fields cooking times can be dramatically reduced, offering possible energy savings, quality improvement, reduced cooking loss and increased yield. Also, production units based on the new technology can be built very compact and require less floor space.

The goal of the project is to adopt the RF-heating technology (13 MHz) with water immersion to the industrial scale cooking of ham. This involves the development of new technical solutions for optimizing the field distribution and heating uniformity inside the form-pressed and vacuum-packed ham of several kilogram weight (Fraunhofer IVV), but also evaluation of microbiological safety and stability (DTI), and of sensory product quality (IRTA).

Also, in another task of the project, different experimental set-up conditions will be studied for IRTA's RF equipment (27 MHz) with the of FEM simulation. These experiments will study the influence of several set-up conditions on the RF process, such as air gap, conveyor belt speed and electric field. Special attention will be given to the fluid surrounding the ham. Several fluids such as air and tap and distilled water will be evaluated. The most appropriate location of temperature probes will be analysed experimentally and using a metaphysics model of the process. The optimal RF processing conditions and set-up parameters will be applied to the elaboration of a cooked ham and the RF-cooking process will be evaluated and compared to a conventional cooking process. The reference process will be a conventional cooking



(Control) in a steam oven at constant temperature (+72ºC) for approx. 360 min until reaching a core temperature of +68ºC. Regarding the RF process, two RF-cooking processes, with an additional conventional heating treatment (RF-C process), will be evaluated. The first RF-cooking (RF-66) process tested will aim at reaching a core temperature of +66ºC. The second RF process (RF-72) will aim at a core temperature of +72ºC. Subsequently, both RF-cooking processes will be combined with an additional Conventional cooking in a steam oven (RF-66-C and RF-72-C) in order to reach +68ºC in the core and in all the zones of the RF-cooked hams and thus, to ensure that all the zones in the ham will be heat-treated equally.

We expect that the project leads to an innovative and safe process for industrial scale ham cooking with improved product quality, better yield, and less time, space, and energy requirement. During the project, a small pilot scale RF-heating equipment for ham cooking will be developed. The equipment will be available for further optimization, for sample production and for tests by interested companies. The project will also provide appropriate heating regimes and a data base for process scale up and industrial implementation.

Results and Achievements

Fraunhofer IVV (13 MHz RF-equipment): We could successfully demonstrate the uniform heating of hams with 100 mm diameter and 3 kg weight from 5°C to 72°C core temperature in an exposition time of 10 to 15 minutes, without overheating the outer areas of the ham. The conventional process for similar ham sizes needs 150 to 200 minutes to bring the core to 72°C. We could also demonstrate that RF-heating the ham in a cool water bath of 20°C to 25°C resulted in more rapid and much more uniform heating. Only by this effect, the rapid and uniform heating of the 100 mm diameter hams was possible. The quality of the RF heated hams was very similar to the quality of conventionally cooked hams (IRTA). Inactivation of microorganisms was effective but did not completely meet industrial standards (DTI). This can be corrected by further improving uniformity of RF-heating or by extending temperature holding times by a few minutes. In hams with 180 mm diameter and 8 kg weight we reached 72°C core temperature after 60 minutes heating time, the temperature in the outer regions of the hams however approached 100°C. With 180 mm diameter hams, the process seems to already touch limits of field penetration. The thermal efficiency, defined as relation of heat energy absorbed by the ham to the RF energy provided by the RF generator, was calculated to 71% for ham heating in cool water. If the heat in the ham is put into relation to electrical energy from mains, the total efficiency amounts to 57%. A small-scale pilot RF water bath heater was built to carry out all RF-heating experiments. The heater is equipped with a transistorised 13 MHz RF power generator and measurement devices for inline temperature measurement, for measurement

of temperature distribution after RF-heating and for measurement of all electric process parameters. The heater is available as demonstrator and experimental platform.

IRTA (27 MHz RF-equipment, Fig. 1): the optimal RF processing conditions and set-up parameters were determined. Distilled water was selected as immersion fluid to fill the sample container in order to have a high heating rate of the hams. This also helps to minimize electric arcs and discharges from the electrode. Tests were carried out with an air gap of 1 cm and a conveyor belt speed of 10 m/h moving the container with the sample forwards through the electrode. A single layer of aluminium foil, placed at both ends of the ham covering approx. 4 cm width from the ends is used to prevent overheating and damage in the ham during RF-cooking. In order to record the time-temperature profiles at different points of the ham immediately after the RF-cooking process, eight temperature-measurement positions are defined (thermocouple distribution). The time-temperature profiles, obtained with the probes inserted immediately after finishing the RF-cooking process, and the thermal camera image indicate that it is necessary the application of an additional conventional heat treatment after the RF cooking to ensure that all the zones in the ham are heat-treated equally and reach the target temperature. The time-temperature profiles showed that the total cooking-process time could be reduced significantly from 360 min in the Control to 230 min in the RF-66-C and down to 180 min in the RF-72-C process. Longer processing times in the RF-cooking process allow decreasing the time duration of the additional conventional cooking process in the steam oven and the total cooking-process time. The RF-72-C process reduced the overall processing time to a half with respect to the Control process, and the cooking losses (1-2% difference between processes). Lethality values in the centre of the ham were similar between Control (conventional cooking) and RF-66-C cooking process and higher for the RF-72-C cooking process. However, near the product surface (at 2 cm depth and at the surface) the RF lethality values calculated were lower than in the core, and lower for RF-72-C than for RF-66-C process. The lower lethality values of the RF-72-C cooking process near the ham surface may affect product safety. Further studies are needed to study the importance of this issue. Regarding the sensory quality studies, no visual colour differences were found during the descriptors generation and the evaluation results showed little differences between cooking processes. The RF-C cooked hams were rated with a slightly harder texture on the external part than the controls.


© RF Cooking of Ham Project

The results obtained in this task are published in Muñoz, I., Serra, X., Guàrdia, M. D., Fartdinov, D., Arnau, J., Picouet, P. A., & Gou, P. (2020). Radio frequency cooking of pork hams followed with conventional steam cooking. LWT, 123, 109104. https://doi.org/10.1016/j.lwt.2020.109104

Impact

The results obtained in the project, together with the acquired technological know-how, can be used by equipment manufacturers to implement the process on industrial scale.

The expected impact of the implementation of RF cooking on industrial level will be on the following aspects:

- Important reduction of cooking time
- Energy savings
- Reduction of space requirement
- Product quality improvement: reduction of cooking loss and higher homogeneity due to product over-cooking reduction.

Conclusion and Recommendations

The massive acceleration of the ham cooking process (RF 13 MHz) from up to 200 minutes down to about 12 minutes and additional 10 to 13 minutes temperature holding time for hams of 100 mm diameter is a clear innovation for the meat processing industry. Manufacturers of cooking equipment can use the technology, to offer innovative RF cooking equipment to the meat processing industry. A transfer of the process to large size cooked sausages is easily possible. This also holds true for the transfer of the technology to the pasteurisation of food in plastic packages.

The physical limits of the process have been touched with 180 mm hams, which we were not able to heat uniformly.

Microbiological safety was principally confirmed. Deficits with respect to industrial standard safety can be overcome by improving uniformity of heating or extending temperature holding time.

Quality of RF-cooked ham is very similar to conventionally cooked ham.

The results of the IRTA contribution in this project also show that RF cooking at 27 MHz can help to reduce processing times and save energy (reduction in thermal energy) while maintaining product quality. The combination of RF and steam cooking allows to obtain a product like that obtained with conventional steam cooking and to reduce process time by 50%. Regarding food safety, the lethality values of the process could be further improved by adjusting the times of both RF and steam cooking. However, existing RF equipment should be adapted for industrial mass production of cooked ham.

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3. ProRef

CALL 2014

Gentle and resource-efficient refining of vegetable oils for preservation of valuable components and simplified reprocessing of by-products.

PROJECT TEAM

Coordinator:

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Partners:

Jean-David Leao

M. Victoria Ruiz-Mendéz

Summary

The objective of ProRef was to develop an alternative refining process for edible oils based on more simplified methods and the use of more gentle process parameters for saving energy as well as minimizing the need of raw materials. Additional benefit should be obtained as the quantity of by-products (spent bleaching earths, SBE, and deodorizer distillates, DOD) generated during the process should be minimized as well as the loss of bioactive compounds. Furthermore the reprocessing of by-products and the recovery of valuable compounds should be simplified.

The first step to reach the project goals was the performance of comprehensive analyses on crude oils, namely, rapeseed, sunflower, olive and olive pomace oil, and also on the by-products obtained after each step of refining.

After collecting the data, it was possible to identify approaches for each type of oil to simplify existing refining processes. These measures included the application of biocatalysts and the implementation of miscella refining. Besides the evaluation of the target figures, the alternative process variants were determined for further influence on the oil composition, the processing yield and the deodorization temperature. With regard to the content of antioxidant polyphenols, for instance, the aim was to answer the question whether enzymatic treatments or the miscella process could preserve these substances in the oil to obtain an additional nutritional effect.

Neither the application of biocatalysts for degumming and de-acidification nor the miscella process led to significant differences in the oil composition compared to the conventional refining methods. However, the oil yield could be improved significantly with both treatments. Miscella refining inclusive process adaption was performed successfully at pilot scale.

Parallel experiments were performed on side streams, spent bleaching earth (SBE) and deodorizer distillate (DOD), of the conventional refining processes with the main aim of retrieving valuable components. A two-step treatment based on supercritical CO_2 extraction was developed with the objective of recycling SBE and recovering valuable compounds. The procedure enabled the removal of almost all the remaining oil from SBE and using ethanol as entrainer pheophytins were also obtained.

Among the various methods tested for the reutilization of DOD, like solvent extraction, adsorptive methods, crystallization, supercritical-CO_2 extraction and short-path distillation, the latter showed the most promising results. The separation of the FFA as FFA esters was very efficient, with remaining levels below 2 wt%. Moreover the residual components were clearly separated into the distillate (squalene) or the residue (unsaponifiables, tocopherols and sterols).

Results and Achievements

WP1: Characterization of industrial samples and generation of a data base

- Results show changes in oil composition from one harvest to another
- The presence of elevated amounts of free fatty acids in the distillates makes it difficult to evaluated contaminants
- The quantification of contaminants has been developed in oil matrices
- A methodological approach should be developed to determine contaminants, especially in olive and olive-pomace by-products. In order to assess the composition of deodorizer distillates, an analytical data base has also been elaborated.

WP2: Development of an innovative gentle and resource-efficient refining process

Application of biocatalysts

- Oil characterization after the enzymatic processes showed no significant influence on the oil composition and quality after the entire refining process.
- Compared to the conventional process an improvement of oil yield was observed for enzymatic processes at laboratory scale.

Miscella refining

- At a pilot scale, results obtained showed an excellent separation of soapstocks after neutralization.
- Oil characterization after the process showed no significant influence on the oil quality after refining.
- Significant reduction of oil losses was attained.

Application of specified bleaching agents

- Irrespective of the type of applied bleaching agent, the oil lightened up and the content of red colouring substances and the yellowness were reduced.
- The change of the bleaching efficiency ΔEab was significantly influenced by the amount of bleaching agent applied.

WP3: By-product recovery

SBE:

- Higher extraction yield due to the co-extraction of polar molecules
- SBE still contained lipids and especially polymerized triacylglycerols.
- Hot ethanol induced higher level of alteration of the oily extract than the CO_2-based option
- The process implemented required ATEX directive

DOD

- The separation of the FFA, as FFA esters was very efficient, with remaining levels below 2 wt%
- Unsaponifiables were concentrated in the residue
- Along with the FFA esters, squalene was concentrated in the distillates
- Tocopherols and sterols were mainly concentrated in the residue

WP4: Scale up, technical validation and product quality

- Degumming and neutralization in miscella phase were efficient
- After miscella processing, improved behavior during decoloration was observed
- Generally, the process was feasible but the residual oil content in the extracted SBE was significantly higher compared to the laboratory scale experiments
- Evaluation of the bleaching efficiency of the extracted SBE also showed that there is a potential for an improvement of the process.

WP5: Environmental and economic assessment

- Based on the results, it cannot clearly be proven that the miscella-phase process is disadvantageous on the environmental aspect
- The performance of a more complete set of experiments is recommended for final evaluation
- Energy inputs (electricity and gas/heat) and water consumption should also monitored during the experiments to complete the missing/ approximate data
- Generally, it is important to note that the refining phase, of which neutralization is one aspect, has a minor contribution to refined rapeseed oil life cycle environmental impacts compared to agricultural phase

Impact

The refining of more than 90% of crude vegetable oils often is necessary to make them available for human consumption. The oil refining industry has a great economic relevance in the sector of edible oils. In a global market, competing with countries with low labor and production costs, a production in terms of resource efficiency, low energy demand and high quality are of strategic importance for the strengthening of the European vegetable oil sector.

ProRef solutions try to eliminate the drawbacks of conventional refining processes such as reagents and waste effluents with very complicated management like phosphoric acid, caustic soda and soapstocks (safety, corrosion, spills etc.) and simultaneously guarantee high product standard.

Furthermore, ProRef wanted to create added value by the implementation of biocatalysts as well as miscella refining, as it aims to retain valuable bioactive oil compounds, which are lost in relevant amounts during existing oil refining. The aim was to reduce the need to enrich food stuff containing these vegetable oils with external bioactive compounds. Developments of ProRef were planned to be advantageous especially for oils like olive and rape seed, which are naturally rich in bioactive compounds.

Besides, improved public perception of olive pomace oil as a source of beneficial compounds for health was assessed to be a factor of great importance and was determined being aware of the strong competition from other vegetable oils for home use. In addition, ProRef aimed to develop knowledge on by-product in order to give them higher value for their valorization.

ProfRef solutions were supposed to increase the profitability of the production process, minimizing costs by optimizing the operating conditions based on the raw material. Additionally, it ought to improve the competitiveness of these oils in the market by diversifying their use and development of their products. In addition, opening markets through the development of a competitive process is proven to be profitable, regardless of public subsidies.

The main subject of the proposal was coped with the priority research and innovation lines established by the three countries involved. The transnational consortium tried to generate greater added value on raw materials, process technologies, products and addressed markets, as it carries out cross-fertilization of necessary technologies and was formed by partners, representing countries with about two thirds of the European vegetable oil production.

ProRef aimed to develop more sustainable and less resource demanding refining technologies with improved environmental impact to secure future quality of life. Until now vegetable oil refining (especially high temperature deodorization) is an energy consuming process leading to high CO_2 emissions forcing the ongoing climate change. Additionally, the demand of consumables is still high. This was the point where ProRef ought to generate positive environmental impact. For example, during bleaching up to 1 w% of bleaching agents are needed. Compared to the production volume of 14.9 Million tons in 2012, a reduction of 50% would lead to a less consumption of bleaching agents of 150,000 tons. The planned improvement of other refining steps would lead to similar results. Against the background of the huge market volume, which is one of Europe´s largest sector along the agri-food chain and the high amount of produced vegetable oil in Europe, the ecological impact an improvement of the vegetable oil refining process could be significant.

ProRef covered large parts of the value chain of the European oil sector to increase its competitiveness by better valorisation of raw materials, improvement of the process efficiency and the development of products (edible oils and food additives) with more added values. SME acting along the oil sector (crushing and refining companies, food and feed manufacturers and also secondary users like cosmetic and pharmaceutical industry) ought to profit from this project as they are in strong competition with big enterprises. SME are unable to afford large R&D departments so they are obliged to gain competitive advantages via projects like ProRef.

Conclusion and Recommendations

Against the background of the current market situation project results will be classified according to their commercial potential, taking into account expected technical and non-technical barriers for the exploitation within the EU market. These barriers are explained in more detail for the miscella refining process.

Companies are not ready to use hexane for all the process (extraction/refining) in short term. The next steps will be that the know-how generated within the project should be checked in regard with its industrial feasibility. Therefore the following aspects should be considered:

Environmental and toxicological aspects:

Is there really less impact in term of COV, chemical product utilization, by-product production? Additionally, it should be kept in mind that hexane is CMR substance.

Economic aspects:

Equipment to adapt miscella refining to current process is available at the market. But the return of invest (ROI) of this kind of new process and the future of the conventional process needs to be clarified.

Nutritional aspects:

A rough investigation in regard with the preservation of nutritional valuable compounds was made. First results showed that there are no significant differences between the processes. Next step should be a complex analysis of the oils in order to guarantee oil quality and to identify all compounds in the oil.

Market aspects:

Recently the market trend is to use edible oil produced only by mechanical process. The demands and requirements (low price edible/technical oil or first price edible oil) of the oil market for refined oil products needs to be evaluated.

This procedure is similar for the extraction of valuable components from spent bleaching earth and deodorizer distillate while both developments require further improvement, before. Industrial partners are especially interested in DOD valorization because of its high content in tocopherol. That is why industrial partners will look with attention ProRef results.

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4. BerryPom

CALL 2014

Adding value to fruit processing waste: innovative ways to incorporate fibres from berry pomace in baked and extruded cereal-based foods

PROJECT TEAM

Coordination:

Harald Rohm, Susanne Struck - Technische Universität Dresden, Germany

Partners:

Isabel Hernando - Universitat Politècnica de València, Spain

Vassilis Kontogiorgos, Grant Campbell - University of Huddersfield, UK

Charlotta Turner - Lund University, Sweden

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Summary

BERRYPOM was coordinated by Prof. Harald Rohm at Technische Universität Dresden (TUD, Germany) with Prof. Isabel Hernando at Universitat Politècnica de València (UPV, Spain) as deputy coordinator. Other partners were University of Huddersfield (HUD, UK), Lund University (LUC, Sweden) and Lincoln University (LNZ, New Zealand).

The project BERRYPOM intended to develop strategies to incorporate fibre and phytochemicals from berry pomace in cereal-based products (Rohm et al. (2015) Adding Value to Fruit Processing Waste: Innovative Ways to Incorporate Fibers from Berry Pomace in Baked and Extruded Cereal-based Foods—A SUSFOOD Project, Foods 4:690). The two main approaches were:

- to determine technical conditions allowing delivery of an optimised product from fresh berry pomace with high polyphenol content and high shelf life,
- to modify and adapt formulations of cereal-based baked or extruded foods, serving as targets for the incorporation of processed berry pomace. Material flow cost analysis gives information on the economic impact of this strategy.

Berry pomace is a valuable by-product of the juice processing industry and contains high amounts of dietary fibre and polyphenols. The main compound in pomace is insoluble dietary fibre (~ 50-60 g/100 g dry matter). Black currant pomace was shown to have a desirable ratio of soluble-to-insoluble fibre. An amount of >50 g/100 g moisture in fresh berry pomace favours microbiological spoilage so that preservation has to immediately follow juice processing, where freezing or drying are suitable techniques. Milling of black currant pomace poses a difficult challenge, since hard seeds in the pomace may cause blocking of mills and induce high temperature in the milling chamber.

The incorporation of berry pomace in cereal products changes dough and product characteristics. Depending on variety, berry pomace has an intense red or purple colour caused by polyphenols, especially anthocyanins. Therefore, incorporation in baked goods will change product colour. The high content of dietary fibre in berry pomace powder caused high water absorption and increased swelling capacity. These technofunctional properties resulted in increased batter viscosity and dough stiffness when applied as wheat flour replacement. Changed batter or dough properties result in increased hardness and decreased volume of baked goods but can be partially counteracted by adaption of the water content in the formulation. Wheat flour replacement levels of 5% for bread, 30% in cakes, 10% in shortcrust cookies, 30% in savoury crackers and 10% in extruded snacks resulted in products with acceptable characteristics compared to the corresponding reference products.

Berry pomace contains valuable compounds which are not extracted with the juice but remain after juice pressing. The fresh pomace could be processed to berry pomace powder and applied to bakery products. Additionally, berry pomace may serve as raw material for extraction of valuable compounds, like dietary fibre, polyphenols or seed lipids. BERRYPOM established extraction methods for these compounds using pressurised hot water extraction or extraction with CO_2 expanded liquids, and resulted in new ways to add value to a by-product, which is often considered as waste.

The results of environmental management accounting support the advantages of a resource efficiency strategy aimed at processing and further use of blackcurrant pomace from both an economic and an ecological point of view and provide useful support for future management decisions.

Results and Achievements

Berries have a generally positive image, so that their inclusion in cereal-based products is likely to be viewed as appealing. Part of the project was to evaluate literature on properties of berry pomace as such, and on its use as food ingredient. The findings are published in three reviews, namely in Struck et al. (2016) Berry pomace - a review of processing and chemical analysis of its polyphenols, International Journal of Food Science and Technology 51:1305, in Quiles et al. (2018) Fiber from fruit pomace: A review of applications in cereal-based products,

Food Rev. Int. 34:162, and in Alba et al. (2019) Dietary fibre from berry-processing waste and its impact on bread structure: a review, Journal of the Science of Food and Agriculture 99: 4189.

In BERRYPOM, pomace of different varieties was collected from local juice processing companies, namely black currant, red currant, rowanberry, gooseberry and chokeberry. All pomace had a moisture of above 50 g/100 g so that immediate preservation is required to avoid microbiological spoilage. The proximate composition, as well as physical and technofunctional properties of all berry varieties were analysed, and the results are summarised in the research paper of Reißner et al. (2019) Composition and physicochemical properties of dried berry pomace, Journal of the Science of Food and Agriculture 99:1284.

Different drying regimes were analysed with respect to minimal degradation of polyphenols during thermal treatment. In-depth analysis of polyphenol profiles showed that the drying temperature has a significant effect on the stability of phenolic compounds. A relatively high temperature (70°C) even for a short time caused significant decomposition of phenolic compounds. Freeze-drying of the pomace was a more suitable method to maintain the maximum amount of the phenolic compounds. In consideration of time economic aspects convective hot air drying at 60°C for 5 h was established as standard procedure. Milling of dried berry pomace proved to be challenging because of the presence of hard and brittle seeds with a high oil content.

Berry pomace powder was applied to wheat dough model systems and in formulations for bread, cookies, crackers, cakes, muffins, and extruded snacks. The application of berry pomace as wheat flour replacement resulted in modified products with enhanced nutritional properties. The high water binding capacity and swelling capacity of the berry pomace caused changes in rheological properties of the respective doughs and batters. The results of pomace application in cakes and savoury crackers are summarised in Quiles et al. (2018) Use of berry pomace to replace flour, fat or sugar in cakes, Int. J. Food Sci. Technol. 53:1579, and in Schmidt et al. (2018) Blackcurrant pomace from juice processing as partial flour substitute in savoury crackers: dough characteristics and product properties, International Journal of Food Science and Technology 53:237.

In model wheat dough systems, the partial replacement of wheat flour by dried black currant pomace increased water absorption of dough and the time for dough development. The results of pomace application in wheat dough and bread are summarised in Struck et al. (2018) Interaction of wheat macromolecules and berry pomace in model dough: Rheology and microstructure, Journal of Food Engineering 223:109, in Alba et al. (2020) Effects of blackcurrant fibre on dough physical properties and bread quality characteristics, Food Biophysics 15:313, and in Reißner et al. (2020) Pre-hydrated berry pomace in wheat bread: An approach considering requisite water in fiber rnrichment, Foods 9:1600. An international sensory study of savoury crackers was conducted and published in Reißner et al. (2021) Cross-national differences in consumer responses to savoury crackers containing blackcurrant pomace, International Journal of Food Science and Technology 56:5007. Consumer perception of fibre enriched sponge cakes was also addressed in Tarrega et al. (2017) Importance of consumer perceptions in fiber-enriched food products. A case study with sponge cakes, Food & Function 8:574.

Another approach in BERRYPOM was to extract insoluble and soluble dietary fibre fractions, as shown in Alba et al. (2018) Fractionation and characterisation of dietary fibre from blackcurrant pomace, Food Hydrocolloids 81:398. Berry pomace polyphenols were extracted by pressurised hot water extraction (PHWE) using water/ethanol/formic acid at 99°C for 1 min. Additionally, an extraction method was developed to study oil content in seeds from berry pomace using green solvents composed of compressed carbon dioxide mixed with ethanol, methanol respectively ethyl lactate – so called CO_2 expanded liquids. This work is published in Al-Hamimi & Turner (2020) A fast and green extraction method for berry seed lipid extraction using CO_2 expanded ethanol combined with sonication, European Journal of Lipid Science and Technology 122:1900283, and in Cunico & Turner (2017) Density measurements of CO_2-expanded liquids, Journal of Chemical Engineering Data 62:3525. Results of the environmental and economic impact were published in May & Günther (2020) Shared benefit by Material Flow Cost Accounting in the food supply chain - The case of berry pomace as upcycled by-product of a black currant juice production, Journal of Cleaner Production 245:118946.

Impact

The transnational cooperation in BERRYPOM

enabled to investigate berry pomace from different varieties. Whereas Sweden, UK and Germany are familiar with berry juice production and consumption of fresh berries, it is not as well known in Spain. Therefore perception of products with berry pomace was expected to vary among the countries, which was proven in the international sensory study. This project benefited from the complementary skills of the consortium concerning fibre and polyphenols. Taking advantage of partner-specific infrastructure allowed addressing research questions that could have not been solved individually. Links to industry partners facilitated conducting the research and implementing results. The international cooperation favoured the investigation of different end-of-life scenarios for berry pomace.

BERRYPOM was very well received in the scientific community, and contributed to 21 national and international conferences. 17 papers were published in peer-reviewed scientific journals. The juice processing companies were very interested in the project and in new ways to upcycle their berry pomace.

SUSFOOD targets food chain optimisation with respect to sustainability and efficiency: it covers processing, packaging and retailing, food services and consumer activities, and promotes a multidisciplinary approach. In the context of food processing, waste reduction also means that innovative ways should be approached to add value to materials currently not utilised in human nutrition. BERRYPOM therefore had the following main impact:

- Value can be added to berry fruit processing when strategies and technologies are developed that make berry pomace usable as a food ingredient.


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- Foods naturally rich or enriched with fibre and phytochemicals in the diet contribute to the health status of the consumer.
- As shown by Material Flow Cost Accounting and other methods, strategies for adding value to berry pomace have a sound economic and ecological basis.

Conclusion and Recommendations

It is generally known that, for both developed and developing countries, approximately 25%–40% of the available food is lost or discarded at some point between harvesting, processing, distribution and consumption. For reducing the devaluation of foods along the value chain it is, among others, necessary to increase the awareness of producers towards materials that, until now, are regarded as losses or waste, and to build systematic strategies to find new markets for value-added intermediate ingredients processed from these losses. Together with awareness that can be created in consumers, the utilisation of processed berry pomace may contribute to a more sustainable food processing chain. Recycling methods that add value to fruit processing residues are of great interest, and it can be expected that the overall profit from fruit processing may be increased by an efficient and sustainable waste stream-management.

The main hurdle, which still has to be taken in our opinion, is the immediate processing of berry pomace. Regarding ecological and economic feasibility, the transport to another location before drying is not reasonable. The preservation of berry pomace in juice processing companies through immediate drying would allow producing a valuable new product for distribution as food ingredient.

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5. SUSMEATPRO

CALL 2014

Sustainable plant ingredients for healthier meat products - proof of concepts

PROJECT TEAM

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Dr Dalija Seglina

Summary

Many epidemiological and experimental studies suggest that a high intake of red and processed meat is associated with increased colorectal cancer risk. However, meat is a healthy food item and has proteins of high biological value, a high content of essential minerals and B-vitamins, but lacks antioxidants. The addition of complex antioxidant plant extracts to processed meat could result in healthier products due to decreased level of oxidation in the meat, thus preventing the inflammation reactions upon consumption. In addition, innovative preservation strategies are needed for both conventional and organic meat products to improve sustainability and reduce potentially harmful effects of processing and meat consumption. Again, complex plant extracts, with high contents of specific phytochemicals obtained from various horticultural plant materials and side streams from the processing of these materials, could have synergistic antimicrobial effects, inhibit the growth of pathogenic and spoilage bacteria in different meat products, and improve overall quality and safety of meat. Therefore, in 2015 the project “Sustainable plant ingredients for healthier meat products - proof of concepts (SUSMEATPRO)” was started, and supported by the EU-ERA-NET SUSFOOD program and national bodies. In this interdisciplinary project, local horticultural plant material and side streams were collected and screened for antioxidant and antimicrobial capacities in different test systems in vitro. Superior plant material powder and extracts of superior capacities were selected and tested in several meat products made from pork, beef and chicken with promising results. Sensory effects and effects on shelf life were also studied. In order to prove the concept of healthier meat products with complex plant additives against colon cancer an animal study was performed and selected extracts were evaluated on mice with promising results. The overall conclusion is that plant-based extracts of herbs, vegetables, fruits and berries, as well as waste materials thereof, have great potential as antioxidants and some also as antimicrobials, and can reduce inflammation at least when tested in a relevant mouse model. There is however a challenge in that plant material and extracts can contribute with unpleasant taste to the product as noticed in sensory trials. This could be handled by combining

extracts of different sources since the concentration of each ingredient then could be reduced still with a similar or synergistic antimicrobial effect.

Results and Achievements

Screening of plant material and side streams for antioxidant and antimicrobial capacities

Samples of vegetables, herbs, spices, fruits, berries, leaves and side streams from processing were collected locally. The plant material differed largely in antioxidant and antibacterial capacities. Very high antioxidant activity was revealed for sea buckthorn leaf extracts and rhubarb root extracts. High and broad antimicrobial effect was noticed for rhubarb root.

Antibacterial effects were found against Campylobacter jejuni, Listeria monocytogenes, Salmonella Enteritidis, Bacillus cereus, Escherichia coli, Kocuria rhizophila, Yersinia ruckeri, Bacillus subtilis and Bacillus pumilus. Synergistic effects on antimicrobial capacity were also revealed. A high antioxidant capacity was not necessarily associated with a high antimicrobial capacity. The novel and solvent free pressurized hot water extraction method was efficient for extraction of both antioxidants and antimicrobials. The most potent antibacterial and antioxidant samples were subject to in depth studies and characterized in detail using HPLC-DAD and HPLC-DAD-MS/MS with a specific focus on polyphenols that largely contribute to the antioxidant activity in ethanol extracts. Some samples were also screened for presence of mycotoxins in fresh plant material by LC-Q-ToF-MS/MS and no mycotoxins were found.

Development of complex natural food additives from selected superior extracts

An in vitro model was developed for more relevant screening of antioxidant activity using sarcoplasmic fraction of meat, and 28 plant extracts were screened. There was a great difference between species and samples, but also between concentrations and storage times tested.

Some extracts were pro-oxidative. The most successful antioxidants were summer savory powder, olive polyphenol powder, and sea buckthorn leaf extract obtained with pressurized hot water.

A minced meat conceptual product prone to oxidization was developed, and different combinations of salt and fat impacting lipid peroxidation were studied using pan-fried and deep-fried cooking methods. Meat products prepared were stored for 1, 7 and 14 days to mimic different scenarios from the daily consumption of meat products. The meat product combination that

oxidized the most was then used for testing the effect of 11 of the most effective antioxidants from the in vitro sarcoplasmic meat model screening system. The selected samples successfully inhibited oxidation at both concentrations where the summer savory powder was the most effective antioxidant.

Test of natural additives in conceptual meat products

The most promising plant extracts were further tested in conceptual meat products such as mild cold cut pork sausages, marinated sliced chicken legs, minced meat, marinades for pork, chicken breast, meat balls and pork fillet. Products intended as marinades or for combination with meat such as chutneys and sauces were also developed and tested with promising results. Complex whole powdered plant samples were tested against Listeria monocytogenes. By using combinations of complex powdered samples, the concentration of plant material added to products could be reduced still maintaining the antibacterial effect, also with synergistic potential. E.g. horseradish combined with either rhubarb, red currant or lingonberry tested in vitro against Listeria was efficient at lower concentrations compared to single extracts. In challenge test against Listeria using chicken breast meat horseradish combined with lingonberry could extend shelf-life against Listeria.

Different combinations of promising samples, e.g. spray dried extracts of rhubarb root + black currant berries, rhubarb root + black currant leaves, rhubarb root + chokeberry berries, black currant leaves + blue honeysuckle, rhubarb root + tomato and rhubarb petioles + blue honeysuckle was tested as antibacterial additives to minced meat. The combination of rhubarb petioles and tomato was quite efficient in preventing growth of aerobic bacteria during storage of cooked minced meat. In general rhubarb petiole extract was the most efficient antimicrobial both in raw and minced cooked pork. Several extracts from e.g bilberries, sea buckthorn and pine inner bark showed promising effects as antioxidants on e.g. pork sausages.

A simple and cheap method for determination of meat freshness on minced pork products was also developed. Sensory profiling and sensory tests were performed on different conceptual products such as sausages and marinated chicken leg with the conclusion that the strong taste and visual appearance using some plant extracts sometimes could be a challenge from sensory viewpoint. By using combinations of plant material concentrations could be reduced thereby also reducing negative sensory effects.

Animal testing to prove the concept of healthier meat products with complex plant additives

The material finally selected for a mouse study was powder of summer savory and extracts of sea

buckthorn, onion skin, black currant leaves and olive mill waste water powder in a meat product. Chronic inflammation was induced in mice by cyclic treatment with low concentration of dextran sulfate sodium in the drinking water. Eight trial groups were tested of which five were given 20% meat product feed with preselected promising antioxidants, one was given 20% meat product feed without antioxidants and two were control groups. The mice were monitored daily and a disease activity index was calculated to control the disease development i.e. to not achieve an acute colitis. Biopsies were taken from small and large intestine, as well as blood and fecal samples, and lymphatic tissue from mesenteric lymph nodes and Peyer's patches. Spleen and colon weights, colonic swelling scores, number of colonic lesions, and number of epithelial dysplasias were also analysed. Lymphatic tissues were analyzed using fluorescence-activated cell sorting (FACS) with three different antibody panels to study the difference in inflammatory response between trial groups. The presence of myeloperoxidase (MPO), an enzyme expressed in white blood cells and malondialdehyde (MDA) a product of lipid peroxidation, were analyzed in both small and large intestine. Multiplex profiling of cytokines and chemokines was analyzed from blood plasma. Terminal restriction fragment length polymorphism (T-RFLP) was used to analyze the diversity index of bacterial strains in the intestinal microflora. There were differences in for instance colon length and in number of epithelial dysplasias where the healthy control had a longer colon length than other trial groups and no dysplasias. The treatment group that was fed 20% meat product without antioxidants had on average more lesions than all other trial groups.

Impact

The project has delivered "proof of concepts" especially with regard to the antioxidant and antibacterial effects of various plant materials when tested on many different meat products. The potential effect on inflammation with regard to colon cancer development as studied in a mice model was also confirmed but further studies are needed to implement the results.

Partners were mainly complementary in competences and facilities, thus, background knowledge, methods, equipment and technologies could be shared and used efficiently for the purpose of the project. Through cooperation new technologies held by any partner could be tested and results shared among partners. Knowledge developed in the project could be disseminated to industry in all countries through local networks.

Conclusion and Recommendations

The project has shown that waste material and other mainly horticultural plant materials not usually being used are rich sources of antioxidant and antibacterial compounds that could be used in meat products for different beneficial purposes, thus, if implemented, could make food production more sustainable in line with the objectives of the SUSFOOD program. However, the use and composition of the ingredients needs to be further developed for each application which is not a scientific but rather an industrial responsibility. Interestingly, we found no correlation between antioxidant capacity studied by the FRAP, DPPH and total phenol content on the one hand and the in vitro screening methods for studying oxidization on the other hand. However, the results of the in vitro sarcoplasmic meat model developed correlated with the results of a meat model system tested, proving its relevance.

Antioxidant and bacterial effects were proven from both plant extracts and plant powders and it was noticed that some materials have synergistic effects and thus extend shelf life of chicken breast with regard to pathogenic bacteria as well as growth of background spoilage microorganisms. Addition of extracts of plant antioxidants in meat can have an impact on inflammation and lipid peroxidation as well as direct physiological effects in mice. Different extracts seem to contribute with different effects but further investigations and studies are needed to obtain conclusive results as well as information on specific compounds contributing to the anti-inflammatory effects.

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6. OATPRO

CALL 2014

Engineering of oat proteins: Consumer driven sustainable food development process

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Summary

There is a global need to change consumer habits for increased plant protein intake. Availability of sustainable plant protein sources could be increased by finding novel protein sources or by efficient valorization of the existing ones. Side streams from cereal processing are currently under exploited or even wasted despite their high content of health promoting valuable components such as dietary fibre, protein and bioactive compounds.

Oats are an important crop with a superior amino acid composition as compared to other cereal proteins. Oats are mainly consumed in the form of flakes and porridge or used as a source of soluble dietary fibre (β glucan). In production of oat bran ingredients rich in β-glucan, a protein rich fraction can also be recovered, but it is currently an underutilized processing side stream which might serve as a protein source.

Development of new plant protein enriched foods requests for understanding of consumers' willingness to accept such products. Consumer acceptance of any food product is a complex phenomenon, and can be expected to be even more complex in the case of highly new product concepts. The sensory aspect is especially important, as protein ingredients often have disadvantageous off-flavours, bitter or astringent taste. Thus, turning promising technology into successful oat-protein food applications is dependent on integrating the consumer view into the product development process from the beginning till the end.

The aim of the project of OATPRO was to create value for a protein-rich side stream obtained from oat β-glucan processing to be used as an ingredient in protein-enriched foods or for replacement of animal-based proteins, and develop food applications where oat protein would best be accepted by consumers. Re-thinking the current food ingredient processing chain and efficient valorization of oat as a protein ingredient assists in increasing protein self-sufficiency in Europe, and benefit environment by providing alternatives for animal-based protein ingredients.

© products: Technische Universität Berlin; oat paste: National Institute of R&D for Food Bioresources IBA Bucharest; consumer/ sensorial test: Aarhus BSS at Aarhus University

Results and Achievements

The project results include data on consumer expectations and preferences, development of new oat-protein rich food models (dispersed systems, solid foams and solid food) and analysis of sustainability impacts of consumption of such new alternative protein sources to replace animal protein from diet.

Dry fractionation of oats was based on VTT's patent. Two different hybrid protein ingredients with protein contents of 45 and 51% were produced and characterized. Protein isolated were produced for comparison. The results were reported in detail in deliverables D1.1 "Oat fractionation to obtain oat protein concentrates and oat protein isolates" and D 3.1 "Characterization of the functional properties of oat protein concentrates". Oat protein was characterized by a high techno-functionality. But with, limitations of protein solubility under acidic conditions, restricting suitability as functional ingredient in semi-solid foods. Usually, semi-solid food like beverages, fermented drinks, yoghurts or non-dairy yoghurt type products have a pH between 3 to 7 where native oat protein has limited solubility. In order to be used as foaming agent or emulsifier, proteins need to be soluble. Several strategies to modify oat protein functionality were tested, such as microbial (fermentation with different strains), limited enzymatic hydrolysis by Alcalase and Trypsin, homogenisation (Microfluidizer), high hydrostatic pressure treatment and thermal treatment.

In developing plant protein enriched food, one important aspect is consumers' willingness to accept such products. s. Therefore, as a first step, we used "consumer as a resource" and investigated consumer reactions to the idea of protein-enriched foods in general, as well as oats as a source of protein in different products. We conducted a focus group discussion on exploring ideas of food products enriched with protein and oat-protein in particular. The results are reported in detail D2.1 "Report on the focus group discussion on exploring ideas of food products enriched with protein and oat protein", published in Banovic et al. (2018a), and communicated in various conferences, seminars and webinar. In summary, results showed that consumer understanding of the concept of

protein-enriched foods was limited and they could not differentiate between natural sources of protein and foods enriched with protein. Older consumers (mean age 65 years) expressed more skepticism towards protein-enriched foods than younger (mean age 40 years). The combination of protein type and food carrier closer to conventional foods received more acceptance among consumers. We further found that the future use and acceptance of protein-enriched foods depends on the extent to which consumer concerns about incorporating additional protein into a diet can be responded. In the same study with "consumer as co-creator" we created 24 product ideas which were reported in D2.1 "Oatpro Products Ideas" (see also Banovic et al., 2018b). These product ideas were further used as a guidance for the selection of food applications and prototypes, as well as for product development and marketing of protein-enriched foods.

The oat protein was incorporated into food models in the form of concentrates or isolates. These differed in protein content, level of accompanying substances (primarily starch) and the extent of processing (precipitation at the isoelectric point). When it comes to the application in food, it can be clearly concluded that the accompanying substances (starch) possess a positive effect if concentrates are used to enrich and replace milk proteins in classic yoghurts or to produce fermented yoghurt alternatives based on oat protein. The starch fraction serves to create creamy properties and improve mouthfeel (Brückner-Gühmann et al. 2019 a,b,c). In addition to suitability for the production of acid-induced gels, possible applications of oat protein within the group of dispersed systems ranged from foams and emulsions to heat-induced gels (Brückner-Gühmann et al. 2018, 2021). It was also possible to use the oat protein concentrate as an ingredient in pasta (Duta, D., Culetu, A., Sozer, N., 2019) and bread.

Prototype product types were selected according to the results of the first consumer study. Three prototypes (bread (VTT), pasta (IBA) and yoghurt (TUB)) with source of protein and high in protein claims were evaluated in consumer studies in Denmark, Finland and Germany. The products were tested using a "consumer as user" through two studies: sensory and communication study. In summary, the results showed that information given in combination with product experience is the key driver of consumer acceptance of oat-protein enriched products. This was dependent on the product and using information before consumption experience worked better for some products such as yogurt and pasta. Generally, oat-protein enriched products with lower protein content were those that generated higher expected scores and higher acceptability among consumers. The findings from the above studies provided relevant guidelines for further product improvements, and all the tested product prototypes seem to have a specific niche within the European market.

Carbon footprints and land use of products enriched with oat protein were compared to that of conventional products to ensure that the use of oat proteins in foods would result in reduction of environmental impacts. The potential of foods containing oat protein concentrate (OPC) to influence GHG emission when substituting animal protein sources in the diet was studied using Danish dietary pattern as starting point. If protein beef and pork were completely replaced by foods containing oat protein (S3), GHG emissions from food could be reduced by 24%. If intake of animal-based foods (milk, meat, eggs) is decreased by 50% and the consequent protein intake loss is covered by foods containing oat protein (S4), GHG emission from food could be reduced by 22% (Mogensen et al 2020).

Impact

The multidisciplinary approach of the project combined consumer science, life cycle analysis and technological work. Oat protein functionality was modified to improve its food applicability and the role of accompanying polymers (egg, starch, dietary fibre) elucidated. Different food prototypes containing oat protein were produced. Consumers were involved from the beginning to the end in the development of novel oat protein food products. In order to determine consumers' motives for consuming, preferences and their willingness to accept oat (and plant in general) protein food products, qualitative and quantitative methodologies were applied (focus groups, experimental studies). Consumer studies provided know-how on consumers' perceptions, attitudes and motives related to oat and plant protein food consumption as well as indicated market potential, advisable modifications of the prototypes and ways of market launch. Environmental analysis allowed the evaluation of the sustainability of the products in the EU target-markets as compared to similar products, and showed the large potential to reduce greenhouse gas emissions when replacing animal protein sources with oat protein, a side product of oat beta-glucan production. The OATPRO project contributed to the competitiveness of European oat production and corresponding ingredient and food processing industry by providing knowledge and tools for targeted processing of plant protein ingredients and foods of high protein quality. Currently, numerous oat-based dairy and meat product alternatives are being launched at the European market, and their use in rapidly increasing.

Conclusion and Recommendations

The interest in food that contains a reasonable amount of plant protein is rapidly increasing. Thus, products with pleasant texture and taste ensuring high consumer acceptance are needed. The OATPRO project followed a multidisciplinary approach and addressed the recovery of the protein from side streams of β-glucan production, consumer studies and the integration of consumers within the product development process, the characterization, fractionation and modification of oat protein ingredients, the production of oat protein-enriched foods and finally the determination of the ecological sustainability.

We showed that oat protein may serve as an ingredient for a broad range of applications such as bread, pasta, heat-induced gels, emulsions, foams and lactic acid fermented, oat-based gels (yogurt analogues). Further work for tailoring the functionality of oat protein concentrate will enable diversification of new food concepts with desired sensory attributes.

As discussed in literature, consumer acceptance and purchase intentions are complex. We found measurable, objective, sensory attributes, which influenced product acceptance as well as the more extrinsic attribute information disclosure, which could help to change consumer-eating habits. As consumption patterns only change slowly, future work should continue with this interdisciplinary approach of combining consumer science and food technology. By directly integrating consumers' perceptions of plant-protein enriched products the food industry can more easily generate products with higher added value.

The potential of foods containing oat protein concentrate to influence GHG emission when substituting animal protein sources in the diet was studied using Danish dietary pattern as starting point. If intake of animal-based foods (milk, meat, eggs) is decreased by 50% and the consequent protein intake loss is covered by foods containing oat protein (S4), GHG emission from food could be reduced by 22%. This shows the environmental potential of using alternative protein foods. The methodology for LCA analysis needs to be further developed, and more research is needed to compare the sustainability of different protein sources.

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PROJECTS FUNDED IN THE COFUNDED CALL OF SUSFOOD2 - 2017

There are 12 projects funded in the cofunded call. Detailed information about the projects listed below is provided in this section.

Nr	Acronym	Project Title
1	BIOCARB-4-FOOD	Extraction and characterization of BIOactives and CARBohydrates from seaweeds and seagrasses FOR FOOD-related applications
2	InProVe	Innovative Processing of Vegetables and Potato
3	FUNBREW	Biotransformation of brewers' spent grain: increased functionality for novel food applications
4	MEFPROC	Improving Sustainability in Food Processing using Moderate Electric Fields (MEF) for Process Intensification and Smart Processing
5	DISCOVERY	Disaggregation of conventional vegetable press cakes by novel techniques to receive new products and to increase the yield
6	ProSeaFood	Innovative processing of seaweed for novel, healthy food products and ingredients
7	AVARE	Adding value in resource effective food systems
8	SPAREC	Sustainable Processing of Agrofood Residues to Elicitors and Chemicals
9	ImPrOVE	Innovative (pre)POmace Valorization process
10	SUSPUFA	Sustainable production of health-promoting n-3 LC-PUFA using agro food industry by-products through microalgae
11	SUSCHOICE	Towards Sustainable Food and Drink Choices among European Young Adults: Drivers, Barriers and Strategical Implications
12	PLATEFORMS	Sustainable Food Platforms: Enabling sustainable food practices through socio-technical innovation

1. BIOCARB-4-FOOD

CALL 2017

Extraction and characterization of BIOactives and CARBohydrates from seaweeds and seagrasses FOR FOOD-related applications

PROJECT TEAM

Coordinator:

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Summary

Extracts from seaweeds and seagrasses are gaining increased interest due to the presence of an array of biologically active compounds including polyphenols, dietary fibre, polysaccharides, and proteins, amongst others. They offer great potential for different industrial applications and represent an attractive and sustainable source of natural compounds for the food sector. Seaweeds and especially seagrasses are still an under-exploited source for raw materials, e.g. carbohydrates, being key ingredients for food formulations as thickeners, stabilizers, or gelling agents, but also as basis for further applications like biodegradable packaging materials.

BIOCARB-4-FOOD is a multidisciplinary project aimed not only at improving extraction procedures from marine resources, but also correlated extraction techniques with structure and functionality. Within the project, we also explored various potential applications of the extracted materials including texture modification, functional ingredient development, and extraction of cellulosic fractions and nanocellulose from alternative resources and related potential applications.

Extraction procedures typically applied for the extraction of polysaccharides (such as agar and alginates) from seaweeds show potential for improvement in terms of processing time, water, chemicals, and energy use. Moreover, the non-extracted remaining biomass (generally more than 50% of the initial material), being still rich in bioactive compounds, is usually disposed as organic waste. In collaboration with industry, the BIOCARB-4-FOOD project has established more environmentally friendly seaweed and seagrass extraction techniques and included the valorisation of the remaining biomass. BIOCARB-4-FOOD has simplified extraction processes and their resource efficiency by combining extraction methods and decreasing purification steps. The resulting extracts from already commercialized seaweed species and from underexploited sources like seagrasses were applied as food additives. Structure, technological properties, toxicity and bioactivity of the extracted fractions and applications were characterized, and a life cycle assessment was conducted for proving procedure sustainability. Life cycle assessment showed that there is a large variation in the environmental performance of the developed agar extraction methods. Possible applications that were

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BIOCARB
-4-FOOD

Results and Achievements

BIOCARB-4-FOOD content and achievements

BIOCARB-4-FOOD extraction processes and applications

Both agar and sodium alginate extractions were carried out following extraction protocols established during the project (Gomez et al., 2020a,b). Apart from exploring the use of novel extraction methods, the protocols for agar and alginate extraction were modified to make them simpler and the processes more cost-efficient. Less purified agars with additional functional properties, reduced costs and environmental impact were extracted from Gelidium sesquipedale by means of simple protocols based on hot water and sonication treatments (Martinez-Sanz et al. 2019a). Ultrasound-assisted extraction of agar was identified as the most promising method, since it led to higher extraction yields and reduced extraction time when compared to the conventional extraction protocol. In the case of agar, the initial sodium hydroxide treatment was skipped, thus reducing extraction times and increasing yield (Martinez-Sanz et al., 2019a). The less purified agar-based extracts contained interesting compounds (mainly proteins and polyphenols) providing additional functionalities like antioxidant properties which is subject to further investigations regarding specific product applications.

Those simplified processes for the extraction of agar from Gelidium sesquipedale were also used to produce high-performance food packaging materials (Martinez-Sanz et al., 2019b). The less purified agar extracts containing residual proteins formed flexible films (without the need of plasticizers) comparable to or better than pure agar films, i.e., they improved mechanical and barrier performance and had antioxidant capacity, showed higher humidity resistance, i.e., did not gel in humid conditions, contrary to pure agar. Further advantages of these agar films were related to mechanical properties, barrier to water vapor, better light blocking capacity and antioxidant properties (Martinez-Sanz et al. 2020), even outperforming some benchmark polymers.

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Sodium alginate extracts were obtained from Saccharina latissima using a conventional extraction protocol based on the industrial process and two other protocols using ultrasound treatments. Ultrasound-assisted extraction produced less purified extracts with higher antioxidant capacity, higher extraction yields and reduced extraction time when compared to the conventional extraction protocol. No significant differences in mannuronic acid to guluronic acid ratio (M/G ratio), molecular weight and gel strength were observed with the ultrasound-assisted extraction process. The methods of enzyme-assisted extraction were investigated Benito-Gonzalez et al. (2019b) showed, that less purified extracts obtained from Posidonia oceanica had bioactive properties, including antioxidant capacity, mainly ascribed to the presence of certain phenolic compounds, proteins and polysaccharides. Some of the obtained extracts also showed antimicrobial properties against several foodborne fungi and the ability to reduce infectivity of viruses.

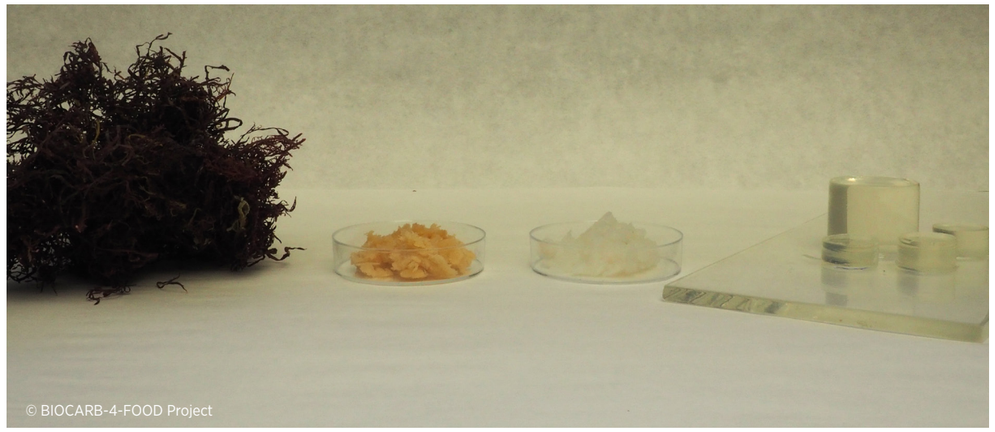
Valorization of seaweed and seagrass residuals and applications

Regarding the valorization of the residuals, BIOCARB-4-FOOD partners worked with the residues from Gelidium sesquipedale and Posidonia oceanica to obtain packaging structures or additives, being able to produce high-performance cellulose-based food packaging materials. The produced bio-based films displayed improved mechanical and water barrier performance and greater stability upon storage, outperforming most benchmark biopolymers (Benito-Gonzalez et al., 2019 a-b). In the context of the project, the cellulose-based fractions and nanocrystals from Posidonia oceanica waste biomass were also used to develop sustainable, lightweight, and hydrophobic adsorbent pads (Benito-Gonzalez et al., 2020), with multiple potential applications.

Alaria esculenta, Saccharina lattissima and Ascophyllum nodosum residues after alginate extraction were further characterized at IATA-CSIC in Spain for subsequent valorisation. Protein content and amino acid profile of the residues obtained after agar and alginate extraction was also carried out within the project.

Life cycle assessment

The environmental performance of products and processes developed in the project and novel applications of these were assessed and evaluated. Life cycle assessment was used to evaluate the environmental performance of the novel seaweed valorisation strategies that were developed in the project. Seaweed and seaweed-based processes are relatively new areas for LCA and thus the work performed by Martínez-Sanz et al. (2021) in which several methods for extraction are compared by LCA is quite novel. The LCA showed that there are large differences in environmental performance between different extraction methods and that the most important factor for good environmental performance is to have a high yield of the targeted product. Utilizing by-products from the



extraction has a large potential to further improve the environmental performance of hydrocolloids extracted from seaweeds.

of compounds left in the residues which can be extracted and used for diverse applications is outstanding and deserves further insights which will be explored in subsequent projects.

Impact

The project is expected to contribute to improved process efficiency, development of ingredients with high added value from already commercialized seaweed species and from under-exploited sources (seagrasses) which can positively impact in the competitiveness of seaweed, food and non-food companies at EU scale by a better valorization of raw materials.

A project website will be found at https://www.biocarb4food.eu/ containing information about the Project.

Conclusion and Recommendation

The BIOCARB-4-FOOD project has set the basis for a sustainable use of seaweed and seagrass biomasses. From the in-depth characterization work carried out along the project, we have learnt about the tremendous existing possibilities, not only regarding the extraction of interesting phycocolloids, like agars or alginates, but also to valorize the remaining residues. Depending on the seaweed species, the variety and amount

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2. InProVe

CALL 2017

Innovative Processing of Vegetables and Potato

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Summary

The global volume of vegetable food waste, not including agricultural waste, is estimated to 400 million tons/year. Valorization of unused biomass during processing thus enhances food production sustainability and contributes to a lower ecological impact. The aim of InProVe was to develop sustainable food production systems addressing novel, innovative technologies for processing of potatoes and vegetables (e.g., carrot, black salsify). Novel processing technologies, including three types of Microwave Heating, innovative food container designs, and Pulsed Electric Field (PEF) were utilized to demonstrate the potential to combine savings in energy and water consumption and improvement of sensorial and nutritional quality. Pre-treatment using PEF, and Supercritical Fluid Extraction (SFE) added value to underutilized by-products and waste. We have demonstrated that waste can be reduced in the food supply chain by pre-treatment for stabilization and efficient extraction with minimal use of solvents, for recycling into the food chain.

Results and Achievements

WP1 Processing Design and Innovative Technologies: Process design was developed for tubular microwave (TMW) processing, microwave tunnel (MWT) and batch (MWB) ovens, convective toroidal heating, PEF and SFE treatment. Process conditions were chosen to meet criteria specific for each process-product combination. The applications studied were

- microwave sterilization (TMW and MWB) and pasteurization (MWT) for selected vegetables.
- PEF pre-treatment of carrots, carrot by-products and potatoes.

  - Carotenoid extraction (WP2) to increase yield

  - Processing of potatoes.


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Evaluation was part of process design based on experimental results (WP1) and modelling (WP3) and formed the basis for process design before determining final conditions to be validated in WP3. WP1 used modelling results (WP3) to design desirable process conditions:

- Thermal and kinetic modelling for MW and convective heating
- Electromagnetic modelling for process design of MW treatment

WP2 By-product processing: Three different approaches were followed:

- Minimal processing
- Stabilization into dry products
- Extraction

In process development, energy efficiency and preservation of quality (color, texture, taste) were studied to optimize the different steps. For product development the specific conditions and aspects connected both to food production and consumer acceptance were considered, e.g., consumer trends (natural, sustainable, convenient, clean label), food safety, shelf-life, nutritional value, marketing arguments, etc. For the most promising derived products a detailed evaluation was carried out to be able to estimate the market potential of the newly developed products. We used both conventional and innovative technologies to progress beyond the current state-of-the art. Close interaction with WP1 and WP3 provided relevant insights into process design, optimization, and validation, always with energy efficiency and product quality as drivers.

WP3 Modelling and Validation:

- MW processes were simulated with experimental validation in lab;

  - Industrial scale TMW

  - Over-pressure (P) MW autoclave

Results were combined with WP1 for design and optimization. With TMW and P-MW system results, innovative suggestions for industrial scale processing were illustrated. Modeling included determination of electromagnetic field (EF) distribution and temperature changes.

- Processing in toroid cans were demonstrated in simulation studies with pasteurization experiments in water bath using custom-made cans for model validation. Temp. changes were linked to nutrient kinetics and quality changes. Results were compared with conventional processing.
- High Temperature - Short Time (HTST) processing >100°C was achieved in a pressurized MW system. Thus, comparative HTST treatments upon quality are now achievable and was performed.
- Sterilization by over-pressure MW for fresh/ frozen vacuum-packaged vegetables.

WP4 Product Quality and Safety: Samples from raw materials, by-products, intermediate and end-products collected and/or produced in the project were characterized using up-to-date analytical methods. Taking into account the current selection of raw materials, i.e., potato, carrots and black salsify, the following components were analyzed:

- Carbohydrates (sugars, starch, dietary fibers)
- Protein and fat as macronutrients,
- Vitamins and minerals as micronutrients
- Carotenoids (carrot) and sesquiterpenes (black salsify), polyphenols (potato) as bioactive compounds.

In addition, chemical and microbiological safety was studied, as well as the organoleptic properties.

Impact

The raw materials used in InProVe have largely consisted of by-products and wastes that have previously been discarded, so this is clearly a major contribution to reducing waste in the value chain for vegetables. By producing sustainable vegetable food products with a high sensorial and nutritional quality, we hope to stimulate to increased intake of vegetables, and thus also contribute to less meat intake. In that case, this will lead to better public health and lower CO_2 emissions. The technologies demonstrated in InProVe can be transferred to other vegetable varieties, such as cabbage and beetroot. The work on green extraction can lead to inclusion of enriched extracts in selected products in the industry partner's portfolios, such as flavours, dyes, antioxidants or other natural, functional ingredients with a 'clean label'.

The project resulted in significant dissemination and communication with diverse target groups as illustrated by the publication of papers in international peer-reviewed journals, and several presentations at international conferences and popular science publications.

The Research institutions involved in InProVe have benefitted from the knowledge transferred between leading food technology institutes, and European food industry. The project has contributed to reinforced cooperation in research, development, and innovation between European countries in order to maximize the contribution of research to the development of more sustainable food systems from production to consumption, and the creation of a European network on sustainability in the vegetable food supply chain.

Norwegian (Fjordland, Hoff), and Belgian (Greenyard Prepared) food companies have all been involved and benefitted from the project through research on the innovative technologies and product development. To some extent, novel technologies were implemented, at least on a pilot scale.


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Conclusion and Recommendations

In InProVe, we have developed sustainable food production systems that deal with new, innovative technologies for processing of potatoes and vegetables. These are technologies that lead to savings in energy and water consumption, better utilization of waste and residual raw materials, and improvement of sensory and nutritional quality compared to conventional processing. We have chosen to divide our research in InProVe into three

thematic areas over variations of “less is more”.

Using a completely new type of can that we call the toroid can, we have documented a time saving in pasteurization and sterilization of several types of canned food of over 50% by static and end-over-end autoclaving, compared to traditional processing. The nutrient retention is better since the products are exposed to a smaller heat load that better preserves the vitamins, and the taste and shelf life are at least as good as in traditionally processed products. In addition, less energy and water are consumed.

Another technology that contributes to reduced energy consumption is HTST microwave heating. This technology has been developed and implemented on a pilot scale. HTST was compared with conventional technology (use of heat exchangers). HTST led to improved mouthfeel and texture of fish and vegetables, colour, etc. The nutritional quality of soups produced in this way is as good as traditionally processed soups.

In InProVe, researchers and industry partners have collaboratively developed technology that makes it possible to transform residual raw materials from peas, mushrooms, and black salsify into protein- and fibre-rich ingredients. These ingredients have been used, among other things, to produce juicy and tasty vegan burgers with a high nutritional content. We have also studied the use of “green” technologies to extract valuable phytochemicals (e.g., beta-carotene and polyphenols) from residual raw materials and unused biomass from potato and vegetable processing. SFE of carotenoids from freeze-dried carrot peel powder was shown to increase the yield significantly while reducing trans to cis isomerization compared to conventional CO_2 extraction. PEF has been evaluated to pre-treat the biomass before SFE to recover carotenoids from side streams from carrot and potato processing. Experiments with PEF extraction of polyphenols from potatoes and sesquiterpenes from black salsify, and also with by-products from other types of vegetables, showed promising results.

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3. FUNBREW

CALL 2017

Biotransformation of brewers’ spent grain: increased functionality for novel food applications

PROJECT TEAM

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Summary

Brewers´ spent grain (BSG) is the most abundant beer brewing by-product, of which ca 4 million tons per year are generated in EU. BSG has very good nutritional quality, due to its richness in fibers and protein, but it has limited use in food processing beacuse of its challenging composition (i.e. high content of lignin) and tendence to spoilage. Economical reasons related to drying, processing, storage, and transportation also contribute to this scenario. The project goal was to establish simple bioprocessing technologies to improve BSG quality as food ingredient and promote its in the food industry.

BSG was bioprocessed with different methods based on fermentation and was succesively used as food ingredient for bread, pasta and breakfast cereals. Different fermentation processes were studied: fermentation induced dextran formation (a natural hydrocolloid acting as texture improver) and increased the antioxidant properties of the spent.

Bread and pasta containing fermented spent showed high volume and softness (bread) better textural and antioxidant potential (pasta) and good sensory properties compared to those containing untreated spent. The in vitro protein digestibility was higher in bread and pasta containing fermented BSG compared to native BSG use. For pasta, the enhanced antioxidant properties after cooking and mimicked digestion was also confirmed with ex vivo trials. BSG bread enhanced the metabolism of gut microbiota in vitro and the effect was more persistent for bread containing dextran and oligosaccharides synthethized during fermentation. Different baked goods were produced also in industrial trials, similar to whole grain products, and having peculiar sensory profile, considered overall acceptable.

Breakfast cereals and snacks recipes containing up to 15-30% of fermented spent were developed by focus groups. The extrudates had good taste and were less soggy after mixing with milk and more compact. The antioxidant activity was higher for snacks containing bioprocessed spent. Finally, a preliminary study focusing on BSG granola hilighted consumers´ interest in food products containing BSG, such as bread, pasta and snacks, showing the great potential for food innovation.

Results and Achievements

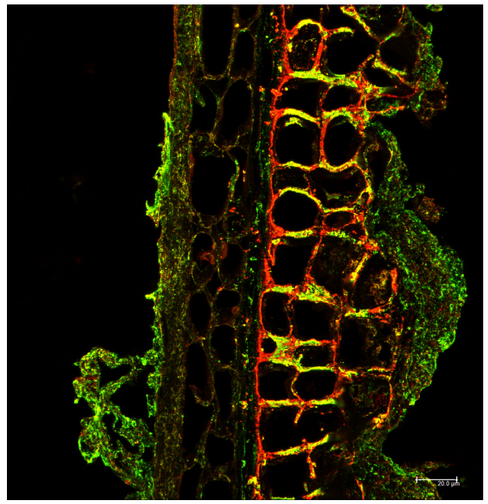
The screening work, focusing on lactic acid bacteria fermentation and enzymatic treatment, was able to identify different potential options for

BSG bioprocessing, responding to the established goals. The selected bioprocessing treatments were successful in upgrading BSG quality as food ingredient and delivered food with improved properties compared to that containing untreated spent grain. Breads containing fermented BSG had overall mild acidity and those containing dextran had improved technological quality, showing the highest crumb homogeneity and lowest roughness compared to the other BSG containing bread. Furthermore, bread containing BSG enriched with dextran and oligosaccharides had a stabilizing effect on the microbial metabolism, allowing prolonged production of short chain fatty acids.

BSG bioprocessing improved the technological properties of fortified pasta due to the degradation of the arabinoxylan structure of BSG, resulting in the release of the components entrapped into the cellular compartments, conferring and a more homogeneous protein network. BSG-containing pasta showed a peculiar sensory profile, with cereal, malt, sourdough bread-like scent and bitter taste among the main attributes, yet, markedly improved by the enzymatic treatment and fermentation. The use of bioprocessed BSG in fortified pasta, compared to native BSG and semolina pasta led to higher protein digestibility and nutritional quality indices. Finally, the antioxidant activity of pasta prodced with bioprocessed BSg was retained after cooking and mimicked digestion.

Concerning breakfast cereals, the process and recipe developed allowed to produce prototypes containing up to 30% of fermented BSG with a pleasant taste and texture. Focus groups were used throughout the work to assess the prototypes and to guide further development. Extruded snacks were also developed with the addition of 15% BSG, allowing improvement in the expansion. Generally, the sensory profile for extrudates containing BSG deriving from different breweries and subjected to different bioprocessing treatments was different, indicating that the composition and processing of the spent have an impact on the sensory quality. Like pasta, also in the case of breakfast cereal, higher antioxidant activity was observed for those containing bioprocessed BSG.

Finally, a small study assessed consumers´ perceptions of BSG-fortified granolas. A multi-method survey was used, containing both quantitative and qualitative questions to obtain a comprehensive picture of how consumers perceive the use of BSG in food products. All participants expressed interest in consuming and purchasing BSG enriched food products. Overall, BSG granolas received appreciation from consumers.



Overall, food containing fermented BSG had good technological quality and nutritional properties, due to the enrichment with fiber and protein and the high antioxidant activity. With the inclusion of spent, the foods qualified for a ”source of fiber” or ”high fiber” and ”source of protein” claims, according to the EU regulation (1924/2006).

Impact

As a wet side-stream, BSG poses several challenges starting from storage after production to processing for food use. Bioprocessing has shown great potential for the enhancement of many food by-products. Tailored bioprocessing with selected microbial starters (i.e. lactic acid bacteria) alone or in combination with hydrolytic enzymes, enabled the production of functional compounds in BSG, improving its overall quality and usability as food ingredient. During bioprocessing, BSG is transformed, resulting in improved structure, as well as enhanced bioactivity and bioavailability of BSG constituents. The results of this investigation showed how tailored bioprocesses, applicable at industrial level, can enhance the technological and nutritional quality of this raw material, providing a blueprint for several applications. Sensory analyses showed that the profile of the BSG containing food was already acceptable at the prototype level, pointing toward successful product development at the industry level. Furthermore, these results highlight the need to study proper logistics and implement regulations for BSG storage and processing, which can encourage the use of this precious side-stream in the food industry. The know-how gained will allow to up-cycle BSG as ingredient for cereal-based food with high nutritional and technological performance, improving food quality while at the same time contributing to waste reduction. FUNBREW integrated both fundamental and applied research in order to fully exploit the potential of breweries side streams and to enable the development of sustainable food systems. During this project, successfull collaboration between the research institutes and industry partners allowed to gain signifcant knowledge on BSG bioprocessing and how to overcome some of the challenges to use it as ingredient in different cereal based foods.

Conclusion and Recommendations

BSG is a challenging but very nutritious side-stream that should be reintroduced in the food chain. Cereal-based products are a good category to use more of the BSG due to the intrinsic qualities of this raw material. Addition of BSG in bread, pasta and extruded snacks significantly improved the nutritional profile of the food products, delivering fibers and proteins. When BSG was bioprocessed, the in vitro digestibility parameters were also enhanced. Thus, BSG holds a great potential as ingredient to develop healthy food products which can be part of our everyday diet. Tailored fermentation proved to be a very successful and feasible way to preserve and enhance the good attributes of this sides-stream and to facilitate its use.

One of the main challenges emerging during the study was how to diminish the detrimental impact of the lignocellulosic fibers of BSG. Processing technologies have to be properly applied to achieve optimal food structure. To make BSG use more feasible, processing steps should be selected wisely to improve structural properties in food, using different treatments and technologies. The food prototypes studied in the project had overall good sensory properties which is an encouraging factor for innovative food development. Thus, more knowledge on consumers´ acceptance should be obtained to increase its use in future food applications. Involving consumers in up-cycled food design could promote its acceptance. Currently, guidelines on how to preserve and process BSG for human consumption are not available for all the countries and/or should still be implemented at EU level. More guidance and implementation of new logistics solutions could contribute to aid supplying of the spent from breweries to food processing plants. Creating and harmonizing logistics and guidelines for BSG storage and supply would contribute to facilitate its use as food ingredient.

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4. MEFPROC

CALL 2017

Improving Sustainability in Food Processing using Moderate Electric Fields (MEF) for Process Intensification and Smart Processing

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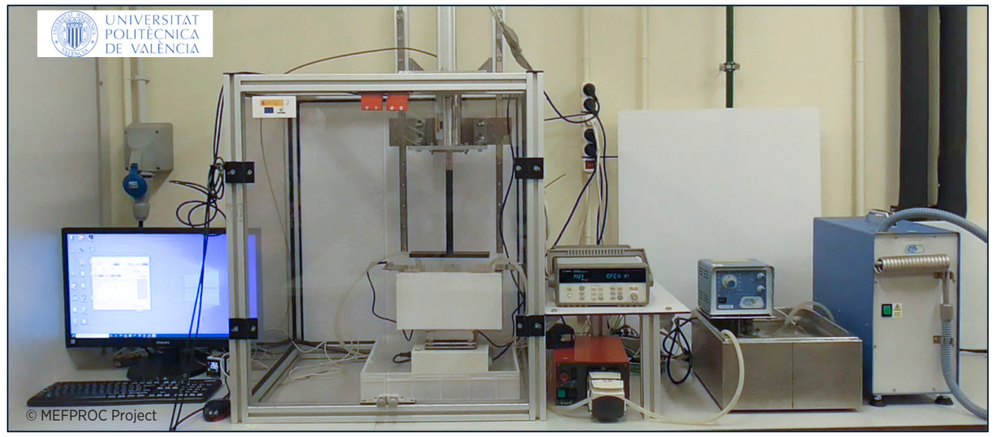
Summary

The development of innovative food processing technologies that can be used to mitigate the challenges in the sustainable production of foods is of great importance for the food industry. As the world population and demands for minimally processed food products are increasing, the development of rapid and lower energy-consuming processing technologies requires innovative solutions to fill this gap. However, the uptake of these innovative technologies is not always simple as the challenges from consumers and food manufacturers are critical.

MEFPROC was aimed at bridging the gap in scientific and technical knowledge that currently prevents the uptake of moderate electric field (MEF) and ultrasound (US) applications for food industry. In addition, it was also aimed at investigating the impacts of MEF (and US) on the yield, quality/safety and energy consumption compared to existing conventional food processing systems.

The innovation hub concept which brought together MEFPROC RPOs with food and equipment manufacturers, served as a key to creating awareness and encouraging the uptake of MEF/US by food manufacturers. This concept also helped not only to identify key potential areas for collaboration and implementation of MEF (and US) in various food processes, but also to build a strong working relationship through consultations and workshops.

In the pasteurization of solid and liquid food products, MEF significantly reduced the processing time and the energy consumption compared to conventional systems while also ensuring the quality and microbiological safety of the products. Furthermore, MEF showed high potential to improve extraction of fruit polyphenols and thereby increase yield or decrease extraction /mash incubation time. MEF processing was also a promising way to extract oleuropein from olive leaves. The combined application of MEF and US was able to increase the MEF effectiveness in the extraction processes even at low intensities. In addition, MEF is also suitable to



reversibly permeabilize rucola leaves enabling the infusion of cryoprotectants.

The physics-based digital tools that can be used to model the heat/mass transfer during MEF treatment of homogeneous and heterogenous products have been developed and validated. The models were used in determining optimum process conditions and parameters were perform sensitivity analysis to identify limiting factors. Through simulations and experimental implementations, it was demonstrated that model-based advanced control systems can produce better control performance, reduce processing time and further improve efficiency.

Interms of consumer acceptance, the contribution of three potential drivers for the slow uptake of electro-heating processed food has been identified: (a) consumer concerns are a potential barrier to commercial update of electro-heating processed products, (b) Senior managers may be hesitant to take up new food processing technologies and (c) on the basis of anti-cartel law, competition authorities might block industry agreement about processing products using electro-heating technology. Overall, MEF (alone or combined with US) has shown great potential to provide alternative, innovative, sustainable food processing solutions with great potential to also play a significant role in the future of the circular and sustainable bioeconomy.

Results and Achievements

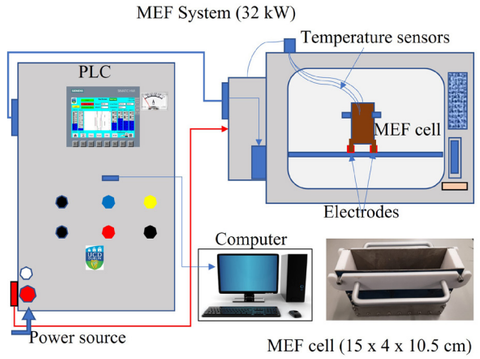
Pasteurisation of solid and liquid food products

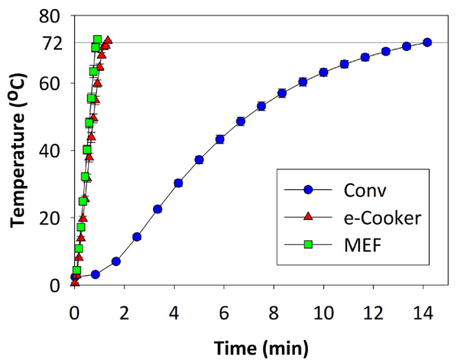
Pasteurisation of solid and liquid foods using MEF processing significantly reduced the time required to raise a product temperature to a target temperature (72°C) and energy consumption compared to conventional water bath heating. A comparison of meat products pasteurised using electro-heating systems (MEF or e-Cooker®) and a conventional water bath indicated that MEF and e-Cooker® significantly reduced the cooking time by about 80.99% and 74.69%, respectively (Fig. 1), while also reduced cook loss and sufficiently delivered appropriate inactivation of the target pathogens.

In terms of pasteurization of freshly squeezed apple juice, MEF resulted in a significant reduction of come-up time to achieve the target pasteurization temperature that corresponds to the microorganism considered. The apple juice treated under MEF preserved its color and was more cloudy than conventionally treated ones. Furthermore, MEF also showed a significant potential on preservation of pesto sauce in reducing processing time compared to conventional systems.

Cryoprotectant (Infusion)

MEF provokes reversible permeabilization of rucola leaves at much lower voltage (and energy) than PEF. However, the MEF treatment time is slightly longer than PEF, leaving PEF as the more attractive industrial approach. MEF or PEF treated, and vacuum impregnated with a cryoprotectant rucola leaves improved the freezing tolerance. The higher the cryoprotectant concentration the higher surviving leaves: 65% of the treated leaves survive the freezing/thawing cycle 5 min after thawing. Within 24 h after thawing, the percentage of surviving leaves decreases to half, presumably due to programmed cell death. No difference in the survival percentage after thawing was detected between leaves treated with MEF or PEF.





Juice extraction

MEF effects on cell disintegration of apple mash were dependent on the particle size. The higher the cell disintegration already achieved by milling, the lower the effect of MEF. The benefits of additional cell disintegration and higher mash softness on the juice yield were dependent on the pressing system used. MEF pretreatment could be suitable for systems with lower layer thickness as rack and cloth presses or belt presses and less for hydraulic filter presses or decanters. Polyphenol content in red currant juice could be increased by MEF pretreatment by 66%. This may replace time-consuming mash incubation operations. Energy inputs used during pilot-plant scale trials ranged from 21 to 232 kJ/kg. This goes together with relatively high costs compared to other cell disintegration techniques like pulsed electric fields (PEF) or enzymatic maceration.

Solid-liquid extraction

The industrial extraction of oleuropein from olive leaves is carried out at 50 ºC with ethanol/water solutions. The use of water as a solvent has a lower effect on the process. The application of MEF during the water-extraction of oleuropein and heating of suspension results in the highly effective use of energy. Moreover, the electroporation induced helps oleuropein migration from matrix to the solvent. The combined application of MEF and US increased the MEF effectiveness even at low intensities.

Design, model and control of MEF systems

Overall, 4 batch (one combined with US) and 2 continuous MEF prototypes were designed, constructed and tested in the project. These systems have the capability to control the power, voltage or energy delivered to achieve a target treatment temperature. Furthermore, digital tools that can be used to model the heat/mass transfer during MEF treatment of homogeneous and heterogenous products have been developed and validated. The mathematical models were able to

determine the optimum process conditions and perform sensitivity analysis of the processes. A standalone application tool based on COMSOL Multiphysics was also developed and used. Through simulations and experimental implementations, it was demonstrated that model-based advanced control systems can produce better control performance, reduce processing time and further improve efficiency.

The sensitivity analysis of the MEF systems indicated that while the electrical conductivity of a food product is the most sensitive variable to the process temperature, from the control point of view, the applied voltage and the magnitude of electric field are the most influential factors to control the process.

Behavioral Economics

The contribution of three potential drivers for the slow uptake of electro-heating-processed foods were identified and studied. These were:

(a) Consumer's willingness to pay for innovatively produced products, (b) Senior management (which is related to cost, uncertainty and the first mover disadvantage) and (C) Stringent anti-cartel law.

The study recommended that emphasizing on the positive characteristics of electro-heating (sustainability, quality) could have a positive impact on consumer acceptance. To mitigate managerial conservatism to take up new technology, firms coordinating the timing of the introduction of their innovation can be effective in concentrated markets but less so in competitive markets. In terms of complying with competition law, the firms involved can inquire at the relevant competition authority whether such agreements are allowed under the European competition law.

Economics of a MEF processing system

The cost of a MEF based equipment depends on (1) power rating, (2) frequency, (3) applicator design, (4) electrode design and (5) the range of products processed. Very often, industrial MEF systems are custom-designed and optimized based on specific applications and this is also a cost to be considered. Owing to differences in the configuration and the processing approach between MEF based and conventional systems, it is very difficult to perform a general comparison of capital cost in a meaningful way.

Impact

The increased demand for healthy, nutritious, high quality and safe products is opening doors for innovative and sustainable processing solutions. MEF offers many innovative benefits including improved sustainability, reduced environmental impact, intensified processing, enhanced quality/ safety and valorisation of wastes. The volumetric heat generation nature of MEF processing not only contributes to a rapid and uniform processing, but also capable of producing microbiologically safe and high-quality food products. This makes MEF technology one of the "greenest" ways electrical energy can be used in food processing. Furthermore, MEF contributes to improving energy efficiency and reduced CO_2 emissions which has a definite role to play in the circular economy.

The interdisciplinary cooperation between RPOs, food and equipment manufacturers in this project maximized the opportunity to design, build and optimise MEF systems that can be incorporated into new processes or into existing processing plants. It also helped to bridge the gaps in scientific and technical knowledge to increase the uptake of MEF (and US) by the food industry.

Conclusion and Recommendations

MEF treatment has shown strong potential in various operations in food processing applied alone or in combination with other processing techniques such as ultrasound. MEF processing is a simple, sustainable and energy efficient technology that can be applied at any scale. Any food product with electrical conductivity between 0.1 S/m and 10 S/m is suitable for MEF processing. Furthermore, the volumetric nature of MEF heating gives more rapid and uniform heating which avoids nutrient and quality degradation. Results of this project also revealed that MEF enhances the extraction yield of high-value products while also reducing energy consumption and associated environmental impact. Through digital tools, optimum process conditions can be determined and used for the design and manufacture of MEF (and US) prototypes. Overall, MEF (and occasionally MEF with US) has shown great potential to provide alternative, innovative, sustainable food processing solutions with great potential to also play a significant role in the future of the circular and sustainable bioeconomy.

The innovation hub approach which involves RPOs, Food and equipment manufacturers is a key to creating awareness and encouraging the food industry to consider the uptake of MEF (and US) in food processing.

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5. DISCOVERY

CALL 2017

Disaggregation of conventional vegetable press cakes by novel techniques to receive new products and to increase the yield

PROJECT TEAM

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Summary

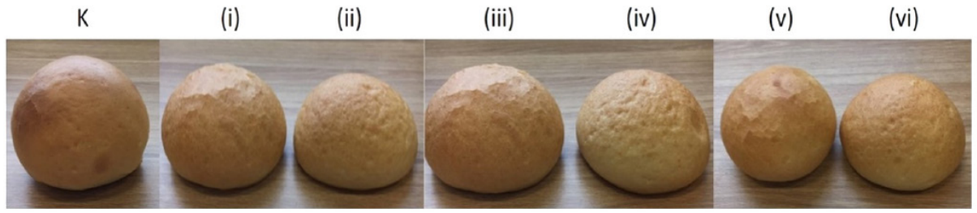
Vegetable beverages and products made of soy, oat and other grains or fruits are a healthy and sustainable alternative to animal products. Popularity and market demand are continuously growing in Europe as well as worldwide. The global soy food market has been rated worth 38.7 billion US$ in 2018 and is expected to have an annual growth rate of 5% reaching an estimated value of 53.1 billion US$.

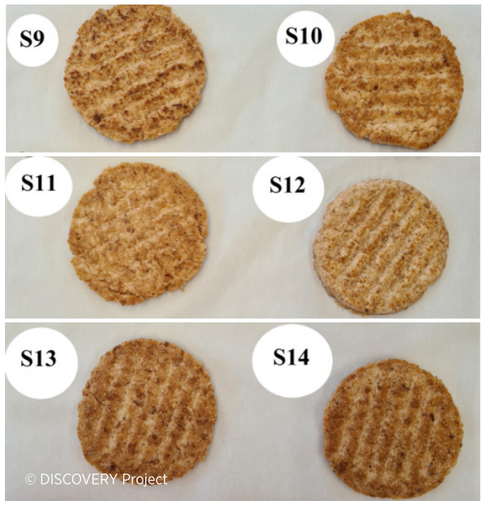
The general manufacturing procedure of vegetable beverages requires a soaking, milling and pressing of the raw materials in water. The separated liquid phase is the base for beverages and other products like tofu. The solid phase is a press cake (PC), which is at the moment regarded as waste stream and used as animal feed. However, these PCs often still contain a significant amount of valuable ingredients such as proteins.

Therefore, DISCOVERY aims to unlock those potentials and hence to improve the yield of food products made of vegetable raw materials. In the end, European food industry as well as consumers shall benefit of the economic and sustainable effects going along with the increasing efficiency within food production.

The project's objective was to investigate promising techniques such as ultrasonic (US) and enzymatic treatment to disaggregate the PCs of soy, oat, rice, almond and coconut and to subsequently separate an additional protein-rich liquid phase. The post-treatment of the liquid fraction by concentration as well as the utilization of the separated PC fibers in meat analogues and bakery products were performed. Furthermore, the influence of the treatments on the nutritional food quality and safety was examined.

Overall within DISCOVERY, the disaggregation, treatment and utilization of soy, oat, almond and coconut PC has been shown to have a broad and promising potential for food production industry. Regarding each specific product and process line, individual treatments have to be chosen to meet technological product properties and economic issues.





Results and Achievements

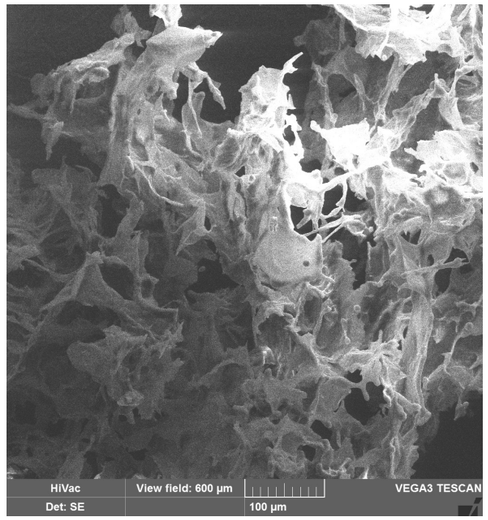
For the disaggregation of PCs, high-power ultrasound (US) was applied to induce acoustic cavitation (18 kHz, up to 4.5 kW). Within batch and continuous treatment, process parameters of temperature, power input and treatment time as well as mixing PC:water ratios could be defined enabling a successful extraction of proteins. Scanning electron microscopy (SEM) and particle size analysis clearly indicate the disruption of cells as well as the reduction of particle size distribution (s. Figure 1). Results show that out of soy, oat, almond and coconut PC protein yields of 30%, 21%, 49% and 24%, respectively, can be recovered.

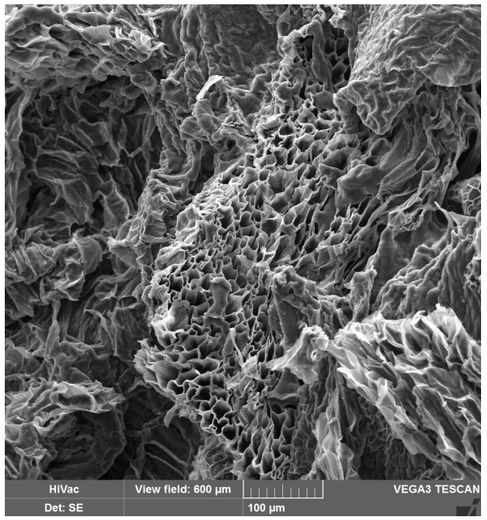
For enzymatic treatment, compositions of enzymes with amylase, cellulose and protease activities have been selected on the individual chemical composition of each PC. The results indicate that functional properties as water- and oil-holding capacities could be improved significantly. Due to their nutritionally valuable amino acid composition, oat and soy PC show highest potentials.

The concentration of the liquid fractions by ultrafiltration in pilot-scale can be achieved by process parameters comparable to typical performance ranges in food industry. Retentates with high protein content can be added to the main production process, while permeate can be used for the production of lactic acid (LA).

Furthermore, the post-treatment and utilization of the fiber fractions were investigated. Combined treatment of US and fermentation can stabilize the PCs and eliminate undesired microorganisms. Both, pasteurization and sterilization were effective to ensure safety parameters, and functional properties. The application of fibers in cereal products was examined concerning PC type, treatment and quantity. Here, addition of 15% fermented oat PC showed the highest acceptability and lowest acrylamide concentration. In meat analogues, 3% and 6% fermented or extruded PCs were added to the matrix and analyzed regarding protein oxidation as well as functional, textural and sensory properties (s. Figure 2). From a technological point of view, meat analogues with the addition of 6% extruded oat PC show the highest potential due to texture, color, sensory and meat-like technological parameters.

Regarding protein quality, no variation in the primary sequence of the storage proteins was observed after US treatment of soy, rice, almond and coconut. Overall, US coupled with temperature increased the protein extraction yield of soy. Also, US improved the soluble protein content for coconut and almond. Modifications induced by the US processing were found on the protein solubility as well as on the water binding capacity. For soy,





US treatment could increase protein solubility by 6.5 times compared to untreated PC. Also, in soy, coconut and almond PC a significant effect on the protein structure regarding the exposition of hydrophobic amino acids containing thiol groups could be detected. Furthermore, a reduction of phytic acid was found for soy, coconut and almond.

Impact

The project's objective was to investigate promising techniques such as ultrasonic (US) and enzymatic treatment to disaggregate the PCs of soy, oat, rice, almond and coconut and to subsequently separate an additional protein-rich liquid phase. The post-treatment of the liquid fraction by concentration as well as the utilization of the separated PC fibers in meat analogues and bakery products were performed. Furthermore, the influence of the treatments on the nutritional food quality and safety was examined. Overall within DISCOVERY, the disaggregation, treatment and utilization of soy, oat, almond and coconut PC has been shown to have a broad and promising potential for food production industry. Regarding each specific product and process line, individual treatments have to be chosen to meet technological product properties and economic issues.

Conclusion and Recommendations

The findings achieved within DISCOVERY show that the food potential of press cakes as side stream of the vegetable food production can be unlocked. By an effective disintegration and a subsequent overall utilization of all press cake components, a significant yield improvement within food production is possible. In the end, European food industry as well as consumers can benefit of the economic and sustainable effects going along with the increasing efficiency within food production.

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6. ProSeaFood

CALL 2017

Innovative processing of seaweed for novel, healthy food products and ingredients

PROJECT TEAM

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Ximo Salvo Agramunt / DPL

Beatriz Molina / Eurocastell S.A.T

Summary

Agricultural food production faces large technological and environmental challenges to remain sustainable. This imposes a need for new sources for food and alternative production sites. Brown seaweeds are important as food in East Asia, but presently underutilized in the Western world. Large-scale, sustainable cultivation is now increasing the availability of high-quality seaweed biomass in Europe. However, for brown seaweed to become a widespread food ingredient, improved processing methods to increase the edibility and nutritional value are required. The primary objective of the ProSeaFood project has been to develop and apply innovative processing methods to increase the digestibility and nutrient availability of brown seaweeds, and to remove inedible or potentially harmful substances. By employing enzymes and fermentation as tools, also novel sensory properties would be introduced. The consortium has included partners from Norway, Sweden, Iceland, and Spain, combining expertise in seaweed cultivation, biomass processing, fermentation, enzyme technology, and product development, to cover the value chain from raw material to products.

The two species Saccharina latissima and Alaria esculenta have been used in the project. In particular S. latissima has a very high iodine content, limiting the amounts that can be included in food products and/or the allowable intake. The project has developed a method based on blanching for reduction of the iodine and salt contents in the algae. The iodine concentration was reduced by 90%, and the total salt (ash) by 65-70%. The nutritional value was increased, since protein is enriched by the process. The process was implemented in the industrial process line of one of the industry partners in 2020.

Enzymatic processing of the seaweed biomass to hydrolyse polysaccharides and protein has been applied for modification of texture and flavour, as pre-treatment to facilitate fermentation and for generation of prebiotic oligosaccharides. The fermentation part has focussed on the use of probiotic bacteria and their ability to utilise the seaweed carbohydrates as substrates for growth, and the properties of fermented biomass as food ingredients.

Here, the project has selected and characterized bacterial strains that efficiently can ferment the

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seaweed biomass and are classified as probiotic. The selected strains can utilise mannitol and have high salt and acid tolerance. As the blanching process reduces the content of soluble carbohydrates, treatment with polysaccharide-degrading enzymes were shown, at least partly, to compensate for this loss. The impact of unprocessed and enzyme-treated biomass on the gut microbiota have been studied in a simulated gut system, using human gut microbiota as inoculum. These data are still under processing.


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The processed brown algae have further been analysed with respect to sensory and technological properties of the processed biomass, and of a range of food products with the seaweed as ingredients. This characterisation revealed important differences between Saccharina and

Alaria, and between the processing methods (freezing, drying, heat treatment, fermentation, etc.). Based on the results, two food product prototypes, guacamole and gluten-free bread, were chosen for a 100-person consumer test to assess market potential. The bioaccessibility of the nutritionally most important minerals of the seaweed was investigated in a simulated digestive system, and were unchanged in the guacamole, but reduced in the bread, compared to the seaweed ingredients alone.

Results and Achievements

Seaweed processing for reduction of iodine and other unwanted compounds

Sugar kelp has an iodine content of 5-6 mg/g dry weight while winged kelp contains only 0.1-1 mg/g. The content, particularly in sugar kelp is too high for the unprocessed seaweed to be directly included in the daily diet. The salt/ash content can be as high as 40% of the dry weight, conferring a strong salty flavor. The project has demonstrated that a simple blanching in warm water reduces iodine to 10% of the original content for both species. The ash content is similarly reduced, which both allow a higher ratio of seaweed in processed foods. Blanching in seawater is equally effective as fresh water in reducing iodine, without reducing the salt content. Potassium, which is the dominating cation in the seaweed is however replaced with Sodium.


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This is not favorable from a nutritional point of view, as the high K/Na ratio makes seaweed a promising salt replacer. An additional positive effect of the blanching is that the protein content increases due to the salt reduction. Blanching at 60-80°C also has a pasteurizing effect reducing the risk of unwanted microbial growth during further processing and prolonging the shelf-life. The results from the ProSeaFood project formed the basis for the industry scale blanching process used today by project industry partner SES.

Enzyme treatment and fermentation

Enzymatic hydrolysis of polysaccharides and proteins has been performed to modify texture and flavor, as pre-treatment for fermentation by increasing substrate availability, and to form prebiotic oligosaccharides. The fermentation experiments have primarily employed probiotic bacteria that can utilize the inherent compounds of the seaweed as substrates and can provide beneficial health effects to the food products. Seaweed has a relatively low content of fermentable sugars when harvested in spring, and this is reduced further by the blanching pre-treatment. Commercial, food-grade β-glucanases have been used to form oligosaccharides from cellulose and laminarin to increase the content of fermentable sugars. These enzymes do, however, form a limited amount of dimers and monomers and did not have a large effect on the fermentation process, as measured by pH decrease and lactic acid production. Oligosaccharides from laminarin (β-1,3-glucans) are potential prebiotics, and a laminarinase developed by Matis was shown to produce trimers as the dominating product (50%), followed by dimers (28%) and tetramers (20%).

A collection of 150 food-approved probiotic bacteria has been screened with respect to their ability to utilize seaweed carbohydrates, as well as other criteria such as salt tolerance. The three most promising strains had their genomes sequenced,

and one of these (Lactobacillus sp KS1-3) was used to ferment the laminarin hydrolysate produced in the project. The strain utilized di- and trimers rapidly and simultaneously, as well as tetramers at a lower rate. This showed that the laminarin oligomers function as prebiotics and that the strain together with the hydrolysate can function as a symbiotic product. The three selected straisn as well as commercial strains of L. plantarum were used to ferment non-processed, blanched or enzyme-treated seaweed. In the non-processed biomass the pH rapidly decreased to 3.6-3.8, while in the blanched biomass it did not go below 4.7. After enzyme treatment of blanched seaweed the pH decreased to around 4.2. All strains utilized mannitol after consuming glucose where available. Lactate was the main product for L. plantarum, while KS1-3 additionally produced small amounts of butyric acid and succinic acid from mannitol. The fermented products were not tested in food, but evaluated by sensory analysis of freeze dried material. Altogether, 7 combinations of enzyme treatment and fermentation were evaluated for each seaweed species. Characterization of the microbiota (by 16S rRNA sequencing) in fresh seaweed and in fermented seaweed showed a variable composition depending on pre-treatment. The analyses also showed that the added culture was outcompeting the natural flora during the fermentation.

Technological and sensory properties

Characterization of the untreated and processed raw materials and derived food products have shown clear differences between sugar kelp and winged kelp, both in terms of sensorics and physical properties, despite having a relatively similar chemical composition. For example, the sugar kelp shows better water binding properties whereas the winged kelp generally scored better in sensory analyses. The reason for this has partially been investigated in ProSeaFood, but is followed up more extensively in other ongoing projects. Model products selected by the food industry partners in the project have been guacamole, hummus, gluten-free bread and bread sticks. After preliminary tests, guacamole and gluten-free bread were selected as prototypes for further optimization, characterization of physical properties, and consumer trials. For gluten-free bread with with 5% unprocessed seaweed the characterization showed a higher moisture content for bread with sugar kelp while sensory properties were comparable with the control. For guacamole, a sugar kelp (unprocessed and blanched) inclusion of up to 19% wet weight resulted in increased compression strength (firmness) compared with the control and the guacamole with winged kelp. This is presumably related to differences in the structure and/or concentration of alginate. Here, winged kelp also resulted in the highest sensory rating, whereas blanching was found to improve the sensory properties of sugar kelp.

Sensory evaluation of enzyme-treated and/or fermented seaweed showed a negative effect of protease treatment alone, whereas fermented seaweed after protease treatment resulted in the highest score, indicating that freed peptides are consumed during fermentation. For glucanase-treated seaweed there were no clear differences in sensory properties compared with the non-processed control. The project carried out a consumer test of gluten free bread and guacamole, where the bread received a high grade and the consumers expressed willingness to purchase the project. The guacamole scored lower, but it should be noted that the control was the La Caña's original product where a product with a different novel ingredient could have been a more suitable control.

Food safety and health benefits

Analysis and processing for lowering iodine, and potentially heavy metals and arsenic, is an important aspect of food safety monitoring and regulation for seaweed-based products. In addition, demands for microbiological quality must be fulfilled. As previously mentioned, blanching was found to be an effective treatment to improve shelf life and reduce eventual pathogenic microorganisms in the raw material. During enzyme treatment there was a noticeable growth of the natural microbiota, whereas this did not occur for thermally processed/ blanched raw material. Fermentation will also contribute by replacing the natural microbiota with beneficial lactic acid bacteria. Shelf life studies of the food prototypes did not show any pathogenic microorganisms or other microorganisms that can reduce the organoleptic quality, after 60 days refrigeration.

Lastly, an experiment was carried out using a simulated intestine which indicated beneficial effects of the different processed seaweed on the intestinal microbiota.

Impact

The primary objective of the "ProsSeaFood" project is to apply advanced

processing methods to increase the digestibility and nutrient availability of brown seaweeds. This will be achieved through employing enzymes and fermentation to increase nutritional availability and remove inedible or potentially harmful substances, and to introduce novel sensory properties. Based on the processed ingredients, the project will further develop innovative food products that are nutritious, tasteful and have well-documented effects on consumer health. The project consortium includes partners from Norway, Sweden, Iceland and Spain, combining expertise in seaweed cultivation, biomass processing, fermentation, enzymology, and product development and quality control, to cover the value chain from raw material to finished food products. The project is research-driven for the development of the processing methods, with a strong industrial collaboration for product conceptualization, development and quality control.

Conclusion and Recommendations

The project has generated new significant knowledge for the exploitation of cultivated sugar kelp and winged kelp for good applications, specifically with respect to interspecies differences and the effects of blanching, enzyme treatment and fermentation on the composition and properties of the biomasses. The work on novel probiotic bacterial strains that can grow on seaweed, and prebiotic effects of seaweed components, forms a basis for further work in the field. The project has contributed greatly to competence development and knowledge exchange between partners, and training of students and young researchers. The project has further led to new research projects and collaborations, building on key results for scientific publications and product development. As the European seaweed cultivation industry is growing, so will the need for more research on food properties, safety and applications to help grow a new Blue Bioeconomy.

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7. AVARE

CALL 2017

Adding value in resource effective food systems

PROJECT TEAM

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Summary

The major losses of resources in the food value chain occur at the consumer stage, in households as well as the hospitality sector. In the hospitality sector relative food losses are the highest. Although numerous studies have investigated how to prevent food waste, food waste reduction and re-utilization of organic materials as a resource is still lacking impetus in many sectors and countries. AVARE project concentrated on identifying and evaluating of barriers, opportunities and solutions, how to prevent and reduce food waste, improve optimal use of organic waste resources to redesign the food chain and to ensure to meet consumer needs and acceptance. In parallel, project defined the amount and composition of residues of certain areas as canteens to be used as feedstock additive in bioprocesses.

According to the findings, around 20% of food served became waste. The results showed that 61% of the restaurants included in the project had reduced food waste and that restaurants with high initial food waste (FW) per guest had the greatest reduction. It was also seen that sustainability can be increased by utilizing food waste as raw material for basic building blocks such as carboxylic acids, and further processing them into high value products such as the polyunsaturated fatty acid docosahexaenoic acid (DHA). Different acids were tested, which are produced as supernatants during acid fermentation. It was observed, how the cell growth and product formation of DHA works with these substrates. The achieved DHA contents with acetic acid supplementation was high. It could be shown that the growth behavior is very similar to the standard cultivation.

Results and Achievements

All the institutes that participated in work package 1 had ongoing national projects on food waste in the hospitality sector, and the data were compiled to be able to compare on a broader basis, both between countries and between the different segments such as school canteens, nursing homes, hotels, cafes and restaurants. In addition to this, a survey was also conducted in each country on how the serving place was organized, how food waste was registered and what measures have been implemented. According to the findings, around 20% of food served became waste. Waste per portion varied widely between establishments, ranging from 50 g/portion for canteens to 192 g/portion for restaurants. The results showed that 61% of the restaurants included in the project had reduced food waste and that restaurants with high initial food waste per guest had the greatest reduction.


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One of the aims were to compare national food waste strategies, how those has been built in each country and how stakeholders and actors of food chain has been involved to reduce food waste. It was seen that all the countries have different approached, for example in Finland the work has been done through workshops with stakeholders and actors of food chain. The wide range of stakeholder of food chain have been participating to the workshops. There were representatives from primary production, food industry, catering sector, trade sector, consumers, authorities, NGOs and associations as well as researchers and experts. Altogether 80 participants have participated to workshops. The research team read also numerous scientific publications and interviewed experts in Finland to provide a more comprehensive and deeper understanding about the ways to reduce food waste at the whole food chain and society. Based on the results of workshops, literature, interviews and brainstorming the research group assembles key guidelines/solutions to reduce food waste in Finland, first national food waste roadmap was created.

In Germany, the Federal Ministry of Food and Agriculture published a National Strategy for Food Waste Reduction, which establishes dialogue forums for different parts of the food chain (Primary Production, Processing, Retail and Wholesale, Out-of-Home Consumption, Private Households (civil society)). Moreover, the Thünen Institute was assigned to publish a baseline for food waste which makes measuring progress possible. The Dialogue Forum on Retail and Wholesale as well as the Dialogue Forum on Away-From-Home Consumption are almost finished. Within those forums, actors from the industry, from research, public organizations and federal institutions


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discuss and implement measures to reduce food waste in the respective step of the food chain. All measures and results are published on the website lebensmittelwertschaetzen.de. This includes tools like apps to help measure food waste as well as information on ongoing research projects, upcoming events regarding food waste reduction and reports on local measures, for instance in schools or canteens. Stakeholders from the Dialogue Forum on Wholesale and Retail Trade signed a voluntary agreement to reduce food waste in June 2020. The signing companies agreed to redistribute leftover foodstuffs, for instance by giving them to charity. Furthermore, they will collect data to improve statistics on food waste. The agreement additionally lists 13 possible measures in 4 categories of which the companies agree to implement at least 4, covering all categories.

In Sweden there are many actors working with food waste and reduction of food waste, but on their own initiative and with their own sources of funding. There are also central authorities that have the task of helping the society to reduce food waste, and there are national goals of reduced food waste. However, there are no national strategy that aims to reduce food waste. Instead, there are many strategies in many different organisations that might have overlapping goals of reducing food waste.

The potential to increase sustainability in the use of food waste through biotechnological products, starting from basic building blocks such as carboxylic acids in acid (dark) fermentation, and their further processing into high value products such as the polyunsaturated fatty acid docosahexaenoic acid (DHA) was

investigated. Microalgae with a high content of DHA can be used as feed additive, e.g. in fish farming, partially replacing fish oil. Different food waste from canteens from all partner countries were chemically characterized and laboratory scale experiment were conducted. Experiments were performed repeatedly to test technical and biological reproducibility. A stable acid fermentation operation was obtained in continuous mode. Carboxylic acid concentrations of up to 15 g/L could be achieved. A further increase by up to 20% was achieved when Paenibacillus sp.were added once and a recirculation of thin slurry was conducted in a continuous operation in the plug-flow digester.

In parallel to the acid (dark) fermentation experiments, work was carried out on the cultivation of microalgae as a second process step. Different acids were tested, which are produced as supernatants during acid fermentation, e.g. acetate, pyruvate, propionate and lactate. It was observed, how the cell growth and product formation of DHA works with these substrates. The oleaginous microalga Crypthecodinium cohnii (C. cohnii) was therefore cultivated in an aerobic monocultivation with acid supplementation in the later growth (product formation) phase. This alga accumulates high concentrations of the so-called omega-3 fatty acid DHA intracellularly. After an initial growth phase, the appropriate acid or its salt is added to the culture and the influence on growth and product formation was investigated. The DHA product concentration when acetic acid was supplemented was 16.6, 13.2 and 13.0%, respectively, reference being 5.9%. In different shake flask cultivations, a reference with the substrate glucose was used with different substrate mixtures of glucose and the acids acetic acid, butyric acid, propionic acid and lactic acid or their salts added as pure substrates in the production phase without glucose. The achieved DHA contents with acetic acid supplementation are among the greatest ever reported (0.27 +/- 0.05 g/g). Experiments were carried out with mixtures reflecting the results from the acid fermentations. It could be shown that the growth behavior is very similar to the standard cultivation. No relevant difference to the previously shown cultures could be detected either. The DHA contents were determined in a range between 9 and 13 wt.%.

Impact

The impact from FW related problems but also solutions including prevention, redistribution and valorization of FW were investigated. Major findings were:

- climate impact of the excess food intake accounted for up to 2% of the total and 10% of the food related annual greenhouse gas emissions in Sweden, depending on the proportion of animal-based foods ending up as metabolic food waste.
- Comparison of two types of disposable plates showed that the leaf plate had substantially higher global warming potential than the paper plate, due to its long-distance transport and use of coal-based electricity in processing the raw material.
- Different incentives and levels of autonomy influence consumers FW and hen incentive and autonomy are low, the amount of FW is higher. The main wasted products are rice and beans, followed by beef, and carbohydrates which reduces the environmental impact from the excessive plate waste in some restaurant settings.
- Food donation was found effective in a case study with 78% of the 237 t redistributed surplus food eaten, benefitting hundreds of people in need. Despite the substantial rebound effect, offsetting 51% of the potential carbon emission savings of food donation, the net results of food donation were almost two-fold in climate negativity in comparison to anaerobic digestion (-0.40 vs. -0.22 kg CO_2e/kg of redistributed food).
- Eighteen third-party redistribution organizations that redistribute surplus food in Sweden were identified and all was found to contribute to a sustainable development, but non of them managed to score high on all the three aspects of sustainable development.
- Docosahexaenoic acid (DHA) produced by microalgae using volatile fatty acids from FW can reduce loss of biodiversity and support sustainable production while satisfying increased future demand for DHA within the food supply chain.

Conclusion and Recommendations

There are still work to be done in field of food waste reduction. The project results showed that reduction can be done but the results vary widely between establishments. It was also shown that resource efficient processing of food waste can be done but more research is needed on economic impacts of the process chain. There should also be discussion on how to value the measures of emission reduction.

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8. SPAREC

CALL 2017

Sustainable Processing of Agrofood Residues to Elicitors and Chemicals

PROJECT TEAM

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Summary

The objective of this project was to apply the circular bioeconomy to waste from fruit juice factories (orange and apple), as well as from wine production, both from the vineyard and from fermentation.

The main objective was to obtain elicitor compounds using the aforementioned wastes as raw materials. In order to favor the possibility of economic viability of the developed process, during the physico-chemical-biological treatment of the same, several compounds of added value and market application have been obtained, such as essential oils and antioxidant compounds (phenolics). Likewise, the production of bacterial cellulose by fermentation of the free sugars present in the raw material has been studied, as well as the production of vegetal nanocellulose from certain residues, which would be used as supports for the elicitors for their controlled release.

The compounds produced with supposed elicitor capacity have been tested in greenhouse and field on cherry tomato and cucumber, being totally positive in their beneficial action for the mentioned crops, being proven against the non-treatment and their comparison with a commercial product.

During the project a very multidisciplinary work has been carried out, without which the success of the project would not have been possible. Numerous experimental and analytical techniques have been used.

It is worth mentioning the role played by the four small and medium-sized companies that have participated in the project; from an enzyme producing company, which has developed enzymes specifically for this project; to a company specialized in the study of LCA and LCC, which has made it possible to check the possible future viability of the process; a pioneering company in the development of elicitors, which started the project as a spin-off of a Spanish university and was acquired by an American multinational during the execution of the project and has allowed the study of the efficacy of the products obtained; and finally, a winery with the Rivera de Duero appellation of origin, which has made one of its vineyards available to the project for field trials in this type of crop, which is so important in Spain.

Results and Achievements

The SPAREC project aims at producing mixtures of antioxidants, essential oils, and oligosaccharides that can act as plant response elicitors.

It is also our aim to produce solid supports such as bacterial cellulose and vegetal nanocellulose to support oligosaccharides. The starting material for all of them has been constituted by diverse agro-residues coming from vineries and fruit processing factories. These materials have been fully characterized by NREL proximal analysis, DRX, SEM-EDS, FTIR and physical techniques. They have been treated by extractions followed by thermal, chemical and enzymatic depolymerizations. Extractive processes were statistically optimized once proper solvents and contacting devices were selected, obtaining diverse mixtures with a high antioxidant activity, specially from residues produced of in Pago de Carraovejas (grape stalks, grape marc, lees), while essential oils were obtained from orange and lemon peels following classical hydrothermal processing and solvent extraction, either using simple liquid-solid contacting or intensifying it by using low energy ultrasounds.

For several of the residues, a previous water extraction of free sugars was conducted. For the hydrolysis of polysaccharides and heterogeneous polymers, such as pectin, thermal, chemical and enzymatic processes were performed. The thermal approach led to mixtures of high and medium MW oligosaccharides that prove to be toxic of plants in the first lab scale screening for elicitor activity. However, enzymatic hydrolysis of original and extracted residues led to medium-small MW with elicitor activity at lab-scale, and the same was observed for oligosaccharides obtained from pectin and pectin-rich residues via an original, here developed, acid depolymerization process based on the use of HCl and TFA. This result has been ascribed to the elimination during thermal processing of the side groups present in pectin and hemicellulose in the residues.

For the enzymatic treatment, a first generation of cellulases, beta-glucosidases and pectinases has been applied, and they have been the catalysts conducting to final elicitor fractions tested at greenhouse and field levels, both at full production scale. However, a set of new endopectinases cloned in P. pastoris has been developed and successfully expressed and produced in the host yeast. As pectin oligosaccharides have proved to have the most evident elicitor activity, further studies with these new, and very active, endopectinases is envisaged.

Several hydrolysates based on orange and apple residues have been tested for the production of cherry tomatoes and cucumbers at full scale in greenhouse and for the protection of vines for two seasons, showing a biostimulant effect on fast-growing plants at greenhouse scale and no effect on slow-growing vines, as observed by manual assessment of the plants and fruits, and aerial study of the vegetable development by energy reflectance analysis in the case of the vineyard. These results suggest that direct enzymatic treatment of original orange and apple residues results in eliciting solutions for fast-growing vegetables.

With the monosaccharide-rich solutions from water extractions of the residues, and selecting proper nitrogen sources, we have developed lab-scale processes to obtain bacterial cellulose in static and dynamic conditions. At the same time, residual lignocellulose has been treated to obtain adequate inks for 3D-printing several supports. They, and agricultural cellulose supports, have been loaded with model elicitors and enzymatic waste-based hydrolysates to study the the controlled release of the loaded elicitors. Genome analysis of chili pepper plants after treatment is underway.

Finally, an LCA-LCC full analysis of simple and complex processes for waste treatment indicates a

high economic feasibility and a low environmental impact at high production, identifying the process steps with higher potential for further optimization.

Impact

SPAREC project has proven that the circular bioeconomy can be applied to waste obtained from agri-food industries, since compounds that improve the growth and production of crops such as cherry tomatoes and cucumbers can be produced from them, using environmentally friendly processes. This type of product could replace certain agrochemicals, such as pesticides.

It has also been shown that in this circular bioeconomy, it is necessary to consider the production of other types of compounds in order to achieve processes that are not only environmentally sustainable, but also economically sustainable. The wastes studied in the SPAREC project are a source of antioxidants, pectin and, possibly, prebiotics, as well as elicitors.

Agri-food companies can make a profit from their own waste by recovering it. The use of elicitors enables farmers to work in organic farming.

Conclusion and Recommendations

In short, waste from agri-food industries is a very useful raw material for the development of second-generation biorefineries, to avoid the use of cereal grains (wheat, barley, rice, corn, etc.) for this purpose, instead of being used for food. Society benefits both in terms of food safety and environment.

The concept "food waste" is a question of technology and opportunity: all wastes can be turned into resources and products once technology is mature and Society accepts new products.

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9. ImPrOVE

CALL 2017

Innovative (pre)POmace Valorization process

PROJECT TEAM

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Summary

The ImPrOVE (Innovative (pre)POmace Valorization procEss) project performed a series of research activities aimed at establishing sustainable process flows for pomace treatment and valorisation.

Pomace is an important and unavoidable by-product of the agricultural industry, especially of fruit and oil ones.

Despite its status of food waste, pomace still contains natural and highly functional compounds. Skin and core of fruit contain protecting and functional molecules: antioxidants, stabilizers, colorants, aromas, fibers with potential in high value applications in cosmetics, diets and, as bio-additives in food and beverages.

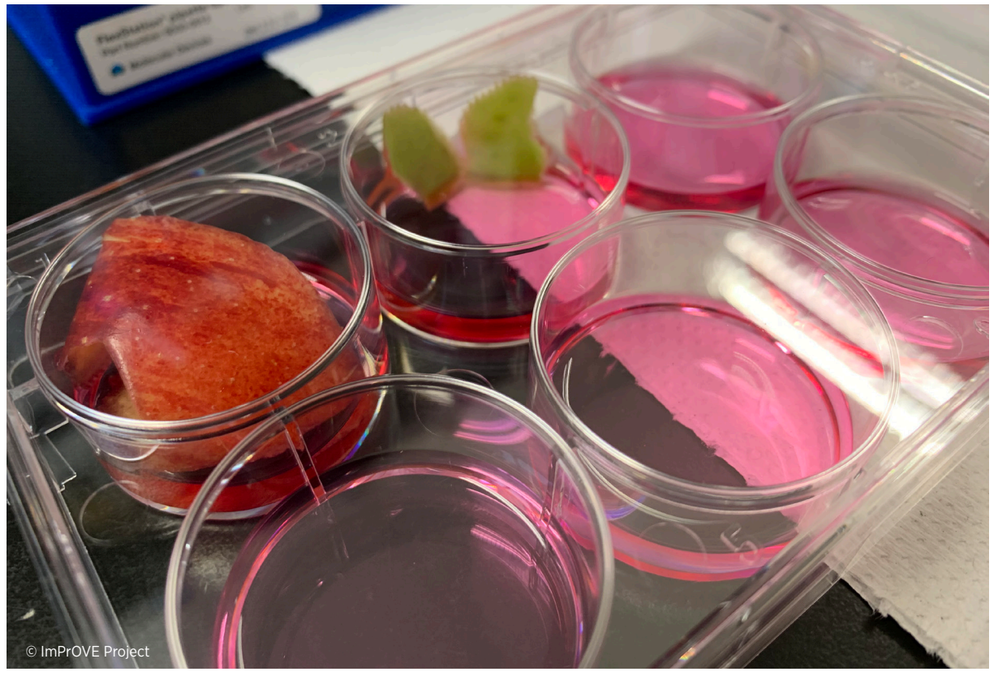
The project experimental activities had been focused mainly on apple and olive pomaces but the obtained results are applicable to other kind of fruits.

The research cluster presented a high degree of networking,.which included an intense exchange of physical samples. Preliminarily, a list of cultivars of several kinds of fruits, that could be of interest for the project, had been compiled.

Pre-treatment of pomace including separation of aroma, separation of seeds from fruit cake had been performed. The extraction of oil from apple seeds had led to low yields. Aroma separation had been performed with mechanical methods and supercritical CO_2 leading to some interesting results. The feasibility of biological and mechanical transformations of the fiber components of pomace (lignin and cellulose) had been tested.

On the pre-treated pomace, the extraction of high valued chemical substances, mainly polyphenols, had been extensively studied.

In order to achieve a full green pipeline for this procedure, environmentally friendly classes of solvents had been used. Deep eutectic solvents based on natural substances (NADESs) and bio-based Ionic liquids (BIOILs), which are innovative and fully sustainable classes of solvents, had been chosen for this duty.



Given their natural origin, these media can be used for storage and conservation of the extract also.

A large set of these solvents had been prepared and tested for the extraction. The extraction conditions had been optimized for pomaces of different nature. Extraction products had been characterized by mean of analytical techniques developed during the process and dataset are now available for apple, olive and cherry pomaces.

It is noteworthy that the knowledge about deep eutectic solvents increased significatively throughout the duration of the project. Experiments had been modified according to the state of art.

Toxicity (ecotoxicity at different tropic levels and cytotoxicity) and biodegradability of the solvents and of the extracts had been tested and assessed. This step represented a turning point for directing part of the investigations.

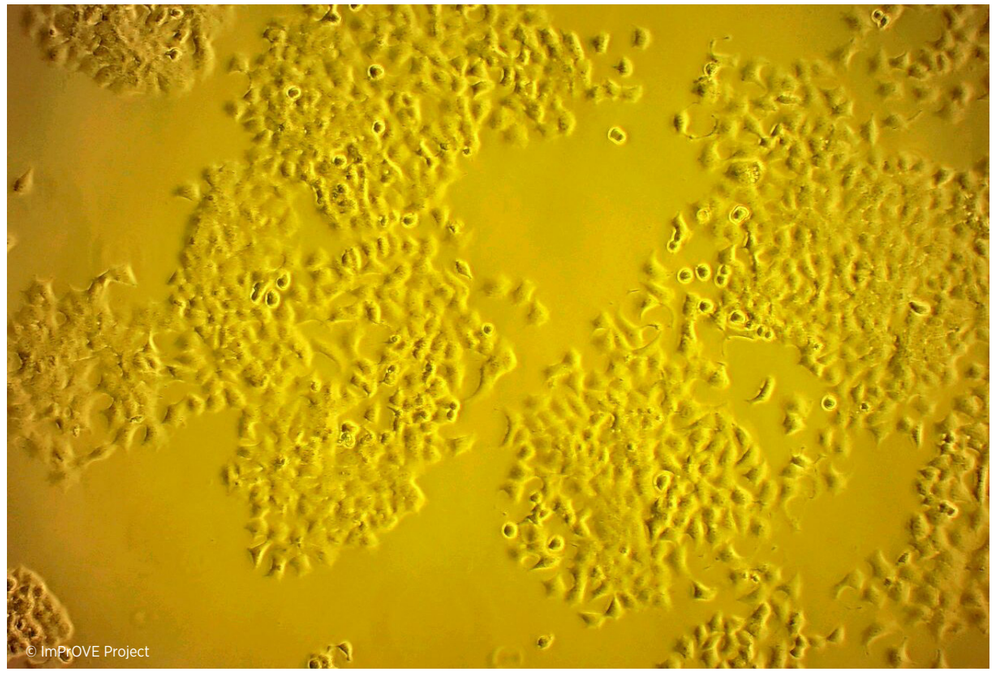
Limited activities of scale-up, sensorial analysis and market research activities had been performed in the last stages of the project.

The project led to several communications to international and national conferences and to five papers on peer reviewed journals. Other papers are in preparation or in the editorial pipeline.

Some researchers involved in the project participated also to divulgation activities to non-expert public audience.

This kind of activities along with the participation to conferences and workshops had been strongly affected by COVID 19 pandemic.

Pandemic affected also the coordination between the different partners leading to delays and mismatches on the exchange of the samples (pomace at the different stage of processing and solvents), some of which of seasonal nature, reducing the global efficiency of the research activity. Nevertheless, the project reached some fundamental goals and represents a seed with the potential to generate value from the agricultural waste, thus turning the perception of fruit pomaces from waste to business opportunity, in agreement with the circular economy concept.



Results and Achievements

17 apple, pear, and cherry varieties relevant for Europe have been selected, pressed and pasteurized. Tests were performed on pilot scale (PcFruit and Konings).

Physicochemical analyses were performed on the press cake and juice at UAntwerp which performed polyphenol, aroma and fiber analysis. Then, samples of the press cake were sent to UNIPI for extraction of polyphenols.

A procedure to concentrate/extract the polyphenols from press cake was elaborated by UAntwerp using water/alcohol extraction and evaporation.

UNIPI checked analytical methods and UCD performed testing on activity on two samples of apple varieties. Thermal stability was tested: temperatures higher than 40°C should be avoided. Polyphenols were also isolated from juice. Literature data on type and concentration were confirmed. A database is available. The classical extraction method was slightly adapted to olive pomaces. Polyphenol analysis was done. UNIPI extraction samples via non-conventional solvents were obtained and analyzed.

The aroma profile was determined by UAntwerp for all apple juices that were made available. A database is available on apples.

Different strategies were tested and evaluated on the ability to separate the seeds afterwards.

Advantages of using BioIL/NADES as extraction solvents were evaluated byUNIPI. Samples of apple polyphenols extracted by UNIPI using BioIL/NADES were also received by UAntwerp.

BioILs and NADES selected by UNIPI were prepared, and samples were sent to UCD for bioactivity investigation, to TalTech for biodegradability studies, and to Nottingham for enzyme compatibility tests. The prepared BioILs and NADES were then employed in the extraction of polyphenols from different pomaces. In particular, 4 different apple pomaces obtained from ILVO and two olive pomaces were employed. Experimental parameters for the extraction were investigated and optimized. Different extraction

efficacies were found among the selected BioILs and NADES. An HPLC method was developed for analysis of the extracted polyphenols; more than 30 different standards have been employed for their identification and quantification. 25 extracted samples in batches have been screened by UCD for their potential bioactivity. Four polyphenol natural extracts were received and one of these, exerted insulin secretory properties. Other samples showed potential tendency to scavenge free radicals with significant antioxidant properties suppressing the formation of radicals.

The valorisation of the fiber rich residue can have an application in beverages of Konings. The milling of the fibres and the evaluation in beverages are fulfilled.

ILVO tested 3 milling devices under different conditions.

The milled powders were added to juices in different concentrations. Physico-chemical analyses were performed to evaluate each product. HPH was indicated as a potential technology to implement to stabilize fiber enriched apple juices.

UAntwerp started introductory experiments on fibers in juices. Laser diffraction has been used as suitable analytical method. A multimodal distribution was found: medium size and high sizes. The latter could be due to agglomeration and flocculation. The method was optimized.

From the literature, an endo-cellulose was identified with a high tolerance for salt, a prerequisite if the enzyme is to function in presence of ionic liquids. Cel124, isolated from uncultured bacteria, has been shown to have endo-glucanase behaviour. The gene for the enzyme was synthesised. This gene was cloned into a DNA plasmid that allows the expression of the protein. Cellulases can be broadly separated into three categories: Cellulases that attack cellulose from the terminals of the biopolymer exoglucanase; Enzymes that breaks up glucose dimer units – cellobioses; Enzymes that break up cellulose randomly – endoglucanase.

For effective degradation of cellulose, a combination will be required. Effective digestion will require an endo-cellulase to break apart larger cellulose fragments, and an exoglucanase degrade the smaller fragments into glucose.

Groups in the consortium have identified the composition of fruit pomace. They have identified that pomace has a significant amount of the carbohydrate pectin in soft fruit pomace. The bacterial enzyme from Streptomyces Coelicolor, small laccase (sLac) has been select as a suitable enzyme as it is active across a broad range of pHs and temperatures. sLac has been shown to have activity on lignin in an industrial setting. It was showed that sLac was active for up to 24 hours at room temperature at pH 7.0. The activity of sLac in the presences of ionic liquids was tested. It was found that sLac is inhibited by most of the ionic liquids used in the project.

A detailed investigation of the biodegradation pathways and transformation products (TPs) was undertaken to select the greener NADES and BioILs.

These tests has been performed on NADES and BioILs: Biodegradability Closed Bottle Test of a series of choline chloride, DL-malic acid, L-proline and NADES using inoculum obtained from a wastewater treatment plant; CBT for samples and their individual constituents; Microbial Degradation using a consortium of different bacterial and fungal species; Tolerance against immobilized enzymes such as Amidase, Esterase, Protease. Majority of solvents studied demonstrated good biodegradation values (and are thus considered to be 'green' and 'safe' for the environment). High biodegradation rates of DES/ILs could be attributed to the components constituted by them.

Impact

The project led to the development of a series of techniques of different kind (like, but not limited to extraction, analitycal procedure, chemical and biological modifications, etc.) to process, analyze, asses environmental sustainability and use of fruit pomaces and other side-products of the fruit industry, with a focus on apple ones, with NADES and BioILs.

Project partners with very different competencies networked, including a continuous exchange of physical samples, and work together to achieve these results. Despite bureaucratic issues and pandemic caused significant delays and lack of synchroniciy, the project achieved a remarkable impact as it can be measured by publications, presentation at scientific and public events.

Here a list of publications on peer-reviewed scientific journals:

1. P. Morone, A. Koutinas, N. Gathergood, M. Arshadi, A Matharu Food waste: Challenges and opportunities for enhancing the emerging bio-economy J. Clean. Prod. 221, 10-16, 2019.
2. N. Almulhim, N.R. Moody, F. Paradisi Engineering novel S-glycosidase activity into extremo-adapted β-glucosidase by rational design Appl. Microbiol. Biotechnol. 104, 4407-4415, 2020.
3. E. Husanu, A. Mero, J. Gonzales Rivera, A. Mezzetta, J. Cabrera Ruiz, F. D'Andrea, C.S. Pomelli, L. Guazzelli Exploiting Deep Eutectic Solvents and Ionic Liquids for the Valorization of Chestnut Shell Waste, ACS Sustainable Chem. Eng., 8, 18386-18399, 2020.
4. J. Gonzales Rivera, E. Husanu, A. Mero, C. Ferrari, C. Duce, M.R. Tinè, F. D'Andrea, C.S. Pomelli, L. Guazzelli. Insights into microwave heating response and thermal decomposition behavior of deep eutectic solvents J. Mol. Liq. 300 112357, 2020.
5. J. Gonzales Rivera, A. Mero, E. Husanu, A. Mezzetta, C. Ferrari, F. D'Andrea, E. Bramanti, C.S. Pomelli, L. Guazzelli. Combining acid-based deep eutectic solvents and microwave irradiation for improved chestnut shell waste valorization Green Chemistry 23, 10101, 2021.
6. H.M. Bottu, A. Mero, E. Husanu, S. Tavernier, C.S. Pomelli, A. Dewaele, N. Bernaert, L. Guazzelli, L. Brennan, The ability of Deep Eutectic Solvent systems to extract bioactive compounds from apple pomace Food Chemistry 386, 132717, 2022.

Several oral and poster presentations online and in presence, have been given in national and international conferences and workshops.

The results have been presented also in events dedicated to the general public in several countries. Furthermore, in the project framework several master theses and a Ph.D. thesis has been developed.

Conclusion and Recommendations

The project brought together research groups from different countries with very different expertise and competencies. The coordination of such a heterogeneous network was not easy but it worth it. This includes a complex activity of fruit-derived samples exchange. This had improved project management competencies of the coordinator and of the partners.

The original project plan included limited activities about scale-up of the processing procedures. These have not been performed due to the non-scientific issues experimented throughout the project. Some of the developed procedures are very promising and a follow-up project about scale-up will be very important.

Last, but not least the coordinator would like to remember Prof. Cinzia Chiappe, beloved colleague and creator and first coordinator ofthe ImPrOVE project.

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10. SUSPUFA

CALL 2017

Sustainable production of health-promoting n-3 LC-PUFA using agro food industry by-products through microalgae

PROJECT TEAM

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Partners:

Anna Martello,Università degli Studi di Napoli"Federico II"

Dr. Antonio Luca Langellotti, Università degli Studi di Napoli"Federico II"

Summary

The rise in non-communicable diseases, immune diseases such as allergies in westernized countries links to changes in lifestyle and diet.

Fish-derived long chain polyunsaturated fatty acids (ω-3 LC-PUFA) are renowned for their positive health impact, which ranges from being essential in neuronal development (cognition, vision and behaviour) to impacting on immunological reactions. Regarding the latter, an 'inflammation-suppressive' effect appears the common denominator for the beneficial effects of ω-3 LC-PUFA. In this regard, ω-3 LC-PUFA have been shown to protect against chronic immune disorders such as allergy. In human, supplementation during early pregnancy and lactation has shown promising results regarding allergy prevention.

Fish oil is the most common natural source of LC-PUFA incorporated into food products using different technologies to avoid modifications in the sensorial quality and prevent oxidation. Global fish stocks are in danger and the most probable scenario is that productivity of 'forage fish' will decline quickly in the near future. Furthermore, marine fishes like salmon, sardine, tuna, anchovy, mackerel or hake, are sometimes contaminated with heavy metals and organic pollutants that could affect the human health.

For such reasons, the use of fish as source of LC-PUFA (without considering human allergies and vegetarianism) are sometimes questioned and marine microalgae have been proposed as alternative sources for LC-PUFA.

In this project, suitable food by-products and wastes have been selected to be used as fertilizer for microalgae growth. Analysis and processing of food by-products and wastes to resolve nutrients deficiency and improve nutrients uptake by microalgae. Ω-3-PUFA-effects on the development and progression of allergic reactions has been studied as a reflection of health-protective properties.

A deep study of food by-products and wastes (FBWs) from relevant agro food industries has been done, focusing on their application as ingredients for microalgae culture media formulation.

Chemical composition of specific FBWs, in terms of main important macronutrients for microalgae growth was assessed.

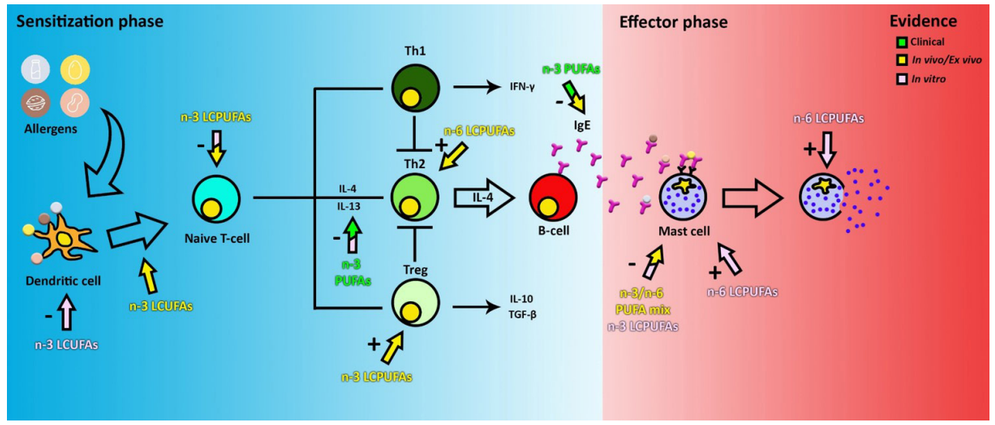
Products and wastes have been chemically and microbiologically analysed on the basis of their origin to ensure their quality and safety. All chemical analysis performed on microalgae were placed in a datasheet. The data regard the lipid content, fatty acid profiles (GC/MS), isotopic data, pigment profiles.

A database of suitable FBWs has been done. A guideline accompanying the database document has been written showing relevant information about nutrient content, methods for hydrolysis, logistic and traceability issues.

Microalgae strains were evaluated for their ability to grow and produce n-3 LC-PUFA on treated FBWs. Selected microalgae have been produced using the developed media by means of different technologies such as indoor and outdoor photo-bioreactors, and open ponds under greenhouse. At patented biofilm technology was applied for cultivation using FBWs as nutrient media.

The chosen microalgae strains have been produced at pilot scale using various technologies such as indoor photobioreactors, open ponds and biofilm technology, which turned out very promising, under greenhouse. cronutrients for microalgae growth was assessed.

A model based on co-culture of dendritic cells (DCs) and T-cells was developed to estimate allergy-mitigating potential of PUFAs. DHA suppressed the pro-allergic DC2 phenotype.



A vegan cheese was developed in which DHA was incorporated that will allow to easily achieve recommended daily allowances in humans.

In conclusion, microalgae appear as a viable and sustainable source of the nutritionally important ω-3 polyunsaturated fatty acids eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), and other fatty acids (FAs), as they do not require freshwater or arable land and have the ability for high fatty acid accumulation.

Results and Achievements

Selection and processing of food industry by-products and wastes to be used as nutrient source in microalgae cultivation.

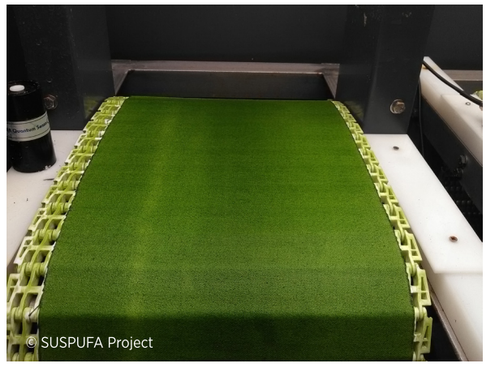
A study of food by-products and wastes (FBWs) from relevant agro-food industries has been done.

Sugarcane and beet-root molasses, corn steep liquor, mozzarella cheese whey, ricotta cheese whey, mozzarella stretching water, spent osmotic solutions from candied fruit industry, spent brewery yeast and olive oil mill wastewater, fruit pomaces and expired fruit juice were assessed. Enzymatic treatments and autolysis were performed on cheese whey (sequential lactose and whey protein hydrolysis) and spent brewery yeast, and thermochemical hydrolyses on sugar molasses and olive oil wastewaters to increase availability

of nutrients and to lower the effects of inhibitory compounds.

These food by-products and wastes selected have been chemically and microbiologically analysed to ensure their quality and safety. The presence of pathogens has been assessed. Cheese factory and brewery FBWs showed to be the most hazardous in terms of possible contaminations from pathogenic bacteria. Cold storage or drying of the product could be a possible solution for their use in the application of the project. Main safety concerns for the other FBWs were trace amounts of pesticide in spent osmotic solution from candied fruit industry and heavy metal in sugar molasses.

A database of suitable FBWs has been set up, with a guideline accompanying this database.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Cultivation of microalgae

Microalgae strains were evaluated for their ability to grow and produce n-3 LC-PUFA on treated FBWs. Selected microalgae have been produced by means of different technologies such as indoor and outdoor photo-bioreactors, and open ponds under greenhouse. A patented biofilm technology was applied for cultivation using FBWs as nutrient media.

The selection of microalgae strains has been done on the basis of lipid content and in particular of LC-PUFAs. Aurantiochytrium mangrovei and Pythium irregulare were selected for their high productivity of n3 LC-PUFA and ability to grow using FBWs in full heterotrophic conditions. Nannochloropsis oculata, Phaeodactylum tricornutum, Porphyridium cruentum, Tetraselmis suecica and Monodopsis subterranea were selected for their LC-PUFA content and potential to be grown in mixotrophic conditions.

Using this lab-scale devices, 10 out of 14 strains demonstrated their ability to form a biofilm. Tetraselmis suecica demonstrated the highest adhesion surface productivity leading to a biomass containing up to 45-50% of omega-3 PUFA i.e. ALA (18:3 n-3, 15-25%TFA, 10-20 mg/g DW) and EPA (20:5 n-5, 8-15%TFA, 3-8 mg/g DW).

The best results have been obtained both in terms of n3 LC-PUFA productivity and FBWs metabolization using the DHA-rich Traustochitrid A. mangrovei and the EPA-rich Oomicete P. irregulare.

Microalgae were grown on a biofilm fixed on a moving conveyor belt. Light access can be controlled accurately by modifying the speed of the conveyor and the conveyor folding according to the environmental conditions. Lethal temperature can be avoided by increasing the thermal inertia of the water volume in which the conveyor is immersed. Moreover, the biofilm can be easily harvested by in situ scrapping.

T. suecica was produced during nine (9) months without interruption achieving seasonal footprint productivities between 3 and 8 g/m2/day. Total omega-3 and EPA levels reached 40-50% of TFA and 8-15% respectively.

The analysis of A. mangrovei production, performed using the SuperPro Design software, showed that sustainable optimized process developed into the SUSPUFA project increased profitability of production with significant higher value of NPV and ROI respect to standard protocols.

After lipid extraction the residual defatted biomass showed promise as protein source for nutrition.

Pigments were very high in some of the tested biomasses. Most were collected into the lipid fraction where they can have a role to prevent oxidation.

For extraction, green food-grade solvents were chosen such as ethanol and 2-methyltetrahydrofuran (i.e. 2-MeTHF, EcoXtract®) and demonstrated to be highly efficient to extract the PUFA-rich lipids from T. suecica on dry biomass (extraction yield: 86% of total lipids; purity: 90% lipids).

In the downstream process, an algae meal containing up to 60-65% protein with essential amino acids such as methionine and lysine was obtained. A pond-to-gate Life Cycle Assessment (LCA) was carried out to analyse the environmental indicators from two microalgae-based products: biomass and protein-rich fraction (algae meal). Compared to soymeal and fishmeal, and with other algae meal from e.g. open raceways, showed that the algae meal has reduced environmental footprints.

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Chemical characterization of microalgae

The lipid content, fatty acid profile as well as isotopic analysis have been evaluated for produced microalgae (conventional and biofilm methods) to assess the best culture conditions and sustainable growth media designed.

With these methods, commercially available nutritional complements may be discriminated (fish oil vs algae/plants).

A new method for the determination of pigments was developed.

Bio-availability of n-3 LC-PUFA

Analysis of biological availability of PUFAs ex vivo in murine serum and membrane incorporation in erythrocytes has been performed.

Effects of microalgae n-3 LC-PUFAs supplementation on human immune response-inflammation and in cow's milk and hen's egg allergy development.

Primary monocytes from human blood buffy coats were differentiated into iDCs, and then into DC2 using a cytokine mix found in literature. The DC2 expressed all DC surface marker, plus significantly higher OX40L, an important DC2 marker. DC2-T-cell interaction, where T-cells would then be differentiated into Th2 cells, represented an in vitro allergy-like model. iDCs were incubated with various n-3 PUFAs. These iDCs were maturated into DC2s and surface markers were measured using FACS analysis. Both AA and, in a lesser extent, DHA, lowered the surface marker expression of CD83 and OX40L, indicating that they are able to suppress the DC2 phenotype. The same pattern was observed using ELISA.

Animal experiments. Different commercial algae oils have been selected based on their DHA content to perform the animal experiments, using a mouse model for OVA allergy. The data from this study are now being prepared for publication.

Product design

The formulation of vegan cheese models was designed to achieve a total composition of 30% total fat and 9% proteins. In addition, the total fat included 0.4% of DHA oil. This amount provides the recommended intake of 250 mg (European Food Safety Authority, 2010). Other ingredients were used in order to stabilize the oil-in-water emulsion.

The formulations produced a hard type of cheese analogues that did not show leakage of fat and were evaluated as the most suitable cheese type to be fortified with n-3 LC-PUFA.

The stability of the developed cheese analogue formulations was evaluated during 14 days of storage, in terms of textural and microscopical properties. The hardness and cohesiveness increased which indicates that the system did not weaken over time.

6 Different cheese models were made at 40, 60 and 80°C and at the end of the production process, pre-gelatinized starch or non-gelatinized starch was added. The textural properties showed the highest values for the cheese models made at 80°C compared to the cheese models made at lower temperatures.

The textural properties hardness, gumminess and chewiness remained stable for pre-gelatinized starch in cheese analogue compared to the non-gelatinized starch in cheese analogue.

For all three model systems, the differences in the rate of oxidation was related to the protein adsorption to the oil droplets and interactions in the continuous phase such that WPI had the most coverage and thus resulting in lower oxidation rate.

Communication and dissemination

Amongst others, to increase the visibility of the Project a dedicated internet site was built (www.suspufa.eu) and social media pages were created and continuously updated (Twitter, Facebook, LinkedIn; https://twitter.com/suspufa, https://www.facebook.com/suspufa/, https://www.linkedin.com/groups/8668388/).

Impact

The objective of the SUSPUFA project, is to develop an innovative process for sustainable production of high value n-3 long chain polyunsaturated fatty acids (n-3 LC-PUFA), using agro food industry by-products through microalgae cultivation and to evaluate the produced n-3 LC-PUFAs as fish oil replacement for incorporation in food formulations.

Scientific evidence points out that an appropriate intake of n-3 LC-PUFA, widely known as 'omega-3', exhibits protective effect on human health. It is recognized that regular consumption of marine n-3 LC-PUFA, eicosapentaenoic acid (20:5 n-3; EPA) and docosahexaenoic acid (22:6 n-3; DHA) reduces risk of chronic and inflammatory diseases.

The use of fish and fish oil, as main sources of n-3 LC-PUFA is increasingly becoming under pressure due to serious public health and ecological concerns. Fish oil quality is dependent on fish diet, it may contain harmful contamination and from sustainability perspective there is a growing issue related to the resilience of current n-3 LC-PUFA sources.

The main idea of this project is the production of n-3 LC-PUFA trough an algae oil production chain, which implies a sustainable approach related to the use of food waste and exploitation of marine n-3 LC-PUFA sources. The development of an innovative, cost effective and sustainable process for the production of n-3 LC-PUFA will increase the resilience of the current supply chain of n-3 LC-PUFA and lower the final cost for these, presently expensive, ingredients, consequently allowing the wider use of n-3 LC-PUFA in food consumer goods. Healthpromoting algae n-3 LC-PUFA produced in a sustainable way will be incorporated in formulations in order to create high added values food products intended to improve the health status of the consumer.

Conclusion and Recommendations

Fish oil is the most common natural source of LC-PUFA incorporated into food products using different technologies to avoid modifications in the sensorial quality and prevent oxidation. Global fish stocks are in danger and the most probable scenario is that productivity of 'forage fish' will decline quickly in the near future. Furthermore, marine fishes like salmon, sardine, tuna, anchovy, mackerel or hake, are sometimes contaminated with heavy metals and organic pollutants that could affect the human health.

For such reasons, the use of fish as source of LC-PUFA (without considering human allergies and vegetarianism) are sometimes questioned and marine microalgae have been proposed as alternative sources for LC-PUFA.

In this project, suitable food by-products and wastes have been selected and were found to be usable as fertilizer for microalgae growth. Analysis and processing of food by-products and wastes helped to resolve nutrients deficiency and improve nutrients uptake by microalgae.

Chemical composition of specific FBWs, in terms of main important macronutrients for microalgae growth was assessed. The food by-products and wastes have been chemically and microbiologically analysed on the basis of their origin to ensure their quality and safety. All chemical analysis performed on microalgae were placed in a datasheet. The data regard the lipid content, fatty acid profiles (GC/MS), isotopic data, pigment profiles.

A database of suitable FBWs has been built, with an accompanying guideline showing relevant information about nutrient content, methods for hydrolysis, logistic and traceability issues.

Microalgae strains could to grow and produce n-3 LC-PUFA on treated FBWs. Selected microalgae have been produced using the developed media by means of different technologies such as indoor and outdoor photo-bioreactors, and open ponds under greenhouse. At patented biofilm technology was applied for cultivation using FBWs as nutrient media.

The chosen microalgae strains could be produced at pilot scale using various technologies such as indoor photobioreactors, open ponds and biofilm technology, the latter turning out very promising, under greenhouse conditions.

Advanced analytical methods were developed that could be used to discriminate n-3-PUFAs from various sources such as plan, fish or algae.

n-3-PUFA-effects on the development and progression of allergic reactions has been studied as a reflection of health-protective properties. A model based on co-culture of dendritic cells (DCs) and T-cells was developed to estimate allergy-mitigating potential of PUFAs. DHA suppressed the pro-allergic DC2 phenotype, confirming similar effectiveness as n-3-PUFAs originating from fish such as tuna. Analysis of data from a murine validation experiment are in progress.

A vegan cheese was developed in which DHA was incorporated that will allow to achieve recommended daily allowances in humans.

In conclusion, microalgae appear as a viable and sustainable source of the nutritionally important n-3 polyunsaturated fatty acids eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), and other fatty acids (FAs), as they do not require freshwater or arable land and have the ability for high fatty acid accumulation. The PUFAs derived from such micro algae show promising biological properties in terms of mitigating allergic reactions in a mouse model.

The development of the vegan cheese-analogue suggests that it is within reach to develop food products that facilitate the intake of RDAs of these health-promoting and sustainably produced fatty acids.

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11. SUSCHOICE

CALL 2017

Towards Sustainable Food and Drink Choices among European Young Adults: Drivers, Barriers and Strategical Implications

PROJECT TEAM

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Prof. Gabriel Popescu / The Bucharest University of Economic Studies (Romania)

Summary

SUSCHOICE project started from the consideration that many young consumers in Europe express the desire to buy and eat sustainable food. However, although the share of sustainable food and drinks in the total consumption in Europe is growing in recent years, it remains low for multiple reasons. Indeed, there is a gap between attitude and behaviour, especially in the young generations, which individual consumer characteristics can only partially explain.

To address this issue, it urges to consider a wider range of determinants of sustainable food and drink choices among young consumers, since the influence of macro and structural factors is not yet fully understood by scholars and practitioners, especially from a cross-country perspective.

The SUSCHOICE project aimed to shed light on this field of research by pursuing a two-fold purpose:

- to identify the effects of different factors (macro-structural, socio-cultural and individual) influencing sustainable food and drink choices in different European countries;
- to evaluate the public policy and marketing strategies for promoting sustainable food and drink consumption.

SUSCHOICE project focused on young adults in four European countries (Germany, Italy, Norway and Romania) representing different cultural and geographical contexts, and food and drink styles.

The three-year project activities covered four research steps: (1) the analysis of the macro and structural factors, (2) the investigation of individual food and drink choices, (3) the study of future scenarios and the evaluation of future trends, and (4) the identification and testing of strategies promoting sustainable eating and drinking behaviours.

The methodological approach combined qualitative and quantitative tools such as policy discourse and media narrative analysis, in-depth interviews with different stakeholders (e.g., experts, policymakers, agri-food businesses, retailers), focus groups, surveys and experiments with consumers.

The project resulted in creating a new theoretical framework reflecting the complexity of sustainable consumer choices and providing new knowledge on sustainable food consumption in Europe. This can contribute to more rapidly reaching the goal of turning Europe into a greener and more sustainable economy. In this regard, promoting sustainable food consumption choices among young people can play a very relevant role from a long-term perspective.

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SUSCHOICE employed a triangulation approach involving a large set of stakeholders in the four investigated countries: large samples of consumers (more than 8,000 young adults in total), national policy makers, non-governmental organizations, consumers associations, agri-food businesses and their associations, retailers, researchers, business consultants, etc.), which secured high credibility of the results. Moreover, the project adopted a multi-product analysis of preferences that combined four different food and drink products (fruits, beverages, milk products) in the choice experiments and included options characterized by sustainability-related attributes together with product-specific characteristics and multiple levels of prices.

Multidisciplinary tools and different theoretical perspectives (combining marketing, consumer analysis, innovation, entrepreneurship, food economics and policy) were applied in an integrated manner producing new insights into sustainable food and drink consumption trends among European young people and the macro-structural and socio-cultural contexts of choice, together with the opinions of private and public stakeholders.

Results and Achievements

SUSCHOICE results proposed a new integrated framework of sustainable food and drink consumption considering a wide range of individual, socio-cultural and macro-structural factors, and involving multiple stakeholders operating in the sustainable food systems.

The project focused on European young adults (in the age class of 20-34 years old) in a cross-country (Germany, Italy, Norway and Romania) and multi-product perspective (fruits, beverages and milk products).

The research activities covered four investigation steps. In the first step, three types of investigations have been performed: the regulatory document analysis based on the critical frame analysis method (forty laws and regulations on sustainable food in the four countries involved); the analysis of

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the main national newspapers' narrative on food sustainability (about 2,000 documents in a time span of five years); the analysis of stakeholders' opinion (forty interviews in the four countries).

One of the research novelties of this step was to have compared national policy approaches and stakeholders' opinions on sustainable food system development, applying a cross-country analysis.

The research findings proposed that the main effort towards sustainability in the food systems should focus on an interdisciplinary and transectorial policy integration. This should be combined with increasing stakeholder collaborations across all sectors of the economy. Another original result of this step was to provide a comprehensive analysis of sustainable food discourse in the major national newspapers from a longitudinal and comparative perspective. The research identified the dimensions of sustainability covered in the four countries, and it added understanding of how the sustainable food concept has developed in Europe over time, and how to enhance consumer awareness about this issue. Indeed, national media discourse captured through newspaper articles in the four countries revealed that food sustainability was mainly represented through three narratives: the promotion of new diets, food patterns and healthy routines; information about business innovation and investment in sustainable production; and consumer involvement in public events promoting sustainable food.

In the second step of the research activity, the analysis was conducted by young consumers. Focus groups, in-depth interviews and online large surveys have been performed. Focus groups contributed to highlighting that, when it comes to thinking about sustainable food, young people mainly focused their attention on eco-friendly and plastic-free packaging, the role of food certification and ecolabels, and the need of food education. They revealed scepticism in business greenwashing and high sensitiveness to price. The attitude towards the protection of their health and wellbeing plays a relevant role in motivating the option of sustainable food.

During the in-depth interviews with young people in the four investigated countries, the q-methodology approach offered relevant insights into the preferred actions for food sustainability. Different opinions emerged about the most efficient ways to implement sustainable options in food purchasing and consumption. They are based on the different attention to the socio-economic issues, the educational tools and the managerial actions to be implemented in the food supply chain.

In this step, a large online survey has been also performed. About 5,000 young people from Germany, Italy, Norway and Romania took part in experiments exploring preferences and perceptions of sustainable food and drinks. Several choice scenarios have been simulated including four products (apple, cottage cheese, apple juice and beer) characterized by multiple attributes of sustainability. Validated scales measuring behavioural attitudes, motivations and involvement have been included in the survey to explain consumers' stated choices. Results highlighted that sustainable choices were mainly driven by motivations related to health, socio-cultural values and perceived personal pro-environment behaviour. During the experiments, young consumers tended to prefer products with domestic origin and organic certification. Moreover, they demonstrated interest in social certification, carbon footprint labels, and eco-friendly packaging, although to a lesser extent than the former attributes.

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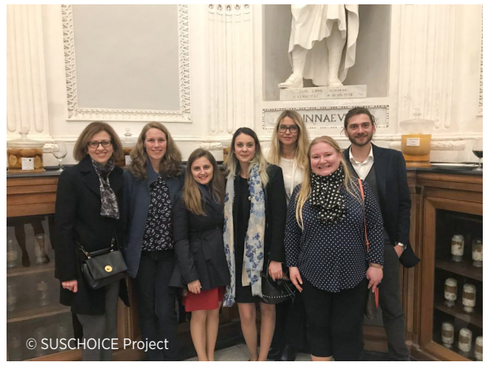
In the third step of the SUSCHOICE project, the research identified food sustainability trends and future scenarios based on forty in-depth interviews with young consumers. Four scenarios have been categorized representing alternative socio-institutional contexts around sustainable food consumption might develop in the future: one scenario represented the status quo; one was very positive, having consumers, governments and firms working together on a more sustainable future; and two were in between – one with governments and firms taking more action, and one with the consumers taking more action. Findings offered a comprehensive understanding of several key factors influencing sustainable food and beverage consumption among today's young adult generation and their next generation. The understanding of sustainability does not differ greatly across the four countries. Low environmental impact and recyclable packaging were the top two areas named when consumers were asked about their understanding of sustainability. Drivers and barriers were also often observed to be similar, with the main barriers being the price, habits and time restrictions. When asked about the most realistic and desirable scenarios, consumers in Italy indicated that they believe in the power of the consumer, while Norway and Germany indicated a less optimistic view on consumer power and Romania less again. Especially Romanian consumers included a high level of management by governments and firms. Consumers in all four countries saw the most positive scenario, governments, firms and consumers working hand in hand on a more sustainable future, as the most desirable scenario. Education, information and media were named as the top measures to achieve a sustainable future.

In the four and final step of the SUSCHOICE research, agri-food businesses and young consumers have been involved in different experiments and strategy evaluations. Forty interviews have been conducted with agri-food business managers or entrepreneurs in Germany, Italy, Norway and Romania to discuss with them possible future strategies promoting sustainable food options in the production and consumption systems, as they resulted from the previous steps of the project. Many stakeholders expressed a need for a clearer definition from the national authorities of what constitutes food sustainability. They considered most of the strategies presented to them as efficient and useful; however, they requested clearer guidelines and rules from the national authorities, preferably in harmony and agreement with the international ones. After that, young consumers have been involved through online q-sorts. Consumers evaluated various policies and strategies that can be assumed as able to lead consumers toward more sustainable food choices. Affordable prices, economic support to sustainable producers, clear labelling and transparent information were chosen as the most desirable actions in all investigated countries.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Impact

The impact of the project has been developed on different levels.

In the communities of business stakeholders and consumers, the project results were presented and discussed during several stakeholder events in Germany, Italy, Norway and Romania. The various stakeholders (policy makers, food industry and retailers) were contacted and involved in the project, and they have been also engaged in several dissemination activities. For example, in Italy, SUSCHOICE results have been shared and discussed with a consumer association, the managers of a bio-district, and during a public round table with food producers. In particular, the project results were considered valuable for a consumers' association to better inform their associate consumers and to elaborate their policy proposal in the field of food sustainability.


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In the research community, the results of the project were disseminated in research articles and book chapters. They were also presented during various academic conferences. The final workshop of the project has been shared with the Italian food economists during their annual conference.

The integrated framework of sustainable food and drink consumption including a wide range of individual, socio-cultural and macro-structural factors represents an important research contribution to the field, which can foster further research on sustainable consumption. The large and valuable amount of information gathered from stakeholders and (young) consumers contributed to offering new knowledge on: the social and institutional contexts for a sustainable food consumption choice; mass media narratives on food sustainability; consumers attitudes toward sustainable food; consumers preferences towards sustainable food attributes; young consumers' opinions on policies for more sustainable food consumption (with comparison before and after covid-19); young consumers' opinions about future scenarios and trends toward food sustainability; stakeholders' opinions about food sustainability (before and after covid-19); differences in sustainable food choices between different age cohorts (Millennials vs Generation X and Baby Boomer consumers).

In the attempt of profiling young consumers' behaviour in sustainable eating and drinking habits, four different approaches emerged: health-conscious consumers seeking physical fitness and good taste, who are particularly sensitive to the health characteristics of food; price-sensitive consumers driven by food price affordability; sustainability- and environment-sensitive consumers who focus on environmental protection; sustainability- and health-conscious consumers who adopt an integral sustainable lifestyle.

Conclusion and Recommendations

The SUSCHOICE findings highlighted the importance of four action areas for promoting sustainable food and drink choices for young European consumers: (1) improve transparency and quantifiability of information about food and drinks' sustainable characteristics; (2) encourage social sustainability in a supply chain perspective; (3) support education initiatives combing practical experiences and entertainment; (4) foster innovation among producers and consumers through intersectoral collaborations and sustainable lifestyle promotion.

Discussions with stakeholders highlighted the recommendation that more active involvement of consumers in the food system networks should be ensured. They also underscored the need of developing information-sharing networks among producers and consumers. A shared recommendation among stakeholders of the four involved countries is the implementation of public-private partnerships and collaborations between actors along the food supply chains.

The analysis of consumers' attitudes and opinions highlighted that consumers' involvement with sustainable food was determined by different drivers according to their food motives and values. Sustainable options tended to be selected when health considerations and the promotion of socio-cultural values are relevant factors to consumers during their product evaluation. The perceived personal effectiveness of environmental protection measures is a further relevant attitude in promoting sustainable food choices, revealing once again the importance of transparent information and educational tools to young people.

The factors identified as particularly relevant for the engagement of young consumers were the altruistic motivations, the environmental considerations, the intergenerational concerns, and curiosity. Conversely, established habits, time restrictions and scepticism towards green marketing were the main barriers to sustainable behaviours. These latter considerations envisage the room of speeding up the transition towards more sustainable food options as these routine obstacles and misperceptions can be overcome and, at the same time, positive pro-social and pro-environment motivations are promoted.

Education, information and media were named as the top measure to achieve a sustainable future by all four countries, second were fiscal measures, restrictions and fees, except for Norway, where this came third and second was packaging solutions.

There were some differences in young consumers' options about some of the most desirable actions to stimulate food sustainability between the four investigated countries. Italian young consumers asked for more education and public guidelines. German consumers preferred strategies aimed at fair working conditions and food waste management. Norwegians focused on diets, new foods and the relevance of role models, while Romanians favoured policies promoting local products and small family businesses.

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12. PLATEFORMS

CALL 2017

Sustainable Food Platforms: Enabling sustainable food practices through socio-technical innovation

PROJECT TEAM

Coordinator:

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Partners:

Prof Mary McCarthy / University College Cork, Ireland

Prof Christian Fuentes / University of Borås, Sweden.

Prof Francesca Forno / University of Trento, Italy

Suse Brettin & Dr Meike Brückner / Humbold-Universität Berlin, Germany

Summary

The PLATEFORMS project was organized in 4 work packages. The primary objective of WP1 was to map and classify digital enabled platforms focused on sustainable food provisioning, to understand their main features and innovative practices as well as their key technical and organizational characteristics. We conducted a systematic mapping of the websites selling food online in the five countries under investigation. For each platform included in the map, we have recorded a list of information such as name, years of activity, number of producers and consumers involved, geographical area covered, description of vision and mission, approaches to sustainable diets and innovative food provisioning practices. The mapping provided important evidence, as it revealed that along with websites owned by traditional food suppliers (e.g. traditional retail shops), there were several new online food provisioning services specialized in the selling of local and regional food.

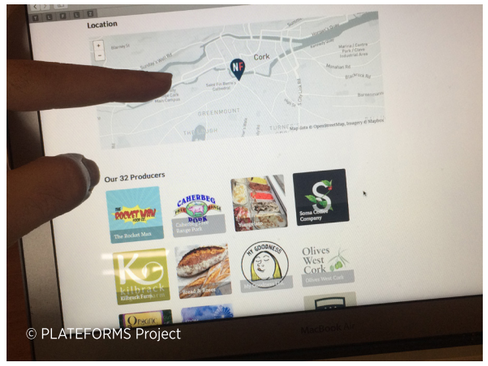
WP2's objective was to produce in-depth knowledge regarding how food provisioning platforms (physical/digital and business/consumer driven) enable and drive households' sustainable food consumption practices. To accomplish this contextualized understanding and explore cross-cultural differences, we studied in-depth the food practices– i.e., provisioning, cooking, eating and disposing of food – of more than 200 households across five countries. We used multiple qualitative methods, including ethnographic interviews, photo-food diaries, kitchen tours, and digital walkthroughs. The focus was on exploring how different innovative platforms shaped the household's food practices and the implications on sustainable food consumption.

In WP3, we explore consumers' food practices, purchase behavior, the effect of the covid-19 pandemic on the platforms' customer base, and preferences for the business model of online food platforms. We conduct surveys in cooperation with online food platforms in Italy and Germany and with representative samples in Ireland and Norway. We find that the covid-19 pandemic has extended but not significantly changed the customer base of many online food platforms. We find few differences in food practices and purchases behavior between early adopters and the new covid-19 customers of online food platforms. Most customers expect to continue using online food platforms at a similar level after the pandemic. Using a choice experiment, we find that convenience and product origin are essential for segmentation. A large segment prioritizes local, seasonal, and high-quality products, which is the core of many of the platforms we have studied. However, if the platforms want to reach out to most people, easy ordering and home delivery will be critical success factors.

WP4 consisted of a series of communication and dissemination activities. Workshops were hosted in each partner country to 1) engage interactively with supply chain stakeholders, policymakers, and researchers of sustainability and 2) unpick mechanisms to maximize the impact of the findings. Press releases, newspaper articles and radio interviews offered discussion points with the public. Participation in citizen events afforded opportunities to showcase how practices in the home can support sustainability and stimulate dialogue. A series of infographics, short videos and summary reports offered ongoing access to information for interested stakeholders via the overall project (https://plateforms.oslomet.no/) and national project websites. A two-part podcast "Tales from the field" brought together the experiences and insights from the work undertaken across the five countries. In addition, many academic outputs have been and continue to be published, including peer-reviewed articles and conference presentations. The research outputs formed a part of Sustainable Production and Consumption (2020) special issue. An anthology with nine chapters with project findings will be published by Palgrave. The results have been integrated into the teaching materials for undergraduate, postgraduate, and executive education programmes.

Results and Achievements

With most European consumers now having internet access and experience in buying products and services online, the number of online food provisioning services has increased in recent years. Eurostat data shows that in 2009, 5 per cent of consumers had bought food online during the past 12 months, in 2018, 15 per cent reported the same. In food retail, digitalization is now enabling new platforms for food provisioning that promote novel and more sustainable ways of buying, storing, preparing, and cooking food. During the pandemic, we saw increased use of online shopping. Food provisioning platforms received unprecedented attention in the context of the Covid-19 pandemic,



because they fit well with the lockdown and social isolation policy by delivering food straight to people's doors.

Despite the growing range and diffusion of physical and digital food provisioning alternatives, very little was known about their real impact on consumption practices when the project began. Grounded in empirical research conducted in five European countries – Norway, Italy, Germany, Ireland and Sweden – the PLATEFORM project explored how socio-technical innovations in food provisioning foster new and more sustainable forms of food consumption in everyday life and investigated if and how food platforms can drive and facilitate sustainable food practices in households. Thus, this project has explored under what conditions online platforms for food provisioning, meal box schemes, and online grocery shopping could change food consumption practices and whether these changes may contribute to more sustainable food consumption. We found that digital innovations help to structure and organize food practices. In some cases they contributed to more gender-equitable distribution of work. In others, they functioned as a door opener to more sustainable value chains in terms of regionality and seasonality. Online food provisioning services can allow consumers to pursue various sustainability strategies, such as eating more vegetables, buying local food or reducing waste, thereby changing household food consumption in a more sustainable direction. But, in their current form, they are not fulfilling their potential as sustainable change agents.

Based on our findings, we make the following overall recommendations for businesses and policymakers wanting to contribute to achieving the sustainability potential of digital food services:

Co-design to align scripts with needs. The intended use of digital technology for food provisioning does not necessarily correlate with how it is used by consumers at home, who are in many cases and for several reasons, circumventing the intended script. Consumers are far from passive agents; they operate and adjust digital technologies according to their social world. Hence, future innovations should be co-designed with consumers to align scripts more closely with their needs.

Focus on convenience. Sustainability may not always be the first concern for the users of these services; however, more sustainable consumption patterns can be achieved through the desire for convenient and efficient grocery shopping and providing a proper meal for the family. Food services should thus develop new scripts, which make it convenient to engage in sustainable food practices. Such scripts could for instance be related to navigation, shopping lists, delivery frequencies, and labelling.

Acknowledge the interrelatedness of consumer practices and focus on context. It is important not to focus on single practices (i.e., acquisition) but to include the entire context in which they exist (everyday life) when developing services and policy measures to reduce the environmental impact of food consumption.

Scaling up online grocery stores is the lowest hanging fruit. We argue that in a short-term perspective, there is greater potential in upscaling online food services that mimic some of the practices of the offline version of them than there is for services requiring more substantial changes within established food practices.

The above recommendations also serve as input to a future research agenda. Future research should further explore how the scripts embedded within digital food services can be developed to contribute to more sustainable food consumption efficiently.

Impact

Societal impact. The project has promoted sustainable practices through direct involvement with households, dissemination and contact with local stakeholders. At the household level, we did this by recommending a combination of practice modifications, substitutions, and new household practices. Our results serve as recommendations for digital platforms owners to organize their sales effort in a more sustainable direction. Our findings will enable sustainable food consumption through food provisioning platforms, and it will be possible to affect consumer practices and choices on a larger scale.

Field of research

The most important contribution from the project to the field of research of sustainable consumption has been to develop theory and methodologies to study social practices on digital platforms. In particular, we will emphasize development on theory of practice methods in terms of "kitchen-studies" to map peoples' behavior. Furthermore, the knowledge base generated by the project will serve as an important contribution to monitor both consumption and public policy development related to a sustainable food system. The project has also created a network of stakeholders within food provisioning and research, by facilitating workshops and seminars, enabling interdisciplinary discussions and exchanges of experiences, knowledge and strategies regarding the promotion of sustainable food consumption.

Dissemination and exploitation of results

The future exploitation of the results from the project will take two directions. From an academic point of view, the project has served as an input to a future collaboration of research application at Nordic level between SIFO and University of Gothenburg/University of Borås. Between those partners, an informal collaboration on research calls has aroused. SIFO and University of Trento have - due to the Plateforms project, agreed on forming a long-term exchange program of researchers and master students. From stakeholders point of view, we have approached online platforms as potential partner into future application for Research Council of Norway research calls. Findings emerging from PLATEFORM have also informed the Nutrire Trento #phase2 project, an initiative organized by the Trento Food Policy Council to help small-scale producers better coordinate their efforts to reach local consumers during the lockdown. These findings have also contributed to SuHeGuide, a FIRM IRL funded research project that seeks to address knowledge gaps required for developing, implementing and supporting sustainable healthy eating guidelines and bringing forward information critical to the food industry in responding to a shift in sustainable eating practices.

Conclusion and Recommendations

The food provisioning services in our study market themselves as sustainable alternatives with the potential to reduce transport emissions, reduce food waste through better portioning and planning, increase the use of organic products and vegetarian meals, and provide information about sustainable choices on their websites and apps. Both box schemes and online grocery store services can be seen to provide both infrastructure and technology that could, and do for some influence food practices to become more sustainable, their potential as sustainable change agents is currently not fully realized. However, by seizing the listed opportunities, we could see them move closer to realization of such a potential

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ONGOING PROJECTS WITHIN THE JOINT CALL OF SUSFOOD & CORE ORGANIC-2019

There are 12 projects funded in the joint call of SUSFOOD2 & Core Organic. Detailed information about the projects listed below is provided in this section.

Nr	Acronym	Project Title
1	FOODLEVERS	Leverage points for organic and sustainable food systems
2	FERBLEND	Fermentation-induced valorization of side stream blends from oilseed and dairy industry
3	Bio4Food	High quality and nutrient rich food through crop waste-derived biostimulant and biopesticide
4	ALL-IN	ALfalfa for sustainable Livestock farming systems: Improve alfalfa -rhizobia symbiosis and New feeding strategy based on ecological leftovers
5	SysOrg	Organic agro- food systems as models for sustainable food systems in Europe and Northern Africa
6	Poultrynsect	The use of live insect larvae to improve sustainability and animal welfare of organic chickens production
7	PROVIDE	PRotein and biOmolecules sources for nutritional security and biodiVersity of bakery products in a cIrcular fooD system
8	FOOdIVERSE	Diversifying sustainable and organic food systems
9	SPiwi	Sustainable production of innovative sparkling wine
10	MILDSUSFRUIT	Innovative Mild Processing Tailored to Ensure Sustainable and High Quality Organic Fruit Products
11	HO-FOOD	Innovative High pressure process to increase the preservation of ready-to-eat Organic FOOD
12	MI-WINE	Mild Innovative Treatment for Wine Stabilisation

1. FOODLEVERS

Leverage points for organic and sustainable food systems

PROJECT TEAM

Coordinator:

Valerie Holzner and Prof. Dr. Markus Hassler-

Philipps-University of Marburg - Germany

Partners:

The Royal Agricultural University, (UK)

Institute of Research on Terrestrial Ecosystems, (IT)

Institute of Soil Science and Plant Cultivation - State Research Institute, (PL)

University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, (RO)

European Forest Institute, (FI)

The Progressive Farming Trust Organic Research Centre, (UK)

Flanders Research Institute for Agriculture, Fisheries and Food, (BE)

Introduction

Despite the recent uptake of innovative production systems, food systems continue to move on unsustainable trajectories. This can be explained by many sustainability interventions addressing solely more obvious but less powerful areas of intervention rather than engaging with the root causes of unsustainability. Instead, FOODLEVERS focuses on identifying those leverage points at which interventions promise far more potential to further develop and scale-up existing innovative organic and sustainable food systems (FSs). It aims to promote higher resource-efficiency, highlight inefficiencies, specify the reasons for decision-making processes that led to the current configuration of FSs, and thus identify configurations that “work” and may be scaled up.

What: identify “deep” leverage points in organic and sustainable food systems

Why: contrary to the common practice of sustainability interventions FOODLEVERS addresses the key problems underlying unsustainability instead of focusing on weak leverage points

Where: Belgium, Finland, Germany, Italy, Poland, Romania, United Kingdom

Background

FOODLEVERS is grounded on the premise that attaining sustainable food production and consumption will require transition from the current linear FSs, to more circular systems that also re-connect producers and consumers. Such sustainability transitions are complex processes. In addition, many sustainability interventions focus on “highly tangible, but essentially weak, leverage points” (Abson et al. 2017, 30), thus they do not address key problems. Based on the framework

of leverage points for sustainability interventions (Meadows 1999), Abson et al. (2017) propose a research agenda based on three realms of "deep leverage" to address in sustainability transitions, such as those required to transition towards resource-efficient, circular and zero-waste food systems:

- "re-connect" people to nature to encourage sustainable behaviours
- "re-structure" institutions and consider how institutional dynamics can create an enabling environment for sustainability
- "re-think" how knowledge is created and used, shared and validated


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Main project activities

To investigate potential leverage points in FSs, FOODLEVERS applies a multi-disciplinary systems and multi-actor approach to consider all dimensions and actors of food systems (FSs) as well as their interlinkages, synergies and trade-offs, rather than treating each unit of FSs separately. Therefore, this project analyses different case studies of organic and sustainable FSs in different geographical (rural, urban) and institutional (e.g. community supported agriculture) contexts throughout Europe and identifies best practice processes from multiple perspectives of resource efficiency: environment, economy, social and governance.

This holistic sustainability assessment of innovative examples of FSs consists of measuring their environmental impacts, resource efficiency and other sustainability aspects from farm to fork e.g. by "cradle-to-grave" life cycle analysis considering all steps from mining raw materials to waste-disposal. Additionally, it takes the role of all actors in the FSs into account by analysing their value chains from a socioeconomic perspective and assessing consumer behaviour and food choices. Based on the resulting identification of critical points, FOODLEVERS will then build scenarios and models (agent-based modelling, stakeholder decision modelling, qualitative scenario modelling) to reveal potential levers for sustainability and discuss future scenarios by drawing on the expertise and experience of FS actors.

Expected results

As a result, the project will identify critical points in the innovative organic FSs studied including barriers, levers and points for intervention. The modelling of scenarios will allow to understand the potential of micro-level changes to achieve system-level change and transition towards sustainable and resilient FSs. Finally, "deep" leverage points will be formulated to re-connect, re-structure and re-think FSs.

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2. FERBLEND

JOINT CALL 2019

Fermentation-induced valorization of side stream blends from oilseed and dairy industry

PROJECT TEAM

Coordinator:

Harald Rohm - Technische Universität Dresden - Germany

Partners:

Università degli Studi di Milano, (IT)

Aarhus University, (DK)

Wroclaw University of Environmental and Life Sciences, (PL)

Universitat Politécnica de Valéncia, (SP)

Istanbul S. Zaim University, (TR)

Introduction

Sustainability in food supply chain is an up-to-date subject that covers, among others, the optimization of energy flow and the reduction of emissions, but also a complete-as-possible utilization of production side streams to reduce food losses as far as possible.

The project FERBLEND aims at exploring innovative solutions for the exploitation of cheese whey and press cakes from seed oil processing through targeted fermentation. The purpose of this joint research project is to explore solutions for creating liquid, semi-solid or solid platform products that may be used as ingredients in beverages, spreads or snack products. The main motivation of the consortium with partners from Denmark, Germany, Italy and Poland, and additional contributors from Spain and Türkiye is to substantially increase the knowledge concerning processing and fermentation of blends of oilseed press cakes and whey, resulting in tailored foods.

Background

Food production chain sustainability which, among others, covers the reduction of losses and the exploration of innovative ways to increase resource efficiency, is of increasing importance. Especially small and medium-sized organic seed oil producers and dairy companies are challenged by adequate handling and downstream processing of their side streams. By combining two side streams, circularity of the processes will be strengthened, and the strategies developed in this project can be exploited by different actors in the food supply chain. The ambition of the project consortium is to develop a platform of innovative food matrices from dairy and oilseed processing side streams of organic origin to be used as is, or as semi-finished ingredients in target foods. The obtained platform products add value to unused materials from organic production and provide new ingredients for novel innovative food products. Fermentation is conceived as a strategic and sustainable process to improve the sensory and nutritional aspects

Main project activities

This project aims at applying technologies for the development of new platform products by bringing

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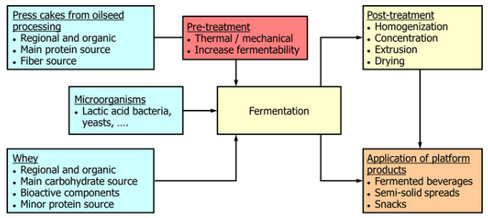

together research and SMEs that provide samples and support for understanding the economic impact and infrastructure development. FERBLEND focuses on the combined valorisation of press cakes from oilseed processing and organic cheese whey. Sunflower is used as a prominent example as it is the oilseed with the second highest production volume in the European Union and gives a press cake that is generally considered as palatable. Processing steps developed for sunflower press cake will serve as the starting point for a transfer to press cakes from, e.g., pumpkin seed or flaxseed.


© FERBLEND Project

Photo 1: Press cakes made from dehulled, hulled and partially dehulled sunflower seeds (from left to right).

The innovative approach of FERBLEND is to combine the mentioned side streams which themselves show only limited benefits for human nutrition. By means of fermentation we intend to create platform products with enhanced techno-functionality and nutritional value for being used as such, or as semi-finished ingredients for other foods. The project objectives will be reached in four work packages for an in-depth analysis of the pre-treatment of side streams (WP1), the fermentation of blends of press cakes and whey (WP2), physical and chemical analysis of the fermented blends (WP3) and the further application of fermented platform products in different model foods (WP4).

Expected results

We expect a substantial increase of knowledge concerning the processing and fermentation of blends of oilseed press cakes and whey resulting in tailored food products.

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3. Bio4Food

JOINT CALL 2019

High quality and nutrient rich food through crop waste-derived biostimulant and biopesticide

PROJECT TEAM

Coordinator:

Danny Geelen - Ghent University/Fac of Bioscience Engineering/Horticell lab - Belgium

Partners:

Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria, (CREA)(IT);

Abdelmalek Essaadi University, Faculty of Sciences and Techniques of Tangier (FSTT) (MO);

CICERO Center for International Climate Research, (NO);

Institute for Food and Environmental Research, (ILU) (DE);

Ajinomoto Omnichem, (BE)

Introduction

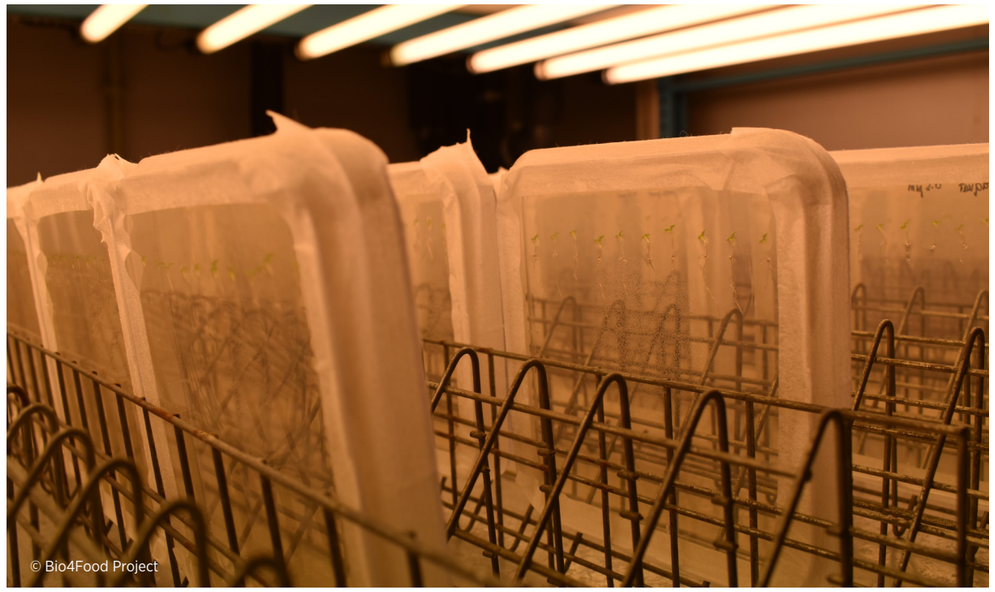
It is generally accepted that the wide-scale use of persistent synthetic pesticides in agriculture is a major risk to biodiversity and the environment. In addition, the public view of pesticides as problematic and seeks pesticide-free products. Addressing these concerns poses an important challenge for farmers to find a sustainable balance between "environmentally-friendly" and "profitable" crop production.

To match the concerns of the farmers and consumers, we need to create innovative solutions to secure crop yield, to minimise food and crop wastes and to produce vegetables and fruits with health-promoting properties.

The Bio4Food project addresses these three problems following a strategy of crop waste valorisation. We are proposing to take advantage of the presence of secondary metabolites, including natural defence molecules in crop wastes generated at the farm and at the food-processing factory and transform these into new types of biostimulants and biopesticides. Biostimulants and biopesticides are eco-friendly products that have the capacity to improve plant health, to enhance tolerance to abiotic stresses (climate change), and to promote crop yield and crop quality (i.e., presence of health beneficial minerals)

Background

Numerous studies show that a significant amount of the synthetic fertilizers and pesticides used on farmland during current agricultural practices, have considerable negative effects on the environment and human well-being. These generally accepted facts have raised public concern and have motivated researchers, farmers, and consumers to get actively involved into seeking for innovative alternatives. To reduce the environmental impact of chemical fertilizers and pesticides, while securing crop yield and consumers safety, several alternative and sustainable products are presently available in the market. Nevertheless, this is still insufficient, new, renewable, sustainable, and eco-friendly products need to be discovered. Bio4Food addresses this problem by proposing a strategy of crop waste valorisation.


© Bio4Food Project

Main project activities

Bio4Food will exploit the biostimulatory properties to promote plant yield and quality, aiming to increase the content of the health-promoting minerals, iron, magnesium and zinc, in vegetable and fruit crops. The socio-economic acceptance of our approach and the market opportunities will be studied to develop a road map for the implementation of bio-based methodology for crop production and protection. The possibility to recycle waste will be evaluated at the level of the farm up to the food processing industry, taking into account the profitability of the technology. Bio4Food will contribute to the reduction in crop waste, providing natural plant protection products, and offer consumers vegetables rich in health-promoting minerals. The socio-economic acceptance of our approach and the market opportunities will be studied to develop a road map for the implementation of a bio-based methodology for crop production and protection. The possibility to recycle waste will be evaluated at the level of the farm up to the food processing industry, taking into account the profitability of the technology.

Consequently, through its strategy, Bio4Food:

1. creates added value for the otherwise wasted biomass,
2. provides natural plant protecting and heath promoting products, and
3. adheres to the concept of circular economy and zero waste.

Expected results

Bio4Food will contribute to the reduction in crop waste, providing natural plant protection products, and offer consumers vegetables rich in health-promoting minerals.

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4. ALL-IN

JOINT CALL 2019

ALfalfa for sustainable Livestock farming systems: Improve alfalfa -rhizobia symbiosis and New feeding strategy based on ecological leftovers

PROJECT TEAM

Coordinator:

UNIFI - Carlo Viti University of Florence – Italy

Partners:

INRA - Khalid AzimINRA RABAT – Morocco;

UNIPI - Marcello Mele - University of Pisa/Centro Ricerche Agro-ambientali “E. Avanzi» - Italy;

UORAN - Abdelkader Bekki - University of Oran – Algeria;

UM I- Majida Hafidi - University Moulay Ismail – Morocco

Introduction

The development of Local Sustainable Food Societies is a key factor to face emerging issues linked to pollution and climate change.

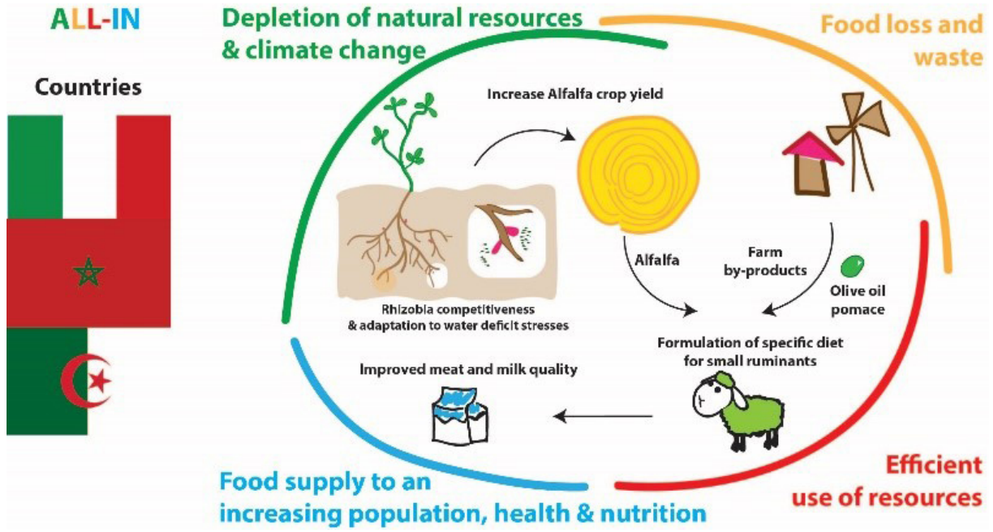
The primary goals of ALL-IN are the increment of alfalfa (Medicago sativa L.) crops yield and the formulation of a balanced diet for livestock based on alfalfa and integrated with local by-products. The development of local sustainable food societies through efficient use of resources. Molecular and bioinformatics approaches permit new strategies for the selection of elite rhizobial inoculants able to enhance alfalfa yield. Ameliorating the production of leguminous plants and using them in combination with by-products is a sustainable strategy to reduce the huge quantity of resources for animal-derived food production. The focus of the project is in the Mediterranean area.

Background

In the future years, it is expected an increase in milk, and meat derived products demand. It is then necessary to develop a new feeding strategy for animals and improve feed production not incrementing the amount of lands used and without the introduction of anthropogenic fertilization. Medicago species are cultivated at different latitudes thanks to their versatility (e.g. drought and disease resistance); considering the forecasted increment of temperature, selection of highly competitive rhizobia adapted to more stressful conditions (e.g., high salt concentration) is fundamental to improve inoculant efficiency

Main project activities

The primary goals of the project are the increment of alfalfa (Medicago sativa L.) crops yield in the Mediterranean area thanks to the development of new rhizobial inoculants and the formulation of a balanced diet for livestock based on alfalfa and integrated with local agriculture by-products. The accomplishment of the first aim requires the selection of rhizobial strains on the basis of three main phenotypes: symbiotic efficiency (high nitrogen fixation rate), high competition capabilities and resistance to dry environments. The second goal is centred on the formulation of diets for ovines (which are widely bred in the Mediterranean



area) coupling agro-food by-products and alfalfa, thus decreasing the production of farm bio-wastes. In vitro fermentation trials will be performed to select optimal diets. Selected diets will be further evaluated in the in vivo feeding trials in terms of animal performance, rumen microbiota composition, milk and meat quality.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Expected results

The results of this project will improve the competitiveness of legume crops by considerable savings of expensive inputs, contributing to enhancing the agriculture competitiveness of the countries in the Mediterranean area. Increased production of legumes will reduce actual needs for importation in some cases, whereas in others it will increment the exportation to demanding markets.

Increase alfalfa production will allow using it as a central component for livestock feeding. The feeding strategy is based on the principle of "ecological leftovers". Diets will be designed to optimize the reuse of bio-wastes (scraps and harvest residuals of local by-products) especially those obtained from olive oil manufacturing (i.e., pomace). The addition of specific amounts of olive oil pomace will allow modulating rumen metabolism improving milk and meat quality and possibly reducing methane emission.

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5. SysOrg

Organic agro- food systems as models for sustainable food systems in Europe and Northern Africa

PROJECT TEAM

Coordinator:

Sebastian Kretschmer, University of Kassel, Germany

Partners:

Ibn Tofail University/Faculty of Sciences, (MA)

University of Copenhagen, (DK)

Warsaw University of Life Sciences, (PL)

Council for agricultural research and economics - CREA, (IT)

FH Münster University of Applied Sciences, (DE)

International Centre for Advanced Mediterranean Agronomic Studies – Mediterranean Agronomic Institute of Bari (CIHEAM-Bari), (IT)

Introduction

SysOrg identifies how pathways to increase sustainable food production and consumption can be successfully designed. This requires a better understanding of food systems, including the multitude of actors involved and the identification of critical points within systems.

This is done by mapping and analysing five case territories (Copenhagen, Cilento, North Hessia, War-saw, Kenitra) in a transdisciplinary way.

Background

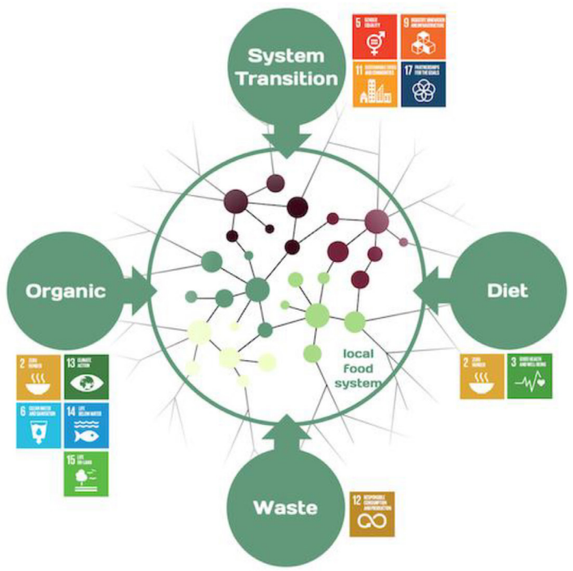
Today's food systems are not sustainable: neither from an ecological point of view nor from a socio-economic perspective. We have to cope with major diet-related health problems, hunger on the one hand and overweight and obesity on the other. Intensive agricultural production is one of the main contributors to biodiversity loss and is one of the biggest consumers of freshwater in the world, and according to the FAO, one third of our food is now wasted along the value chain.

The main cause-effect chains are known, but what is missing is how to motivate food system actors to produce and consume more sustainably. Our hypothesis is that there are similar entry points for transitions, although food systems vary widely across regions. These need to be identified in order to derive recommendations for making them more sustainable. Organic food systems can serve as a model here.

Main project activities

Thus, the following questions are addressed from four perspectives: transition, diet, organic food and farming, and food waste.

- What is the understanding of sustainability to drive the transformation towards sustainable food systems?
- How can pathways to increase sustainable food production and consumption across the system be successfully designed?
- What are the reasons, motivations, drivers or



barriers for actors to opt for more sustainable solutions?

- What are the promising entry points for developing, consolidating and disseminating organic food and farming, reducing waste and shifting to sustainable diets?
- What are critical points to bring these perspectives together in a systems approach?

Expected results

SysOrg will result in improved and locally adapted strategies and tools for transformation of food systems across Europe and Northern Africa to sustainable, resilient and resource efficient food systems with less environmental impact and high socio-cultural acceptance.

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6. Poultrynsect

JOINT CALL 2019

The use of live insect larvae to improve sustainability and animal welfare of organic chickens production

PROJECT TEAM

Coordinator:

Francesco Gai - CNR (Consiglio Nazionale delle Ricerche), Italy

Partners:

Achille Schiavone, University of Torino, (IT)

Sergiy Smetana, DIL e.V. (German Institute of Food Technologies), (DE)

Carl Coudron, Inagro VZW, (BE)

Anne Rieder, Nofima AS, (NO)

Introduction

Poultrynsect project, exploiting the use of live insect larvae, aims to give concrete solutions to the expectations of organic poultry meat consumers and European citizens responsive to environmental impact, animal welfare and healthy nutrition.

Poultrynsect is a research project developed by a consortium of scientists with expertise in agronomy, poultry nutrition, entomology, food and veterinary sciences belonging to research and academic institutions of four European countries (Belgium, Germany, Italy and Norway).

Background

Poultry meat production has a negative environmental impact mainly due to feed production, where soybean meal is the most common protein source. A promising alternative source of proteins is in-sects, which has shown great potential environmental benefits because as efficient bioconverters they are able to recycle nutrients from organic residue. Moreover, live insect larvae fed to poultry enable birds to express their normal active behaviour reflecting positive impacts on animal welfare.

Main project activities

The project aims to test the effects of an innovative feed ingredient (insect larvae) for slow-growing organic chickens to allow sustainable meat production, to improve animal welfare and to potentially meet the consumer demand for healthier and more natural meat products with enhanced palatability. Insect larvae will be reared on organic food side streams, allowing the valorisation of secondary raw materials produced in excess from the food industries, and then used as feed ingredient and environmental enrichment for the chickens.

© Poultrynsect Project

Expected results

This study will focus on animal welfare, productive performance, gut health and meat quality and will contribute to the development of cost-effective and environmental-friendly diets for poultry, aiming at improving sustainability in organic chicken meat production.

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7. PROVIDE

JOINT CALL 2019

PRotein and biOmolecules sources for nutritional security and biodiVersity of bakery products in a cIrcular fooD system

PROJECT TEAM

Coordinator:

Michael Rychlik - Technical University of Munich - Germany

Partners:

Italian National Agency for new Technologies, Energy and Sustainable Economic Development, ENEA (IT)

National Institute of Research & Development for Food Bioresources, IBA Bucharest (RO)

Chouaib Doukkali University, UCD (MA)

Norwegian University of Science and Technology, NTNU (NO)

Association of Operators in Organic Farming, Bio-Romania, (RO)

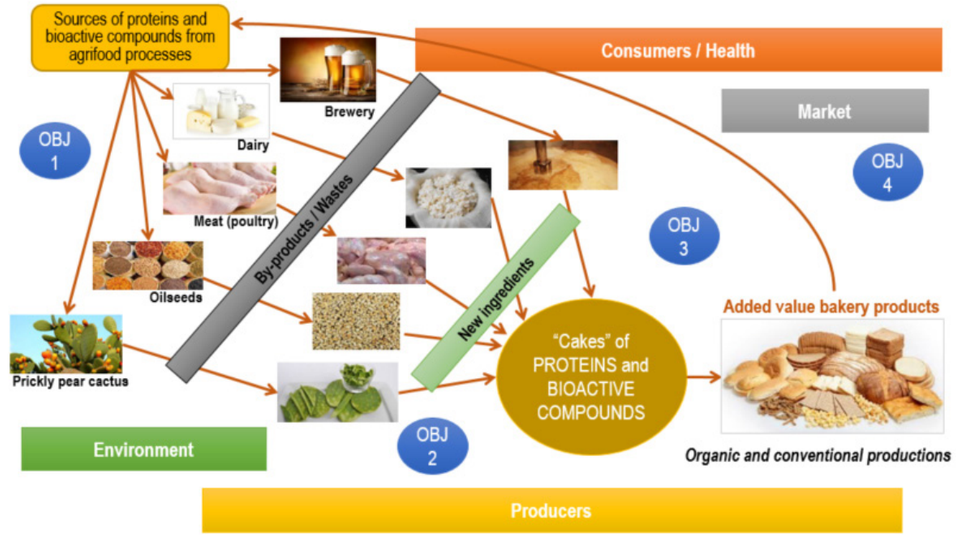
Introduction

According to the FAO on global food losses and food waste, agrifood rest raw materials contribute to about 45% of global quantitative food waste/year. Therefore, PROVIDE focuses on valorisation of food transformation industry by-products for use in bakery production. This will be based on "green" innovation processes, which will use also material from organic products and the resulting new products can be marketed "organic".

PROVIDE is designed to achieve a multi-sector impact (public authorities, market system, consumers/society, healthcare, environment, sustainability & circular economy), thus reflecting its multidisciplinary (anal. chemistry, (micro) biology and biotechnology, environment, food technologies, etc.), multi-actor and Pan-European (Scandinavia - Norway; Central Europe - Germany; South - East Europe - Romania; Southern Europe - Italy) & Northern African (Morocco) approach

Background

The growing world population leads to an increased need for food, especially valuable proteins. Agriculture and food processing lead to generation of several billions of metric tons of rest raw materials. Side streams are generated at all phases of the value chains, from production to distribution. These raw materials are an easily available source of biomass, however good preservation and processing methods are needed to utilize them for value-added products. At the same time, according to FAO report on global food losses and food waste, agrifood rest raw materials have the highest wastage rates: ca. 45% of global quantitative food waste/year. Utilization of some agroindustrial by-products for value-added foods will lead to increased availability of valuable ingredients such as proteins, lipids, vitamins, dietary fibre, polyphenols, antioxidants. They may contribute to consumers' health and well-being when incorporated into food matrices, through increase of essential nutrients and bio-active compounds in the diet. Current developments in food industry and biotechnology provide a big potential for better utilization of by-products as viable carriers of functional ingredients, which may enrich conventional foods if applied together in a food matrix on the basis of synergistic effects, while contributing to further development of novel food products for specific groups according to EU Reg. 609/2013



Main project activities

With the aim to promote circularity in the agri-food systems, 4 specific objectives have been identified:

1. identify by-products rich in nutrients and bioactives
2. valorise wastes and by-products
3. promote circular Food Systems
4. define strategies to put the new products into the market.

After having mapped sources of proteins and bioactive compounds from side streams of agrifood processes, byproducts from different food production chains (e.g.: dairy, oilseeds, brewery, meat, prickly pear cactus) will be valorised treating them with innovative "clean technologies" in pilot facilities to extract bioactive compounds (e.g. oils, waxes, fatty acids, carotenoids, polyphenols, tocopherols) and obtain defatted protein cakes to be used for producing new bakery products.

Three case studies for these new bakery products will be implemented. Quality & safety of sources, intermediate-, end- and by-products, as well as the health enhancing properties of plant and by products extracts, will be assessed. The new products will be tested for consumers' perception and acceptance and the technologies implemented at industrial scale. Environmental and socio-economic sustainability will be assessed, and integrated traceability systems and innovative processes for human health and well-being developed.

Expected results

The pilots are designed to generate innovative bakery products with high consumer acceptance. Environmental and socio-economic sustainability will be assessed, and integrated traceability systems and innovative processes for human health and well-being developed.

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8. FOOdIVERSE

JOINT CALL 2019

Diversifying sustainable and organic food systems

PROJECT TEAM

Coordinator:

Stefan Wahlen - University of Giessen - Germany

Partners:

University of Trento, (IT)

Coventry University, (UK)

OsloMet - Oslo Met-ropolitan University, (NO)

Jagiellonian University in Krakow, (PL)

Introduction

The purpose of the FOOdIVERSE project is to produce practice-oriented knowledge on how diversity in diets, novel food supply chains and food governance contributes to more organic and sustainable food systems. The project provides multi-level perspectives on transforming local food systems across Europe by promoting diversity of consumers, producers and key stakeholders, as diversity has diverse meanings, for example in urban Norway or in rural United Kingdom, but also to German consumers, Italian government officials or Polish food producers.

Background

Food consumption significantly influences resource use and the environmental effects of food production and distribution. Currently a rather homogenous group of well-educated and affluent consumers is strongly interested in organic food. The mainstream food supply chains and their governance are characterised by a food regime that creates large quantities of standardised food. A more diverse food system could deliver more choices and could be more sustainable. What is lacking is a systematic and practice-oriented characterisation of diversity in the food system and its impact on resilience, enhancing socio-economic and environmental pillars of sustainability

Main project activities

Methodologically and theoretically this project takes a relational approach on diversity, emphasising different characteristics in various contexts and across different scales. We seek to identify the relations in characteristics of diversity that accelerate a transformation toward more sustainable food systems.

Expected results

The project directly promotes organic food systems through involving consumers, producers, food-processors and those governing food systems with a living lab methodology. A user-centred and innovation approach in local contexts of Italy, Germany, Norway, Poland and the United Kingdom assists in comparing whilst instantaneously implementing the results in real-life scenarios. We engage different actors and include a diverse range of viewpoints on organic food systems.

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9. SPiwi

JOINT CALL 2019

Sustainable production of innovative sparkling wine

PROJECT TEAM

Coordinator:

Vicky Everaerts - Proefcentrum Fruitteelt vzw - Belgium

Partners:

Staatliches Weinbauinstitut Freiburg, (DE)

Fondazione Edmund Mach, (IT)

From 19-on B.V.B.A., (BE)

S.M.C.S., (BE)

Introduction

The SPiwi-project aims to investigate and optimize strategies for the production of future oriented organic 'SParkling' wines, made from 'Piwi' (fungus-resistant) grape varieties. Hence the name 'SPiwi'.

To optimize the sustainability and economic crop return of novel, fungus-resistant grape varieties and their potential in the production of a local sparkling wine. Fungus-resistant varieties give the opportunity to cultivate grapes for wine production in an organic and more sustainable way. With sparkling wine world consumption increasing each year, together with the growing interest for more organic and sustainable products, the use of these novel varieties in the production of this type of product can be of economic importance.

The potential of the fungus-resistant grape varieties for the organic production of grapes will be evaluated in one classical vine producing region (Northern Italy) and a more northern region (Belgium). Grapes will be send to Germany where they have a good knowledge about the potential of the fungus-resistant grape varieties in the vinification. Therefore they'll develop a chemical-free sparkling wine vinification process. As Belgium is a relatively new winegrowing region, the consumer acceptance of the resulting product will be evaluated. Also the use of waste streams in innovative products in the local Belgium industry will be assessed.

Background

Europe has a leading role of organic wine production in the world (almost 90% of the total organic grape production worldwide is located in Europe). New insights in organic and sustainable viticulture are therefore of economic importance. The introduction of fungus-resistant varieties (piwis) can partly avoid the yield losses that often occur in organic viticulture. However, there is a lack of knowledge of these novel varieties among the consumers and wine makers which hampers further expansion of piwis and thus sustainable and resilient development of the wine industry.

To further optimise the sustainability and economic crop return of these varieties, this project will develop guidelines for organic crop protection, it will develop a chemical-free vilification process, it will research its waste streams and finally the consumer acceptance of these organic wines. These findings will be demonstrated and an economic feasibility study will be communicated to the public.

Main project activities

The Spiwi project aims to investigate and optimize strategies for a future oriented production of organic sparkling wines in 2 classical European vine producing regions (Northern Italy and Southern Ger-many) and a more northern region (Belgium), in which the area of vinegrapes is currently small but yet increasing with approximately 15-20% per year.

Sustainability is addressed from multiple angles :

1. in the field phase the emphasis is on the selection of suitable resistant cultivars and on the development of guidelines for organic crop protection
2. a chemical-free vinification process is developed and will form the knowledge base for organic wine production with resistant cultivars
3. a consumer sur-vey for the acceptability of those novel type of wines is executed.
4. Qualification and quantification of vinification waste streams, the presence of bioactive compounds and their potential for added value products in the local industry.

Moreover, the waste streams of the vinification process are qualified and quantified and the presence of bioactive compounds herein is described. The potential for the creation of added value products based on these bioactive compounds in pharmaceutical, cosmetical and food industries is assessed by presenting the results to those industries and by exploring their needs and interests in further product development.

Expected results

Besides guidance on the selection of disease resistant grape varieties for planting, the management practices of the organic vineyard will be demonstrated and an economical feasibility study will be communicated to farmers so that grapevine growers, oenologists and advisers can adapt their vineyard crop management and/or their vinification procedures according to the outcome of this projectRegional differences at the location of the consortium members will address local farmers needs and give insights on the best choice in view of upcoming climatological challenges.

Contact

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10. MILDSUSFRUIT

JOINT CALL 2019

Innovative Mild Processing Tailored to Ensure Sustainable and High Quality Organic Fruit Products

PROJECT TEAM

Coordinator:

Prof. Pietro Rocculi - University of Bologna – Italy (Coordinator)

Dr. Urszula Tylewicz - University of Bologna – Italy (Co-Coordinator)

Partners:

Prof. Mona Elena Popa - Universitatea de Stiinte Agronomice si Medicina Veterinara din Bucuresti, (Romania)

Prof. Malgorzata Nowacka - Warsaw University of Life Sciences, Institute of Food Sciences, (Poland)

Dr. Tuulikki Seppanen-Laakso - VTT Technical Research Centre of Finland Ltd, (Finland)

Dr. Daniele Asioli - University of Reading, (United Kingdom)

Mrs. Nurcan A. Güzelsoy - Central Research Institute of Food and Feed Control, (Türkiye)

Prof. Fahrettin Gogus - Gaziantep University, (Türkiye)

Introduction

In order to develop novel fortified organic processed products and functional ingredients, aiming to boosting organic processors and the whole organic market by offering to consumers a wider range of novel solutions, the study and optimization of specific gentle processing technologies is still strongly needed and has to be extended to different organic fruits.

MILDSUSFRUIT will address the increased quality and sustainability of organic fruit processing, through the optimization of specific mild technologies that can reduce the environmental impact and preserve quality and nutritional characteristics of the final products. This activity is aimed to meet consumers expectations and favour a healthy life-style, but also to valorise by-products stimulating the development of a circular processing system.

Organic fruits are characterized by high quality and nutritional properties, that are widely appreciated by consumers, but they can present also a high perishability. Processing could contribute to increase their shelf-life reducing waste formation; however traditional technologies can have a negative effect on quality and environmental impact. Therefore, innovative mild technologies need to be developed and carefully tailored for this kind of commodities.

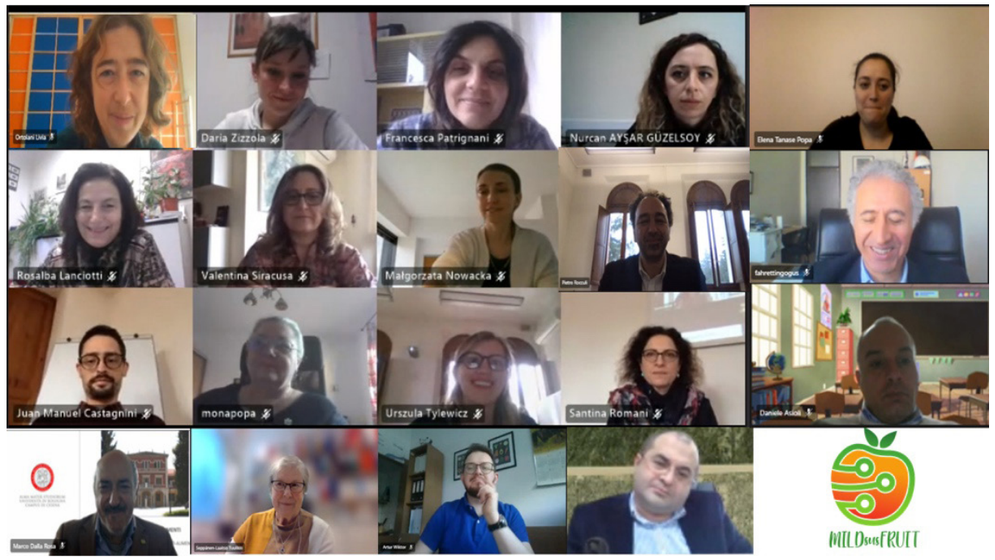
The project involves research groups from Italy, Romania, Poland, Finland, United Kingdom and Türkiye

Background

The global demand for organic processed fruit characterized by high quality, long shelf-life and improved nutritional value is growing due to an increasing interest in a healthier and more environmentally friendly food production. Consumers expect a superior quality compared to conventionally processed foods, such as less pesticide and additives residues, less nutritional/ qualitative reduction due to processing operations and a low environmental impact. Nevertheless, the research on the optimization of processing for organic fruit products is still scarce.

Main project activities

The project aims to improve the competitiveness of the organic sector, increasing the level of quality, sustainability and consumer confidence of organic



fruit (apple, citrus and berries) products and valorising by-products and side streams.

The activity will follow a "processing-guided" strategy, aimed to answer to stakeholders needs in order to have an important impact on the EU organic sector. The main activities are:

- define and optimize mild technologies tailored to each organic raw material, in order to increase the stability and functionality of a wide range of organic processed fruit products, including minimally processed, semi-dried and dried ones.
- define and optimize gentle and more sustainable technologies for the extraction and stabilization of functional ingredients, developing specific protocols aimed to reduce waste and valorise by-products.
- characterize and reduce the environmental impact of the production of organic processed fruit products and functional ingredients in order to increase the overall sustainability.
- evaluate the consumer preferences and acceptance in relation to the innovative processed organic fruit products aimed at developing and suggesting improved communication strategies.
- disseminate the obtained results and elaborate concrete recommendations (development of a Code of Practice) to stakeholders such as farmers, food producers and packers, distributors, retailers and consumers associations.

Expected results

A fundamental output of the project will be the development of a Code of Practice for European organic fruit processing industries. An active engagement with multi-actors and a dissemination plan will ensure that the outputs of the project will be comprehensive and accessible, meeting the needs of the end-users. These finding will be used for the creation of a virtuous production system able to maximise product quality, minimising waste and environmental impact, enhancing consumer confidence on organic pro-cessed fruit products."

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11. HO-FOOD

JOINT CALL 2019

Innovative High pressure process to increase the preservation of ready-to-eat Organic FOOD

PROJECT TEAM

Coordinator:

Sara Spilimbergo - University of Padova (UNIPD) - Italy

Partners:

Institute of Agricultural and Food Bio-technology (IBPRS), (PL)

Council for Agricultural Research and Economics Research Center for Olive Citrus and Tree Fruit (CREA), (IT)

Université Ahmed Benbella Oran 1 (UNIO1), (AL)

Ataturk Central Horticultural Research Institute (TAGEM), (TR)

Introduction

The increasing demand for a healthy diet calls for an evolution of the food processing chain, with special attention to fresh and organic products. In particular, quality and safety are key characteristics for a sustainable development.

Background

Ready to Eat (RTE) fresh organic products are rich in macro and micronutrients, have a good taste and appearance but are affected by quick spoilage, mainly caused by microorganisms and enzymes on their surface. Current available technologies to increase their safety and shelf life are still very limited

Main project activities

The overall goal of the project is to foster the whole fresh vegetable food chain via the development of a new food pasteurization technique, based on the use of high-pressure CO_2 at low temperature, efficient to inactivate microorganisms and enzymes present on the surface and responsible of food spoilage. The product will be pre-packed before undergoing the pasteurization process, thus avoiding the risk of post-process contamination. By using low temperature (< 45°C), sensorial and chemical properties will be preserved, resulting in healthy and palatable food while preserving the phytochemical components of organic foods. The


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beneficial impacts of the new technique in terms of safety, shelf-life duration, nutritional value, sensorial profile and the potential to improve business and environmental sustainability.

Expected results

Small and medium equipments will be designed, set up and validated to be used by local organic farms, SMEs and retails to develop innovative wholesome products, to reduce the food waste, energy costs and support the development of sustainable supply chains."

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12. MI-WINE

JOINT CALL 2019

Mild Innovative Treatment for Wine Stabilisation

PROJECT TEAM

Coordinator:

Giuseppina Paola Parpinello - UNIBO - Alma Mater Studiorum - Università di Bologna - Italy

Partners:

National Reserach Council, (IT)

DLR Rheinpfalz, (DE)

Wrocław University of Environmental and Life Sciences, (PL)

Introduction

The MI-WINE aims to obtain a fast and cost-effective continuous process by using engineered high-performance material, which will be able to subtract metals and proteins, responsible for the main instability in wine, through a flow-system, environmentally friendly, able to stabilize wine in continuous and without waste production.

Background

The main critical issues in white wine production are protein instability (responsible for haze or unsightly sediment during storage in bottle) and oxidation (causing wine's browning). To counteract the common approach is the addition of adjuvants and antioxidant. However, these actions have some disadvantages, as they require discontinuous processes with production of large volume of wastes, and possible allergenic effect related to sulfur dioxide addition, with limited preservation effect in long storage-bottled wine.

Main project activities

The current project pursues two objectives. The first objective is to advance the knowledge in ceramic materials (metal oxides) design strategies for adsorbing and removing typical contaminants responsible for the instability of wine and other organic beverages; a further, secondary objective, is to implement the aforementioned design strategies in a new resource-efficient process that improves the overall quality and nutritional value of organic wine and other beverages.

The first objective is pursued increasing knowledge on the mechanistic processes underlying the adsorption of specific chemical compounds (undesirable wine contaminants such as proteins and metal ions) on the surface of metal oxides, in form of mesoporous materials, submicrometric powders, nanostructured coatings. For this purpose the physical/chemical/electrostatic effects involved, the adsorption selectivity, the absorption strength and effectiveness, the desorption processes will be investigated. Based on mechanistic results, the secondary objective is pursued exploring manufacturing technologies to integrate the developed innovative material, with reduced processing time and costs, also entailed in the recovery or disposal of waste provided by batch treatment systems currently used in the food industry.

© MI-WINE Project

Expected results

As final outcome, the MI-WINE project will deliver a mild process lab flow-system that will be lab validated versus specific Key Performance Indicators (KPIs) such as the technical, economic, production advantages and social benefits, outlined in the impact section.

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ONGOING PROJECTS WITHIN THE JOINT CALL OF SUSFOOD & FOSC - 2021

There are 5 projects funded in the joint call of SUSFOOD2 & FOSC. Detailed information about the projects listed below is provided in this section.

Nr	Acronym	Project Title
1	AlgaeBrew	Unlocking the potential of microalgae for the valorisation of brewery waste products into omega-3 rich animal feed and fertilisers.
2	MedAgriFoodResilience	Socio-environmental shocks assessment and resilience empowerment in Mediterranean agri-food heritage systems: Italy, Morocco, Algeria FAO GIAHS sites
3	IPSUS	Climate smart food innovation using plant and seaweed proteins from upcycled sources
4	Olive3P	Innovative sustainable food system for olive oil production converting solid and liquid by-products into edible yeast and biopesticide.
5	SmartDairy	Climate-smart Dairy: Assessing Challenges, Innovations, and Solutions

1. AlgaeBrew

JOINT CALL 2021

Unlocking the potential of microalgae for the valorisation of brewery waste products into omega-3 rich animal feed and fertilisers.

PROJECT TEAM

Coordinator:

Dr. Ronald Halim, Ireland - University College Dublin (UCD)

Partners:

Italy – University of Camerino (UNICAM)

Türkiye – Bilecik Seyh Edebali University (BU)

Morocco – National School of Agriculture in Meknes (ENA)

Belgium – Lambers Seghers (LS)

United Kingdom – Swansea University (SU)

Romania – University of Agriculture and Veterinary Medicine (USAMV)

Morocco – Mohammed V University (MU5)

Ireland – Diageo Ireland plc.

Introduction

As one the largest agri-food industries, beer production generates large amounts of nutrient-rich wastewater and spent grain. The conventional linear “collect-treat-discharge” way of handling waste is costly and environmentally unsustainable. AlgaeBrew will use microalgal biotechnology to convert these wastes into useful products, thereby creating new revenue streams for breweries, decreasing their environmental impacts and promoting a circular bioeconomy.

Eicosapentaenoic fatty acid (EPA) is essential for the immune system and widely used in dietary supplements for human and animals. Commercial EPA production relies on fish oil derived from wild-caught fish, thereby putting enormous strain on the fish stock and the ocean ecosystem. A group of microalgae known as Nannochloropsis produces EPA naturally and can be exploited as an alternative source of EPA. By recapturing waste nutrients, Nannochloropsis can help breweries treat their waste products while producing sustainable EPA. This will be a win-win solution for both breweries and EPA producers.

Aim

AlgaeBrew aims to develop scalable processes that use Nannochloropsis to upgrade brewery wastewater and spent grain into high-value EPA for the feed industry. The residual Nannochloropsis biomass after EPA extraction will be developed into biofertiliser to achieve a zero-waste goal. The project will address technical challenges associated with Nannochloropsis cultivation on brewery waste, EPA extraction, feed formulation and socio-economic analysis.


© AlgaeBrew Project

Main project activities

The project will be undertaken by 7 universities, a beer producer (Diageo) and an animal feed producer (Lambers Seghers) across 4 EU (Ireland, Belgium, Italy, Romania) and 3 associated countries (Morocco, Türkiye and the UK). Our estimation suggests that the brewery-microalgae system proposed by AlgaeBrew has a future potential to treat up to 26.8% of spent grain and 19.3% of brewery wastewater produced globally, while replacing the global demand for 21.6% of fish oil.

Expected results

As final outcome, the MI-WINE project will deliver a mild process lab flow-system that will be lab validated versus specific Key Performance Indicators (KPIs) such as the technical, economic, production advantages and social benefits, outlined in the impact section.

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2. Med Agri Food Resilience

JOINT CALL 2021

Socio-environmental shocks assessment and resilience empowerment in Mediterranean agri-food heritage systems: Italy, Morocco, Algeria FAO GIAHS sites

PROJECT TEAM

Coordinator:

Dr. Antonio Santoro, Italy - University of Florence (Unifi)

Partners:

Morocco - Mohammed VI Polytechnic University (UM6P)

Algeria - University of Biskra (UMKB)

Algeria - Scientificand Technical Research Center on Arid Regions (CRSTRA)

Morocco - University of Ibn Zohr (UIZ)

Introduction

Traditional agri-food systems are increasingly receiving attention at international level. This is thanks to their multifunctional role and as examples for alternatives to agricultural models based on maximizing productivity. Traditional agri-food systems developed through the centuries by local communities and are still actively supporting the livelihood of local farmers, providing solutions for climate change mitigation and adaptation as well as contributing to the preservation of agro-biodiversity, traditional knowledge and cultural identity. The importance of traditional agri-food systems is recognized by the Food and Agriculture Organization (FAO) and the establishment of the Globally Important Agricultural Heritage Systems (GIAHS) Programme. The GIAHS Programme has the aim to identify and preserve worldwide sites characterised by agricultural systems created and managed over time by local communities, that today represent examples of local adaptation and mitigation towards global challenges, contributing to food security and sustainable development of rural communities.

Aim

The importance of traditional agri-food systems is recognized by the Food and Agriculture Organization (FAO) and the establishment of the Globally Important Agricultural Heritage Systems (GIAHS) Programme. The GIAHS Programme has the aim to identify and preserve worldwide sites characterised by agricultural systems created and managed over time by local communities, that today represent examples of local adaptation and mitigation towards global challenges, contributing to food security and sustainable development of rural communities.

Main project activities

The project will focus on studying three GIAHS sites (in Italy, Morocco and Algeria) applying a multidisciplinary approach to identify the possible

MedAgriFood RESILIENCE

social and environmental shocks impacting agri-food heritage systems in the Mediterranean area, linking together landscape structure, climatological studies, social role and biodiversity assessment. Over the centuries, local communities have adapted to challenging environmental conditions such as a dry and hot climate, water scarcity and steep slopes. The selected systems produce for a Mediterranean diet and are still fundamental for the food security of local communities. They have demonstrated to be more resilient towards possible shocks than modern and intensive food systems. The results of the project will lead to the identification of the best practices to be replicated in other GIAHS sites and in other traditional agri-food systems to increase the adaptation and resilience to social and/or environmental systems shocks.

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3. IPSUS

Climate smart food innovation using plant and seaweed proteins from upcycled sources

PROJECT TEAM

Coordinator:

Dr. Parag Acharya, United Kingdom - University of Greenwich

Partners:

Italy – University of Parma (Unipr)

Türkiye – Istanbul Sabahattin Zaim University (IZU)

Morocco – Ecole Nationale d'Agriculture de Meknes (ENAM)

Romania – BEIA Consult International (BEIA)

Italy – Experimental Station for the Food Preservation Industry (SSICA)

Morocco – Mohammed V University (UM5)

Türkiye – Kaanlar Food Inc.

France – KEDGE Business School

Introduction

Food choices impact human and planetary health. The negative environmental impacts of the food system, increasing food insecurity and the prevalence of unhealthy diets are driving policymakers, scientists, companies and consumers to demand sustainable solutions. Globally, livestock emits 14.5% of GHGs, is associated to 30% of biodiversity loss, and, with meat demand is projected to double by 2050, transitioning to diets that include more sustainable sources of protein is crucial. Plant-based proteins are currently the fastest growing food trend but are unsustainably dependent on soy.

Aim

The IPSUS project will exploit inter-disciplinary and eco-innovative approaches to upcycle plant and seaweed proteins from agri-food raw materials otherwise destined to join the ~1.6 billion tonnes of annual global food loss and waste (FLW). The quantity, quality, and upcycling opportunities of six protein-rich FLWs (pumpkin, hazelnut, grape, potato, brewers' spent grain, and seaweeds) across the value chains will be investigated in the UK, Italy, Romania, Türkiye, and Morocco to address Net Zero opportunity by linking sustainable protein shift and food waste valorisation.

Main project activities

Novel protein extraction methods will be assessed to identify and optimise the less energy and more sustainable techniques. The nutritional quality and safety of the plant and seaweed sources and upcycled proteins will be assessed, taking bio-accessibility and potential allergenicity into account. In addition, incorporation of upcycled proteins into meat alternative and dairy alternative formulations will be tested at lab-scale, followed by prototype development at pilot-scale by the industrial partners. Functional and sensory

acceptability of the prototypes will be evaluated along with the improved nutritional (low salt/sugar/fat) and cleaner label (fewer food additives) offerings which are currently lacking in the plant-based meat and dairy alternatives. Exploration of consumer behaviours, preferences and the enabling regulatory and policy environment will reveal drivers and barriers of the sustainable protein shift via upcycled plant proteins.

Contact

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4. Olive3P

JOINT CALL 2021

Innovative sustainable food system for olive oil production converting solid and liquid by-products into edible yeast and biopesticide.

PROJECT TEAM

Coordinator:

Dr. Imene Chentir, Algeria - Higher Institute of Food Science and Food Agri-Industry (ESSAIA)

Partners:

Morocco – Cadi Ayyad University (UCAM)

Morocco – University of Sultan Moulay Slimane (USMS)

Türkiye – Olive Research Institute (ORI)

Türkiye – Düzen Biological Sciences R&D and Production Inc. (DÜZEN)

Introduction

The Olive3P project aims at transforming conventional olive oil production into an integrated innovative food system through treatment of solid by-products along with treatment of olive mill effluents combined with the recovery of novel products comprising activated carbon, edible yeast, and biocontrol agents containing polyphenols.

Aim

Biochar obtained from carbonisation of solid residues (branches from olive harvest, olive stone from the milling process), will undergo physicochemical activation. Biochar and activated carbon will be applied as adsorbent for polyphenols capture from olive mill effluent and recovered as a natural biocontrol agent with biocidal activity. Polyphenols will be extracted from biochar and activated carbon by conventional and supercritical CO_2 extraction using green solvents and tested as biopreservative in table olive conservation, whereas adsorbents (activated carbon or biochar) containing residual polyphenols will be applied as soil conditioner, and their biopesticide potential on soil-borne pathogens of olive seedlings will be evaluated.

Treated olive mill effluents with reduced concentrations of inhibitory polyphenols will be applied for efficient cultivation of edible yeast, adding cheese whey as a low-cost nitrogen source for optimal yeast growth. Harvested edible yeasts will be evaluated as health-promoting animal feed rich in carotenoids with potential application in poultry and fish production.

Main project activities

Lab scale results will be transferred at a pilot scale by the participating Turkish company in view of future commercial exploitation. The evaluation of the innovative system in Food Systems Approach (FSA) will be applied on following drivers: (1) Healthy diet: Quality and safety of edible yeast and biocontrol agent, (2) Cost and revenues: Socio-economic feasibility of the innovative food system for small 3-phase olive oil factories, and relation to current sustainable practices, (3) Food security: Resource-efficiency evaluated by mass/energy balance and Life Cycle Analysis, compared with current practices.

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5. SmartDairy

JOINT CALL 2021

Climate-smart Dairy: Assessing Challenges, Innovations, and Solutions

PROJECT TEAM

Coordinator:

Dr. Doris Laepple, Ireland - National University of Ireland Galway, (NUI Galway)

Partners:

United Kingdom – University of Sussex (US)

Italy – University of Ferrara (UNIFE)

Finland – University of Helsinki

United Kingdom – University of Reading

United Kingdom – University of Bristol

Introduction

Food systems are responsible for one third of global greenhouse gas (GHG) emissions. Dairy production is a significant contributor to those emissions and, given that global demand for dairy is projected to increase, there is an urgent need to reduce emissions from this sector. For example, a clearer understanding of the functioning and acceptability of climate-smart innovations that can be implemented along the dairy supply chain can contribute to achieving a climate-neutral EU continent by 2050.

Aim

In Italy, we will simulate the implications of new climate-smart policies and business models along the dairy supply chain. In the UK, we will explore consumers' perceptions and willingness to pay for climate-smart innovations. In Finland, we will analyse socio-cultural issues related to the consumption of milk and alternative products, as well as dairy-based food waste reduction behaviour. Country specific outcomes will be consolidated during the final stage of the project. Here, we will present findings from all countries to local stakeholders for co-creation of solutions that enable a climate-smart dairy system that is acceptable to all actors from farm to fork. Overall, SmartDairy will create impact by reducing GHG emissions, increasing resource efficiency, and reducing waste, bringing us a step closer to a climate-neutral future.

Main project activities

Novel protein extraction methods will be assessed to identify and optimise the less energy and more sustainable techniques. The nutritional quality and safety of the plant and seaweed sources and upcycled proteins will be assessed, taking bio-accessibility and potential allergenicity into account. In addition, incorporation of upcycled proteins into meat alternative and dairy alternative formulations will be tested at lab-scale, followed by prototype development at pilot-scale by the industrial partners. Functional and sensory acceptability of the prototypes will be evaluated along with the improved nutritional (low salt/sugar/fat) and cleaner label (fewer food additives) offerings which are currently lacking in the plant-based meat and dairy alternatives. Exploration of consumer behaviours, preferences and the enabling regulatory and policy environment will reveal drivers and barriers of the sustainable protein shift via upcycled plant proteins.

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